Appendix B – Air Quality Technical Report

AIR QUALITY TECHNICAL REPORT

Marina Way Extension
0639-076-348

Annapolis Way to Gordon Boulevard
0639-076-348, P-101, C-501, R-201
UPC 120778

Northern Virginia District

Prepared for:

Environmental Division

Prepared by:

JMT

March 2024

This page is intentionally blank.

Table of Contents

List of Exhibits

ACRONYMS

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
CAA	Clean Air Act
CEQ	Council of Environmental Quality
CF	Categorical Finding
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
DEIS	Draft Environmental Impact Statement
EA	Environmental Assessment
EIS	Environmental Impact Statement
EO	Executive Order
FHWA	Federal Highway Administration
FONSI	Finding of No Significant Impact
FY	Fiscal Year
FTA	Federal Transit Administration
GHG	Greenhouse Gas
HAP	Hazardous Air Pollutant
HEI	Health Effects Institute
HOT	High-Occupancy Toll
HRTPO	Hampton Roads Transportation Planning Organization
I-	Interstate-
IECI	Indirect Effects and Cumulative Impacts
IRIS	Integrated Risk Information System
L&D	Location & Design Division (VDOT)
LOS	Level of Service
LRTP	Long Range Transportation Plan
MOVES	Motor Vehicle Emission Simulator
MPO	Metropolitan Planning Organization
MSATs	Mobile Source Air Toxics
MTPY	Metric Tons per Year
NAAQS	National Ambient Air Quality Standards
NCHRP	National Cooperative Highway Research Program
NCRTPB	National Capital Region Transportation Planning Board
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NO_2	Nitrogen Dioxide

NO_x	Nitrogen Oxides
OIPI	Office of Intermodal Planning and Investment
O_3	Ozone
PA	Programmatic Agreement
Pb	Lead
PM	Particulate Matter
$PM_{2.5}$	Fine inhalable particulate matter, with diameters that are generally 2.5 micrometers and less
PM_{10}	Inhalable particulate matter, with diameters that are generally 10 micrometers and less
POM	Polycyclic Organic Matter
PPM	Parts per million
Ppb	Parts per billion
RTP	Long-Range Transportation Plan
SIP	State Implementation Plan
S&B	Structure & Bridge Division (VDOT)
SLR	Sea Level Rise
SO2	Sulfur Dioxide
TIP	Transportation Improvement Program
TMPD	Transportation Mobility and Planning Division (VDOT)
TPY	Tons per Year
TSD	Technical Support Document
USACE	U.S. Army Corps of Engineers
USDOT	US Department of Transportation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VA	Virginia
VAC	Virginia Administrative Code
VDEQ	Virginia Department of Environmental Quality
VDOT	Virginia Department of Transportation
VDRPT	Virginia Department of Rail and Public Transportation
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
VPHPL	Vehicles per Hour per Lane
VTRC	Virginia Transportation Research Council

This page is intentionally blank.

Executive Summary

The Prince William County (County) Department of Transportation, in coordination with the Virginia Department of Transportation (VDOT) and the Federal Highway Administration (FHWA), is proposing to construct the Marina Way Extension between Annapolis Way and Gordon Boulevard (Route 123) in Woodbridge, Virginia. The proposed four-lane, 0.26-mile roadway would be on new alignment. It would be a four-lane median-divided roadway with curb and gutter, a 4-foot buffer, and 5-foot-wide sidewalks on both sides of the road. Lane widths will be 11 feet wide with turn lanes present at the Route 123 intersection and main entrances into the Home Depot and Aldi grocery store. The proposed raised grass median will be 15 feet in width and will transition down to 4 feet at intersections where turn lanes are needed. The project does not involve additional capacity on existing Marina Way.

The proposed improvements were assessed for potential air quality impacts and compliance with all applicable air quality regulations and guidance. All models, methods and assumptions applied in modeling and analyses were made consistent with those provided or specified in the VDOT Resource Document.[1] Based on the assessment, the project would meet all applicable federal and state transportation conformity regulatory requirements as well as air quality guidance under the National Environmental Policy Act (NEPA). As such, the project would not cause or contribute to a new violation of the national ambient air quality standards (NAAQS) established by the Environmental Protection Agency (EPA).

Mobile Source Air Toxics (MSATs) Federal Highway Administration (FHWA) guidance (2023)[2] states that "…*EPA identified nine compounds with significant contributions from mobile sources that are among the national and regional-scale cancer risk drivers or contributors and non-cancer hazard contributors from the 2011 National Air Toxics Assessment (NATA).*[3] *These are 1,3-butadiene, acetaldehyde, acrolein, benzene, diesel particulate matter (diesel PM), ethylbenzene, formaldehyde, naphthalene, and polycyclic organic matter*." Following FHWA guidance for projects with low potential impacts based on forecast traffic volumes and other technical criteria, a qualitative assessment of potential MSAT impacts was conducted for this project.

Based on that assessment, best available information indicates that, nationwide, regional levels of MSATs are expected to decrease in the future due to ongoing fleet turnover and the continued implementation of increasingly more stringent emission and fuel quality regulations. Nonetheless, technical shortcomings of emission and dispersion models and uncertain science with respect to health effects effectively limit meaningful or reliable estimates of MSAT emissions and effects of this project at this time. While it is possible that localized increases in MSAT emissions may occur as a result of this project, emissions will likely be lower than present levels in the design year of this project as a result of EPA's national control programs that are projected (in the FHWA 2023 Guidance) to reduce annual MSAT emissions by 76 percent between 2020 and 2060 while vehicle-miles-travelled (VMT) are expected to increase on a national level by 31 percent. Although local conditions may differ from these national

1 The latest version of the VDOT Resource Document, Scoping Guidelines, and Template Report along with a link to the associated online data repository for modeling inputs are available on or via the Environmental Division website: https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/environmental/

2 FHWA, "*INFORMATION: Updated Interim Guidance on Mobile Source Air Toxic Analysis in NEPA Documents*", January 18, 2023. See: https://www.fhwa.dot.gov/environment/air_quality/air_toxics/

3 See: https://www.epa.gov/national-air-toxics-assessment

projections in terms of fleet mix and turnover, VMT growth rates, and local control measures, the magnitude of the EPA-projected reductions is so great (even after accounting for VMT growth) that MSAT emissions in the study area are likely to be lower in the future in nearly all cases.

Greenhouse Gases (GHGs)

For each alternative in this EA, the amount of GHGs emitted would be proportional to the vehicle miles traveled (VMT), assuming that other variables such as fleet mix are the same for each alternative. The VMT estimated for a Build Alternative therefore may be slightly higher than that for the No-Build Alternative, because additional capacity increases the efficiency of the roadway and attracts rerouted trips from elsewhere in the transportation network. This increase in VMT could lead to higher GHG emissions for the build alternative along a highway corridor, along with a corresponding decrease in GHG emissions along the parallel routes. Also, regardless of the alternative chosen, emissions will likely be lower than present levels in the design year as a result of fuel efficiency improvements and electrification policies that are projected to reduce annual statewide GHG emissions from on-road sources by nearly 50 percent between 2015 and 2040 (VDOT, Statewide Planning-Level GHG Assessment, December 2021).

Climate Change: Considerations Relating to the Affected Environment

Greenhouse gas emissions have accumulated rapidly as the world has industrialized. According to the U.S. Global Climate Change Research Program,[4] if emissions continue, projected changes in global average temperature could range from to 0.4° — 2.7°F (0.2°–1.5°C) under a very low emissions scenario, to 4.2°–8.5°F (2.4°–4.7°C) under a higher scenario by the end of the 21st century. Based on information developed by the Georgetown Climate Center,[5] Virginia's transportation infrastructure faces risks from a changing climate including increased levels of coastal flooding, inland flooding, and extreme heat.

Resiliency is an important consideration for VDOT when planning and designing future infrastructure investments. Resiliency considerations include siting and design of facilities both to minimize risk to the facility, and to minimize impacts on natural resiliency features such as wetlands, forests, and floodplains. Resiliency strategies that are cost-effective and can be adopted during the planning, project development, construction, and/or maintenance phases of a given infrastructure project are supported.

VDOT, and regional and local agency partners in the Commonwealth, have already engaged in efforts to plan for resiliency. As part of the development of VTrans, Virginia's transportation plan, the Commonwealth Transportation Board (CTB) has developed a Policy for the Development and Monitoring of VTrans Long-term Risk & Opportunity Register, which allows for quantification of impacts of ten macrotrends, including long-term flooding risk due to sea-level rise, storm surge, and inland/riverine flooding, as well as a Long-term Risk & Opportunity Register based on an assessment of these impacts. The CTB has also adopted strategic actions to mitigate the identified long-term risks and maximize opportunities, including collecting data to accurately assess flooding risks for the state- and locally-maintained roadways that can be used to identify funding needs and prioritize investment; developing policies based on robust data collection and

4 U.S. Global Climate Change Research Program (2018). Fourth National Climate Assessment.

5 Georgetown Climate Center (undated). "Understanding Virginia's Vulnerability to Climate Change." See: https://www.georgetownclimate.org/files/report/understanding-virginias-vulnerability-to-climate-change.pdf (accessed September 2021)

analysis to ensure flooding risks are reflected in transportation asset life-cycle and/or transportation project planning processes; and collaborating with state and regional agencies to systematically identify solutions that facilitate consistent and systematic prioritization and support the allocation of state resources to address flooding risks. Finally, the Office of Intermodal Planning and Investment (OIPI) is required to track trends related to all macrotrends, including the flooding risk, and report annually.

Indirect Effects and Cumulative Impacts (IECI)

A qualitative assessment of the potential for indirect effects and cumulative impacts attributable to this project was conducted. It concluded that the potential effects or impacts are not expected to be significant given available information from pollutant-specific analyses (CO and MSATs) and regional conformity analyses.

First, regarding the potential for indirect effects, the quantitative assessments conducted for programmatic CO, qualitative analyses for MSAT impacts and the regional conformity analysis conducted for ozone can all be considered indirect effects analyses because they look at air quality impacts attributable to the project that occur in the future. These analyses demonstrate that, in the future: 1) air quality impacts from CO will not cause or contribute to violations of the CO NAAQS, 2) MSAT emissions will be significantly lower than they are today, and 3) conformity requirements for the transportation plan and program will be met, including the mobile source emissions budgets established for the region for purposes of meeting the ozone NAAQS.

Second, regarding the potential for cumulative impacts, the annual conformity analysis conducted by the National Capital Region (NCR) Transportation Planning Board (TPB, which is the Metropolitan Planning Organization or MPO for the Washington, D.C. metropolitan area) represents a cumulative impact assessment for purposes of regional air quality.

- The existing air quality designations for the region are based, in part, on the accumulated mobile source emissions from past and present actions, and these pollutants serve as a baseline for the current conformity analysis.
- The conformity analysis quantifies the amount of mobile source emissions for which the area is designated nonattainment/maintenance that will result from the implementation of all reasonably foreseeable regionally significant transportation projects in the region (i.e., those proposed for construction funding over the life of the region's transportation plan).
- The most recent conformity analysis was completed in June 2022. FHWA/FTA issued a conformity finding on June 15, 2022 for the Transportation Improvement Program (TIP) and Constrained Long Range Plan (CLRP) covered by that analysis. This analysis demonstrated that the incremental impact of the proposed project on mobile source emissions, when added to the emissions from other past, present, and reasonably foreseeable future actions, is in conformance with the SIP and will not cause or contribute to a new violation, increase the frequency or severity of any violation, or delay timely attainment of the NAAQS established by EPA.

Mitigation:

Emissions may be produced in the construction of this project from heavy equipment and vehicle travel to and from the site, as well as from fugitive sources. Construction emissions are short term or temporary in nature. To mitigate these emissions, all construction activities are to be performed in accordance with VDOT *Road and Bridge Specifications.*[6]

The Virginia Department of Environmental Quality (VDEQ) provides general comments for projects by jurisdiction that in part address mitigation. For Prince William County, VDEQ stated that[7] "*…all reasonable precautions should be taken to limit the emissions of VOC and NOx. In addition, the following VDEQ air pollution regulations must be adhered to during the construction of this project: 9 VAC 5-130, Open Burning restrictions*[8]*; 9 VAC 5-45, Article 7, Cutback Asphalt restrictions*[9]*; and 9 VAC 5-50, Article 1, Fugitive Dust precautions.*[10]"

Project Status in the Regional Transportation Plan and Program: Federal conformity requirements at 40 CFR 93.114[11] and 40 CFR 93.115[12] (as incorporated by reference into the Virginia conformity SIP) apply as the area in which the project is located is designated as nonattainment for ozone. Accordingly, there must be a currently conforming transportation plan and program at the time of project approval, and the project must come from a conforming plan and program or otherwise meet the criteria specified in 40 CFR 93.109(b).[13] As of the date of preparation of this analysis, the project is included in the currently conforming FY 2023-2026 Transportation Improvement Program (TIP) and 2045 Long Range Transportation Plan (LRTP) developed by the designated metropolitan planning organization (MPO) for the region, the National Capital Region Transportation Planning Board (TPB).[14]

---

6 https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/technical-guidance-documents/road-and-bridge-specifications/

7 Spreadsheet entitled: "DEQ SERP Comments rev8b", March 2017, downloaded from the online data repository for the VDOT Resource Document. The repository may be accessed via the Environmental Division webpage: https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/environmental/

8 See: https://law.lis.virginia.gov/admincode/title9/agency5/chapter130/

9 See: https://law.lis.virginia.gov/admincode/title9/agency5/chapter45/

10 See: https://law.lis.virginia.gov/admincode/title9/agency5/chapter50/

11 See: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#93.114

12 See: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#93.115

13 See: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#93.109

14 See: http://www.mwcog.org/transportation/tpb/

This page is intentionally blank.

Project Background

This section presents background information including the project purpose and need, description, alternatives, summary traffic data and the project status in the regional transportation plan and program (for areas subject to conformity).

Purpose and Need

The extension of Marina Way within Prince William County (County) from Annapolis Way to the intersection of Gordon Boulevard (Route 123) and Horner Road was initially identified as part of the Marina Way Extension Environmental Assessment (EA) (County, 2023). The Final EA documented the need for an extension to mitigate traffic delays across multiple intersections in the area which are anticipated based on future traffic demands and the planned revitalization of the North Woodbridge area. Prior to the completion of the EA, Prince William County completed a traffic analysis which identified congestion and safety issues in this corridor. The traffic analysis is included in Appendix A.

The purpose of the proposed extension of Marina Way is to provide an adequate multi-modal transportation system that:

- Provides traffic congestion relief for traffic demand on local roads and intersections.
- Provides access to local businesses and homes in the North Woodbridge area and is consistent with existing and planned local development.
- Provides safe pedestrian accessibility and connectivity in the North Woodbridge area.

Project Description

The Prince William County (County) Department of Transportation, in cooperation with the Virginia Department of Transportation (VDOT) and the Federal Highway Administration (FHWA), is proposing to construct an extension of Marina Way between Annapolis Way and Route 123 in Woodbridge, Virginia.

Exhibit 1.2.1 provides an overview of the study corridor for the proposed project and Exhibit 1.2.2 provides an aerial of the project area. The proposed four-lane, 0.26-mile roadway would be on new alignment. It would be a four-lane median-divided roadway with curb and gutter, a 4-foot buffer, and 5-foot-wide sidewalks on both sides of the road. Lane widths will be 11 feet wide with turn lanes present at the Route 123 intersection and main entrances into the Home Depot and Aldi grocery store. The proposed raised grass median will be 15 feet in width and will transition down to 4 feet at intersections where turn lanes are needed. The project does not involve additional capacity on the existing Marina Way.

Exhibit 1.2.1: Project Location Map

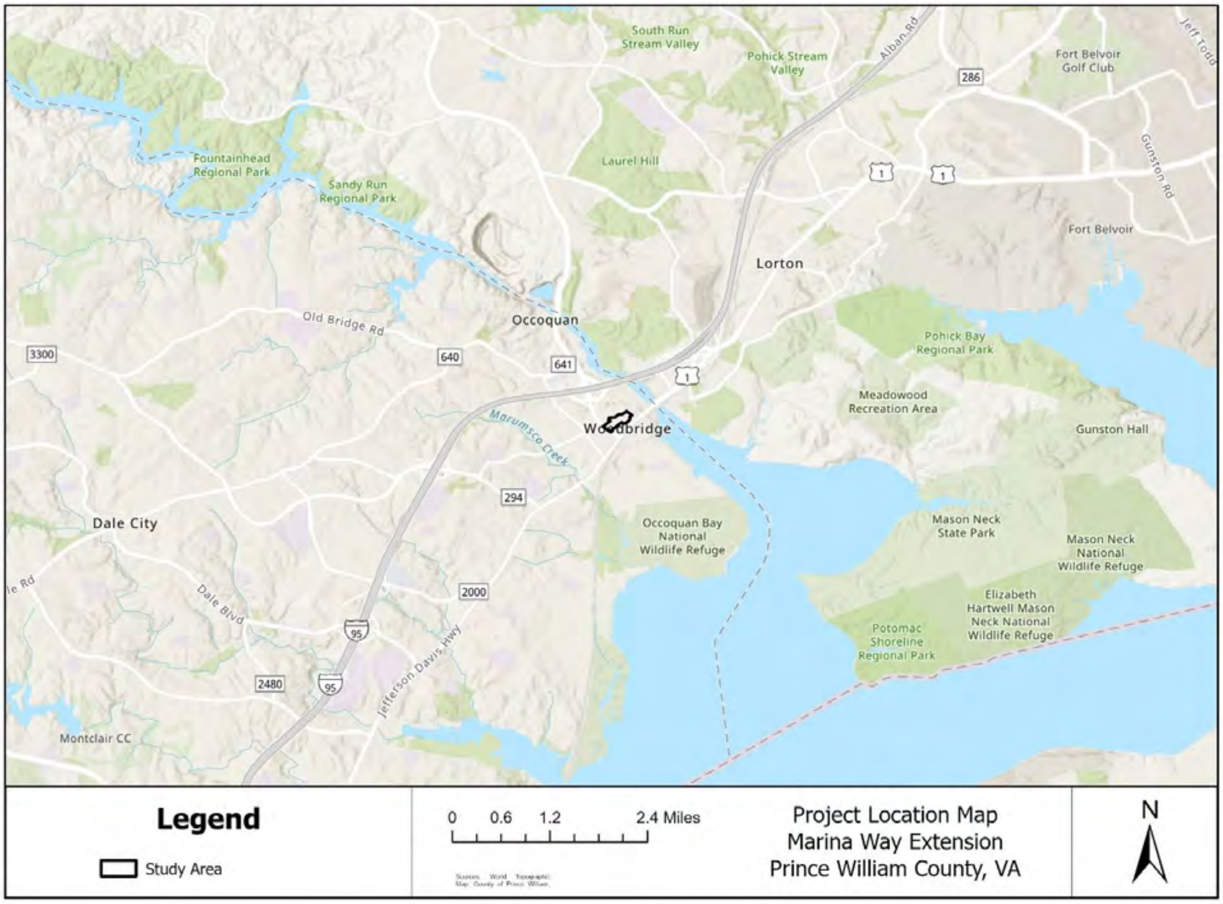


Exhibit 1.2.2: Aerial Imagery Map

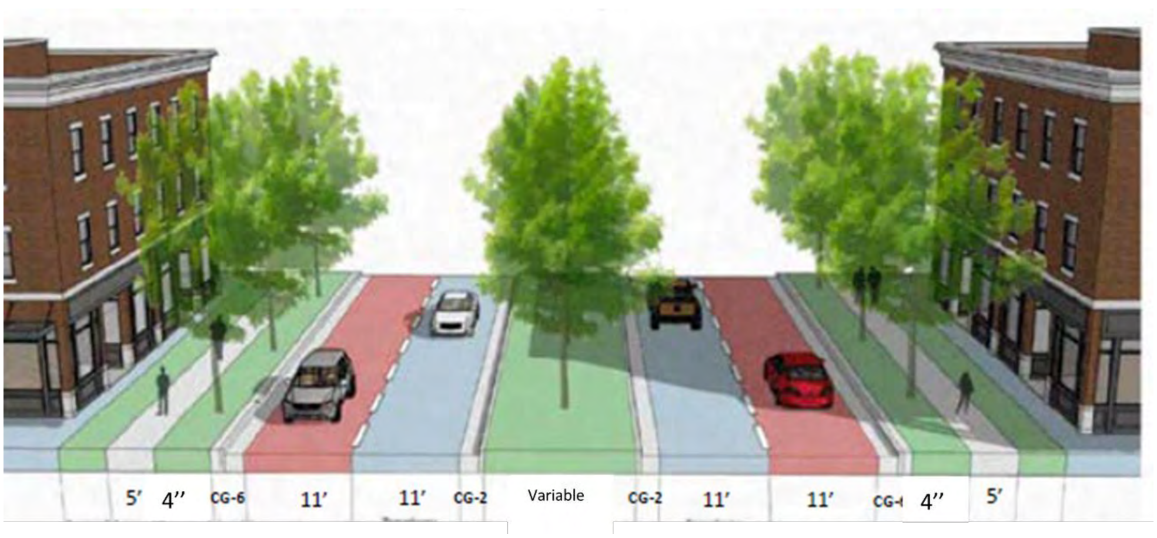
Alternatives

Based on the project purpose and need, Prince William County developed two alternatives: a Build Alternative and the No-Build alternative. The Build Alternative includes the proposed extension of Marina Way. The No-Build Alternative assumes that Prince William County takes no action to address the project purpose and need, other than those typically completed as part of existing system preservation (i.e., resurfacing, landscape management, sign replacement, etc.).

The No Build Alternative assumes the Marina Way Extension roadway and associated improvements are not constructed but considers proposed development and transportation projects in the area will continue as planned including North Woodbridge Town Center, Annapolis Way Extension, Route 1 and Route 123 Interchange, and Route 123 widening.

The proposed alignment will connect the existing Marina Way roadway at Marina Way and Annapolis Way. The proposed section between Horner Road and Route 123 Intersection will be constructed on new alignment through the Gordon Plaza. The alignment will provide a continuous four-lane divided section and continuous 5-foot-wide sidewalks on both sides of the road from Annapolis Way to the Horner Road and Route 123 Intersection. Sharrows have been identified in the Mobility Plan for this section of roadway and will be assessed during the design process. The alignment would require new ROW for the entire proposed section and be required to meet building setback requirements. Exhibit 1.3.1 shows the proposed typical section for the new alignment.

Exhibit 1.3.1: Proposed Typical Section



Source: Marina Way Environmental Assessment, 2024

Exhibit 1.3.2: Build Alternative

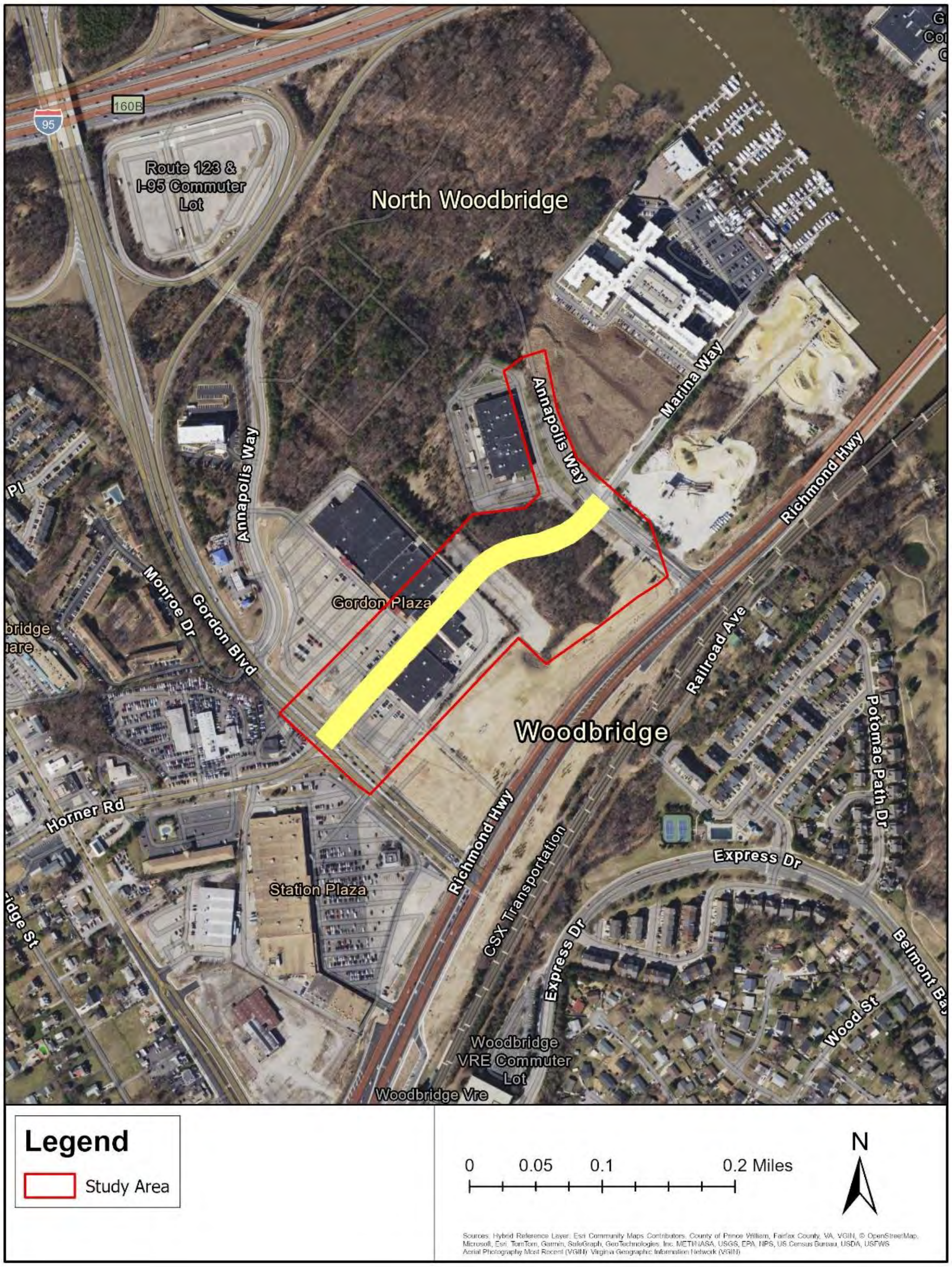


Exhibit 1.3.3: Plan and Profile

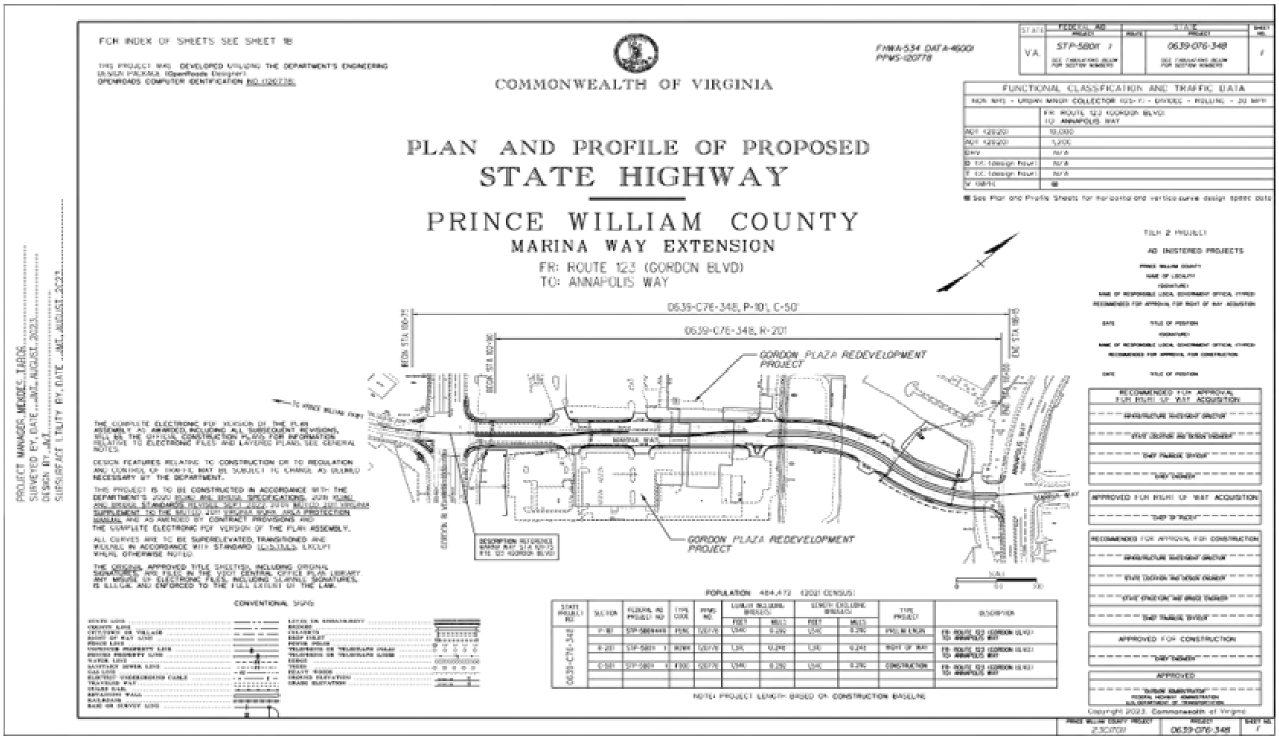


Exhibit 1.3.4: Roadway Grades (Existing Contours)

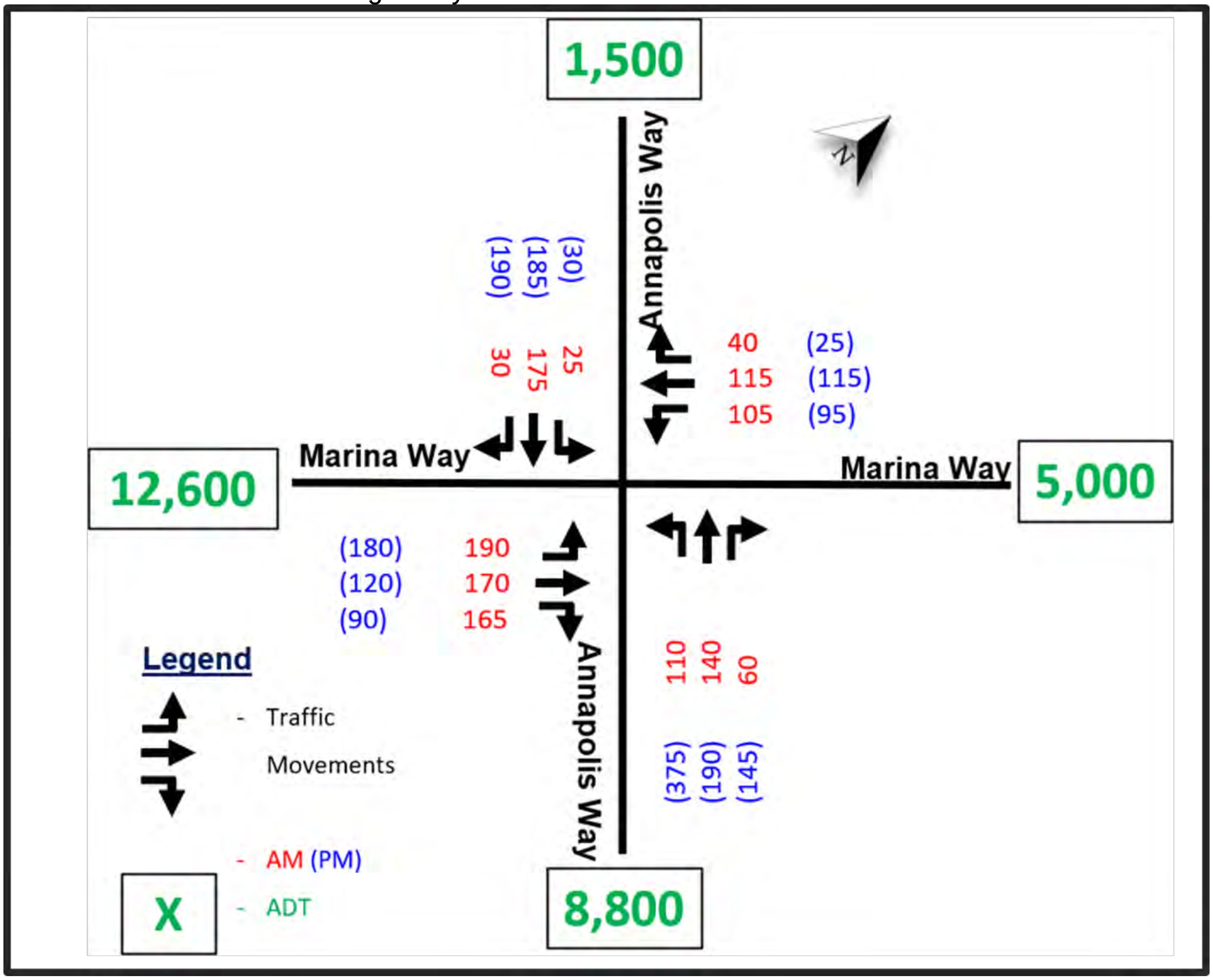
Source: JMT Survey, 2024

Summary of Traffic Data and Forecasts

Environmental traffic data for the Study Area include peak period volumes for each intersection for the build and no build conditions. In situations where design-operational speeds were not available, posted speed limits were used. The detailed traffic data and forecasts are provided in the Preliminary Noise Analysis Report, July 2022. Exhibit 1.4.1 presents a summary of the mainline segments' base (2023) and design year (2050) average daily traffic (ADT) forecasts for the project. As shown in the exhibit, the peak ADT forecast for the design year is 12,600. The corresponding no-build forecast not available. Truck percentages for Marina Way are displayed in Exhibit 1.4.2.

Traffic forecasts are provided in Appendix A to this report.

Exhibit 1.4.1: Average Daily Traffic Forecasts for Boulevard and Other Local Roads



Source: Marina Way and Annapolis Way Alternative Intersection Report, November 22, 2023

Exhibit 1.4.2: Truck Percentages for Marina Way (Combined with Local Roads)

	Truck Percentages	
	2X-6T	3X+
Daily	2%	0.2%
AMPH	1%	0.2%
PMPH	1%	0.0%

Source: Marina Way and Annapolis Way Alternative Intersection Report, November 22, 2023

Project Status in the Regional Transportation Plan and Program

As of the date of preparation of this analysis, the project is included in the currently conforming FY 2023-2026 Transportation Improvement Program (TIP) and 2045 Long Range Transportation Plan

(LRTP).[15] The LRTP and TIP are developed by the metropolitan planning organization (MPO) for the region.[16]

Ambient Air Quality and Attainment Status

National Ambient Air Quality Standards (NAAQS)

Exhibit 2.1.1 presents the national ambient air quality standards (NAAQS) established by the EPA for criteria air pollutants, namely: carbon monoxide (CO), sulfur dioxide (SO_2), ozone (O_3), particulate matter (PM), nitrogen dioxide (NO_2), and lead (Pb). There are two types of NAAQS—primary and secondary: "*Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings*."[17]

As a requirement of the Clean Air Act, EPA periodically reviews the NAAQS and revises them as needed, e.g., to make them more stringent and/or, on occasion, to revoke previous standards that were less stringent.[18] For example, EPA revoked the 1997 annual primary $PM_{2.5}$ NAAQS effective October 24, 2016, with the implementation of the more stringent 2012 $PM_{2.5}$ NAAQS.[19]

Areas that have never been designated by EPA as nonattainment for one or more of the NAAQS are classified as attainment areas, while areas that do not meet one or more of the NAAQS may be designated by EPA as nonattainment areas for that or those criteria pollutants. Areas that have failed to meet the NAAQS in the past but have since re-attained them may be re-designated as attainment (maintenance) areas, which are commonly referred to as maintenance areas.

Exhibit 2.1.1: National Ambient Air Quality Standards (US EPA Tabulation)

Pollutant [links to historical tables of NAAQS reviews]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)	primary	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	
Lead (Pb)	primary and secondary	Rolling 3 month average	0.15 μg/m^3 (1)	Not to be exceeded

15 TIP: https://projectinfotrak.mwcog.org/projects/?includeControls=false&planCycleId=242&page=1&pageSize=100
Plan: https://visualize2045.org/plan-update/approved-2022-plan/

16 See: https://www.mwcog.org/committees/transportation-planning-board/

17 From the preamble to the EPA NAAQS table: https://www.epa.gov/criteria-air-pollutants/naaqs-table

18 On January 27, 2023, EPA issued a proposed rule for "Reconsideration of the National Ambient Air Quality Standards for Particulate Matter" (18 FR 5558). At the time of preparation of this report, that rule has not been finalized. The NAAQS table presented here may be updated for PM when the rule is finalized.

19 On August 24, 2016, EPA issued a final rule (81 FR 58010), effective October 24, 2016, on "*Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements*" that stated, in part: "*Additionally, in this document the EPA is revoking the 1997 primary annual standard for areas designated as attainment for that standard because the EPA revised the primary annual standard in 2012.*"
See: https://www.gpo.gov/fdsys/pkg/FR-2016-08-24/pdf/2016-18768.pdf .

Note the revocation of the 1997 annual primary NAAQS for $PM_{2.5}$ also eliminated the associated conformity requirements. For example, conformity requirements for that NAAQS were eliminated for northern Virginia, which until then had been in attainment (maintenance) for that standard.

Pollutant [links to historical tables of NAAQS reviews]		Primary/ Secondary	Averaging Time	Level	Form
Nitrogen Dioxide (NO_2)		primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		primary and secondary	1 year	53 ppb (2)	Annual Mean
Ozone (O_3)		primary and secondary	8 hours	0.070 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 μg/m^3	annual mean, averaged over 3 years
		secondary	1 year	15.0 μg/m^3	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 μg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

(1) In areas designated nonattainment for the Pb standards prior to the promulgation of the current (2008) standards, and for which implementation plans to attain or maintain the current (2008) standards have not been submitted and approved, the previous standards (1.5 µg/m3 as a calendar quarter average) also remain in effect.

(2) The level of the annual NO2 standard is 0.053 ppm. It is shown here in terms of ppb for the purposes of clearer comparison to the 1-hour standard level.

(3) Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) O3 standards are not revoked and remain in effect for designated areas. Additionally, some areas may have certain continuing implementation obligations under the prior revoked 1-hour (1979) and 8-hour (1997) O3 standards.

(4) The previous SO2 standards (0.14 ppm 24-hour and 0.03 ppm annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet 1 year since the effective date of designation under the current (2010) standards, and (2)any area for which an implementation plan providing for attainment of the current (2010) standard has not been submitted and approved and which is designated nonattainment under the previous SO2 standards or is not meeting the requirements of a SIP call under the previous SO2 standards (40 CFR 50.4(3)). A SIP call is an EPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required NAAQS.

Source: Excerpted from: https://www.epa.gov/criteria-air-pollutants/naaqs-table, accessed 1/23/2024.

Air Quality Attainment Status of the Project Area

The EPA Green Book[20] lists non-attainment, maintenance, and attainment areas across the nation. It lists the jurisdictions within the area in which the project is located as being in attainment for all of the NAAQS except ozone.

As noted in Section 6 on consultation, the Virginia Department of Environmental Quality (VDEQ) provides general comments by jurisdiction on proposed projects. With regard to attainment status for the area in which project is located, their comment[21] is: "*This project is located within a Marginal 8-hour Ozone Nonattainment area, and a volatile organic compounds (VOC) and nitrogen oxides (NOx) Emissions Control Area …*"

20 EPA Green Book: https://www.epa.gov/green-book
21 Spreadsheet entitled: "DEQ SERP Comments rev8b", March 2017

Ambient Air Quality Monitoring Data and Trends

VDEQ issues an annual report summarizing air quality monitoring data for the previous year, covering criteria pollutants (those for which EPA has established NAAQS) and other pollutants including air toxics.[22] Excerpts of the monitoring data from that report are presented below.

Criteria Pollutants

For transportation sources, the criteria pollutants of primary interest are CO, PM, and NO_2. As the region was previously in maintenance for the 1997 ozone NAAQS, the trend in ozone levels relative to current (more stringent) NAAQS is also of interest.

Carbon Monoxide

EPA provides the following background information on CO:[23]

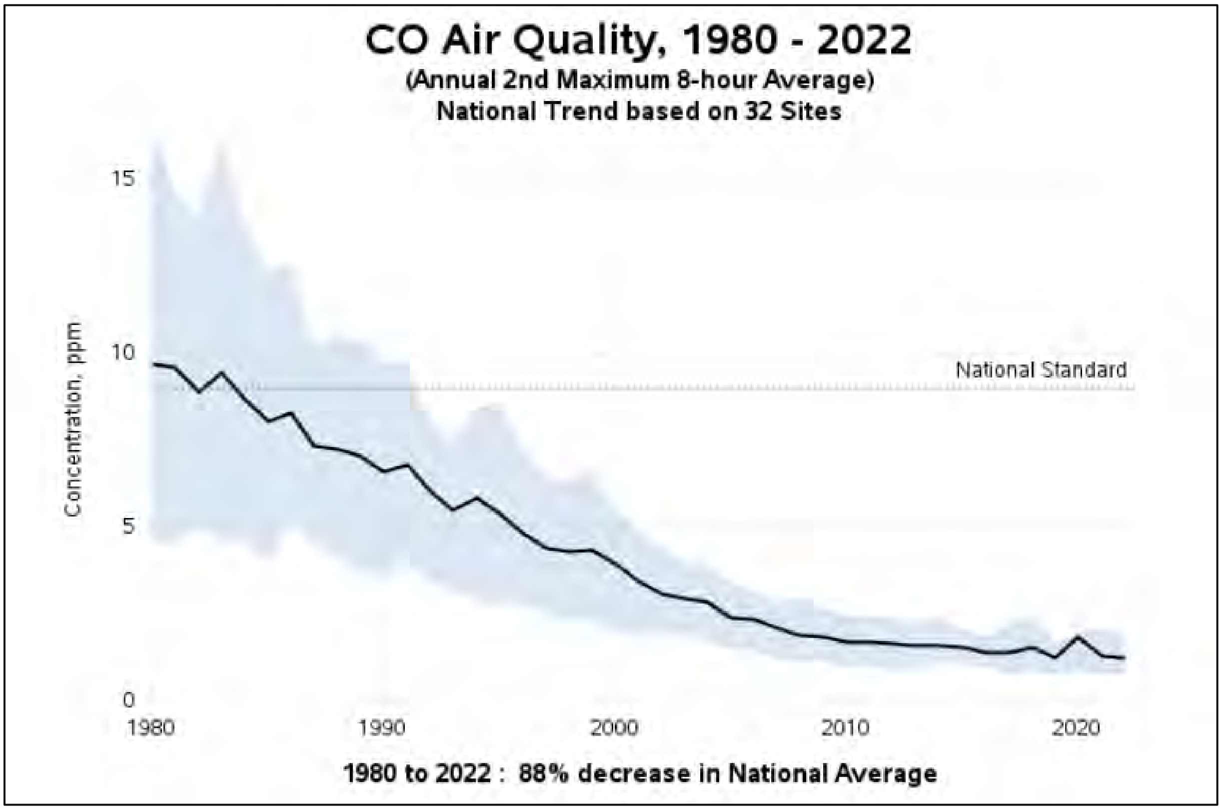
> *"CO is a colorless, odorless gas that can be harmful when inhaled in large amounts. CO is released when something is burned. The greatest sources of CO to outdoor air are cars, trucks and other vehicles or machinery that burn fossil fuels. A variety of items in your home such as unvented kerosene and gas space heaters, leaking chimneys and furnaces, and gas stoves also release CO and can affect air quality indoors."*

As shown in Exhibit 2.3.1, and due primarily to the implementation of more stringent vehicle emission and fuel quality standards, the national trend in ambient concentrations of CO over the past few decades has decreased to a level substantially below the current eight-hour NAAQS of nine parts per million (ppm). The national trend is reflected in the very low ambient CO concentrations currently observed in Virginia, which are presented in Exhibits 2.3.2 and 2.3.3. As noted above, Virginia is in attainment for both the one- and eight-hour NAAQS for CO.

22 https://www.deq.virginia.gov/our-programs/air/reports

23 https://www.epa.gov/co-pollution/basic-information-about-carbon-monoxide-co-outdoor-air-pollution#What%20is%20CO

Exhibit 2.3.1: National Trend in Ambient CO Concentrations



Source: https://www.epa.gov/air-trends/carbon-monoxide-trends, accessed March 6, 2024

Exhibit 2.3.2: Ambient Concentrations of Carbon Monoxide in Virginia

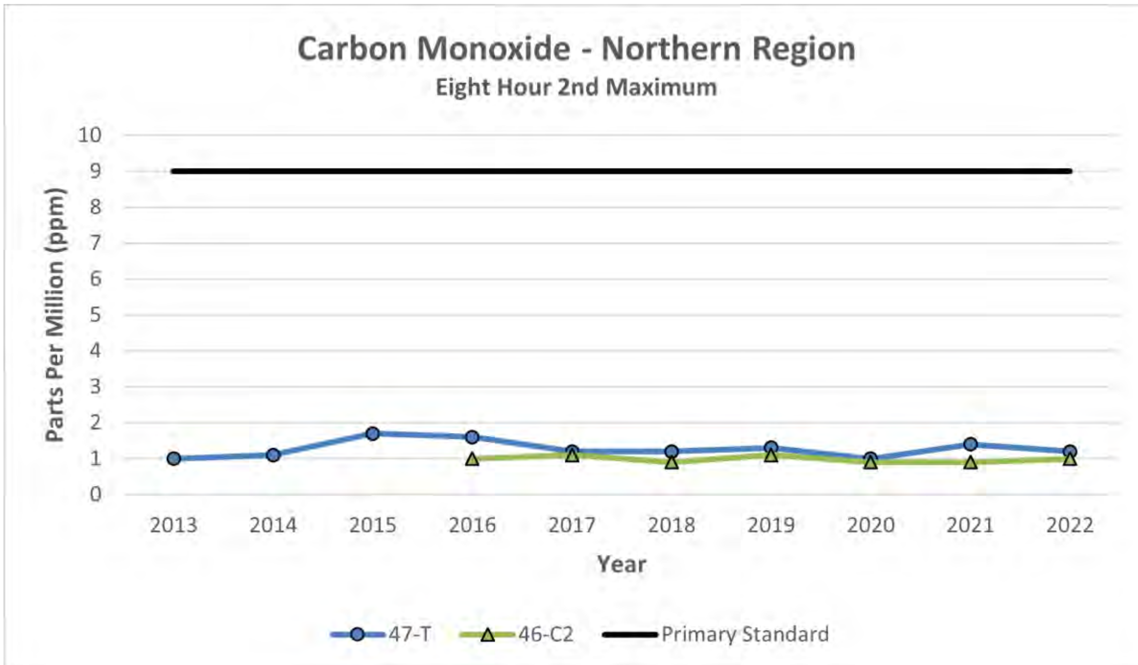
Primary NAAQS: 35 ppm (1-hour) and 9 ppm (8-hour)

Site	2021			
	1-Hour Avg. (ppm)		8-Hour Avg. (ppm)	
	1st Max.	2nd Max.	1st Max.	2nd Max.
(19-A6) Roanoke Co.	0.8	0.8	0.7	0.6
(72-M) Henrico Co.	1.2	1.1	0.8	0.8
(158-X) Richmond	1.3	1.2	1.1	1.0
(179-K) Hampton	0.7	0.7	0.6	0.6
(181-A1) Norfolk	1.2	1.2	1.1	0.8
(46-C2) Fairfax Co.	1.4	1.3	1.0	0.9
(47-T) Arlington Co.	1.7	1.6	1.5	1.4

Eight Hour Averages stated as Ending Hour

Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See: https://www.deq.virginia.gov/our-programs/air/reports

Exhibit 2.3.3: Trend in Ambient CO Concentrations



*Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See:*http://www.deq.virginia.gov/Programs/Air/AirMonitoring/Publications.aspx
https://www.deq.virginia.gov/our-programs/air/reports

Particulate Matter

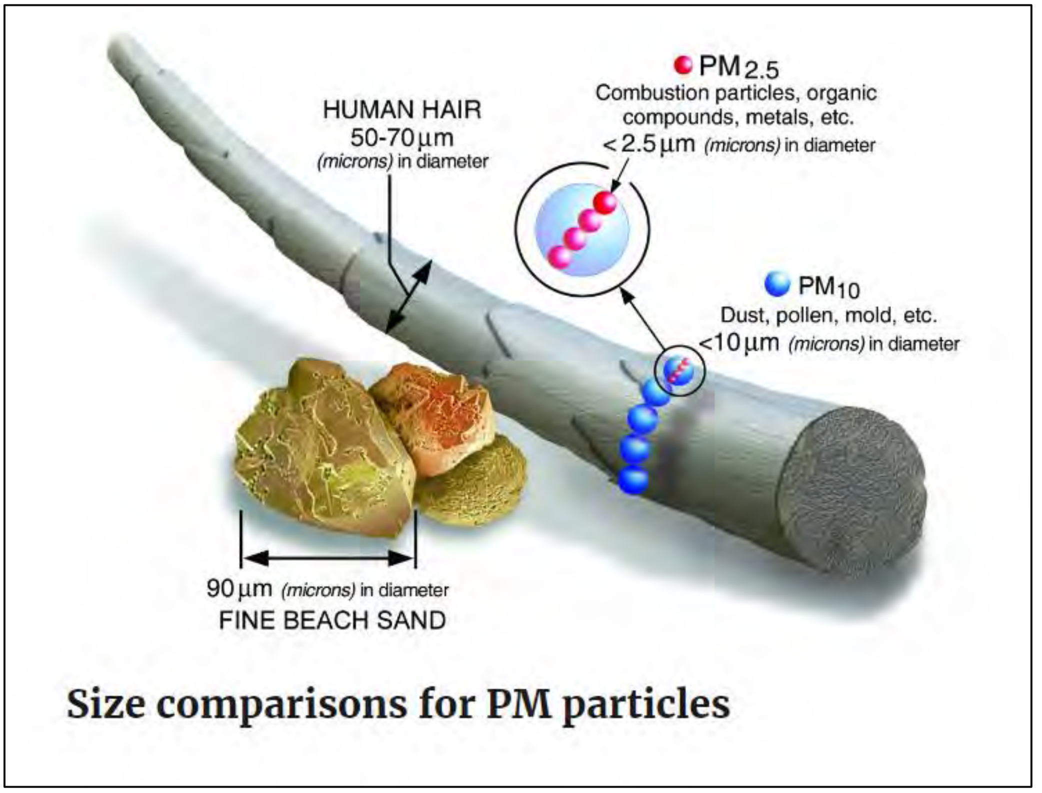
EPA provides the following background information on particulate matter (PM):[24]

> *"PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.*
>
> *Particle pollution includes:*
>
> - *PM_{10} : inhalable particles, with diameters that are generally 10 micrometers and smaller; and*
> - *$PM_{2.5}$: fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller."*

Exhibit 2.3.4 from EPA shows the size of $PM_{2.5}$ and PM_{10} particles relative to a human hair and to fine beach sand.

[24] See: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

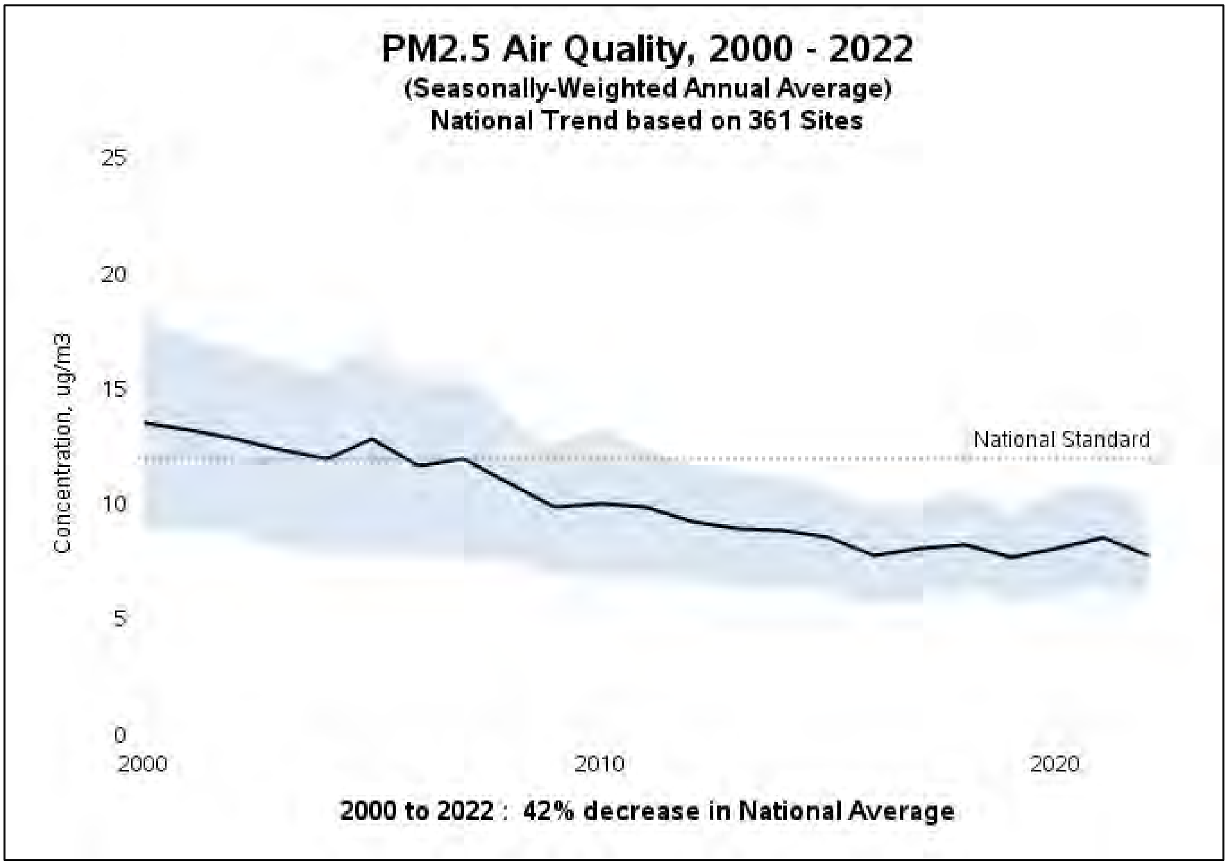
Exhibit 2.3.4: EPA Size Comparisons for PM Particles



Source: US EPA website accessed March 6, 2024. See: *https://www.epa.gov/pm-pollution/particulate-matter-pm-basics*

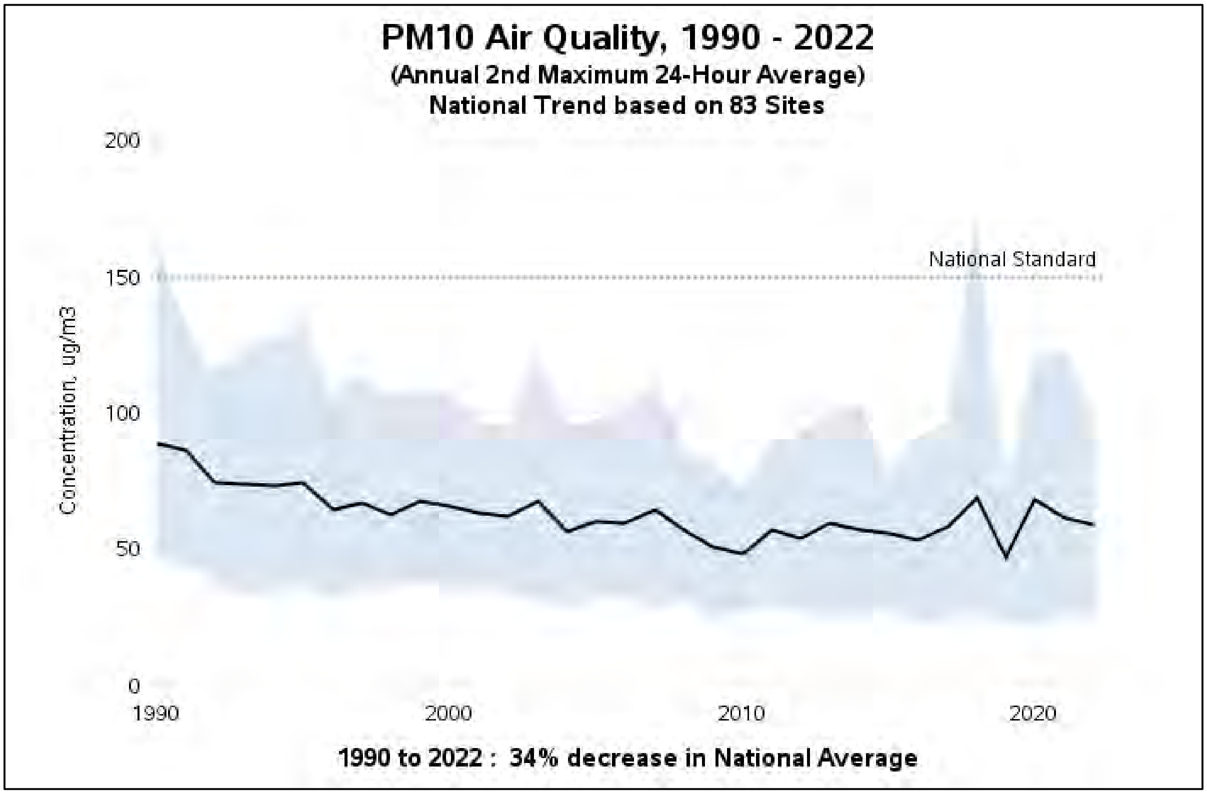
Exhibits 2.3.5 and 2.3.6 present the national trends in $PM_{2.5}$ and PM_{10} levels respectively.

Exhibit 2.3.5: National Trends in $PM_{2.5}$ Concentrations (Annual Average)



Source: US EPA website accessed March 6, 2024. See:
https://www.epa.gov/air-trends/particulate-matter-pm25-trends

Exhibit 2.3.6: National Trends in PM_{10} Concentrations (24-Hour Average)



Source: US EPA website accessed March 6, 2024. See:
https://www.epa.gov/air-trends/particulate-matter-pm10-trends

Exhibits 2.3.7 through 2.3.9 respectively present tabulations of $PM_{2.5}$ (24-hour and annual standards) and PM_{10} (24-hour standard) concentrations, which were excerpted from the referenced VDEQ annual air quality monitoring report. As noted above, all of Virginia is in attainment of the NAAQS for both pollutants.

Exhibit 2.3.7: Ambient Concentrations of $PM_{2.5}$ (24-Hour Average)

2020-2022 $PM_{2.5}$ 24-hour Averages, 98th Percentile Values (µg/m³, LC)				
Site	**2020**	**2021**	**2022**	**3-Year Average**
(101-E) **Bristol**	13.7	16.2	13.0	14.3
(26-F) **Rockingham Co.**	14.0	18.3	13.0	15.1
(28-J) **Frederick Co.**	16.2	21.2	19.2	18.9
(33-A) **Albemarle Co.**	12.3	17.9	15.0	15.1
(19-A6) **Roanoke Co.**	14.7	19.7	15.7	16.7
(110-C) **Salem**	13.5	18.8	12.6	15.0
(155-Q) **Lynchburg**	11.7	17.5	11.5	13.6
(71-H) **Chesterfield Co.**	11.4	18.9	11.9	14.1
(72-M) **Henrico Co.**	14.5	18.0	15.9	16.1
(72-N) **Henrico Co.**	12.7	17.2	11.1	13.7
(75-B) **Charles City Co.**	11.5	17.0	12.9	13.8
(158-X) **Richmond**	15.7*	17.6*	16.4	16.6
(179-K) **Hampton**	12.8	15.5	13.0	13.8
(181-A1) **Norfolk**	12.1*	15.4	12.8	13.4
(184-J) **Va. Beach**	15.1*	15.1	13.6	14.6
(38-I) **Loudoun Co.**	19.3*	16.0	13.0	16.1
(47-T) **Arlington Co.**	17.7	17.1	13.5	16.1
(46-B9) **Franconia, Fairfax Co.**	14.6	17.6	14.0	15.4
(46-C2) **Springfield, Fairfax Co.**	16.3	19.9*	15.7	17.3

Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See: https://www.deq.virginia.gov/our-programs/air/reports
http://www.deq.virginia.gov/Programs/Air/AirMonitoring/Publications.aspx

Exhibit 2.3.8: Ambient Concentrations of $PM_{2.5}$ (Annual Average)

2020-2022 $PM_{2.5}$ Weighted Annual Arithmetic Means ($\mu g/m^3$, LC)				
Site	**2020**	**2021**	**2022**	**3-Year Average**
(101-E) **Bristol**	6.0	7.3	6.2	6.5
(26-F) **Rockingham Co.**	6.1	7.4	6.5	6.7
(28-J) **Frederick Co.**	6.6	8.6	7.7	7.6
(33-A) **Albemarle Co.**	6.5	7.7	7.7	7.3
(19-A6) **Roanoke Co.**	6.7	8.3	7.4	7.5
(110-C) **Salem**	5.9	7.1	6.4	6.5
(155-Q) **Lynchburg**	5.4	6.6	5.7	5.9
(71-H) **Chesterfield Co.**	5.5	7.0	5.8	6.1
(72-M) **Henrico Co.**	6.9	8.3	7.7	7.6
(72-N) **Henrico Co.**	5.6	7.2	6.0	6.3
(75-B) **Charles City Co.**	5.6	7.0	5.8	6.1
(158-X) **Richmond**	6.9*	8.3*	8.0	7.7
(179-K) **Hampton**	5.9	7.0	6.8	6.6
(181-A1) **Norfolk**	6.0*	7.2	6.3	6.5
(184-J) **Va. Beach**	6.2*	7.3*	6.5	6.7
(38-I) **Loudoun Co.**	6.2*	7.4	6.4	6.7
(47-T) **Arlington Co.**	6.6	7.9	6.7	7.1
(46-B9) **Franconia, Fairfax Co.**	6.6	7.9	7.2	7.2
(46-C2) **Springfield, Fairfax Co.**	7.9	9.1*	8.1	8.4

Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See: https://www.deq.virginia.gov/our-programs/air/reports
http://www.deq.virginia.gov/Programs/Air/AirMonitoring/Publications.aspx

Exhibit 2.3.9: Ambient Concentrations of PM_{10} (24-Hour Average)

2020-2022 PM_{10} 24-Hour Average Concentrations (units in µg/m³ STD)							
Site	**2020**		**2021**		**2022**		**>150 µg/m³**
	1st Max	**2nd Max**	**1st Max**	**2nd Max**	**1st Max**	**2nd Max**	
(23-A) **Carroll Co.**	16	15	36	27	25	22	0
(28-J) **Frederick Co.***	-	-	51	46	45	42	0
(44-A) **Stafford Co.**	24	16	34	30	18	13	0
(46-B9) **Fairfax Co.***	17	16	45	27	30	23	0
(72-M) **Henrico Co.**	16	15	39	23	29	27	0
(154-M) **Hopewell@**	16	15	34	19	25	16	0
(179-K) **Hampton***	13	10	17	14	28	26	0
(181-A1) **Norfolk**	29	20	24	21	22	20	0

* Continuous monitoring started in 2022
@ Did not meet 4th quarter data completeness criteria in 2022
- No data

Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See:
http://www.deq.virginia.gov/Programs/Air/AirMonitoring/Publications.aspx*https://www.deq.virginia.gov/our-programs/air/reports*

Nitrogen Dioxide

EPA provides the following background information on NO_2:[25]

"Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NO_x). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 is used as the indicator for the larger group of nitrogen oxides.

NO2 primarily gets in the air from the burning of fuel. NO_2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment."

and

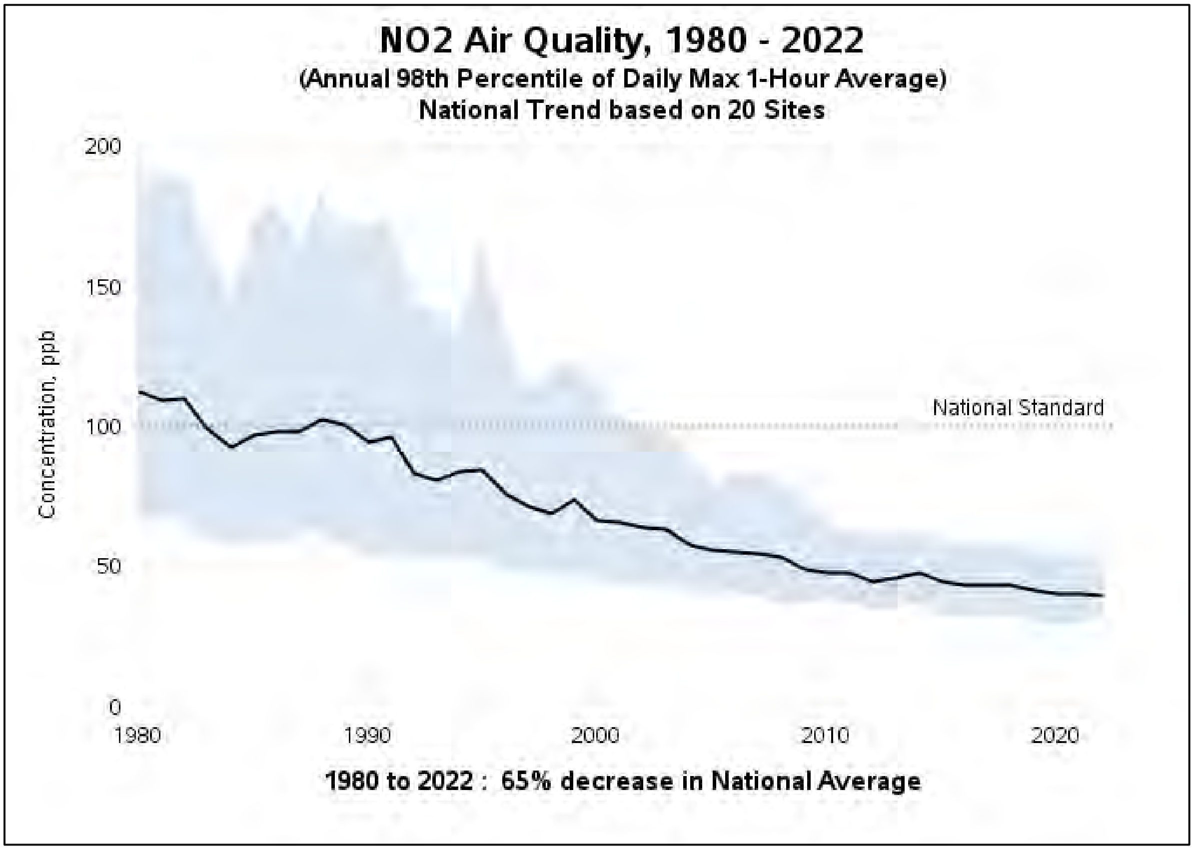
"Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.

NO_2 along with other NO_x reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system."

Exhibits 2.3.10 and 2.3.11 present the trend in levels of NO_2 on a national level and for northern Virginia respectively.

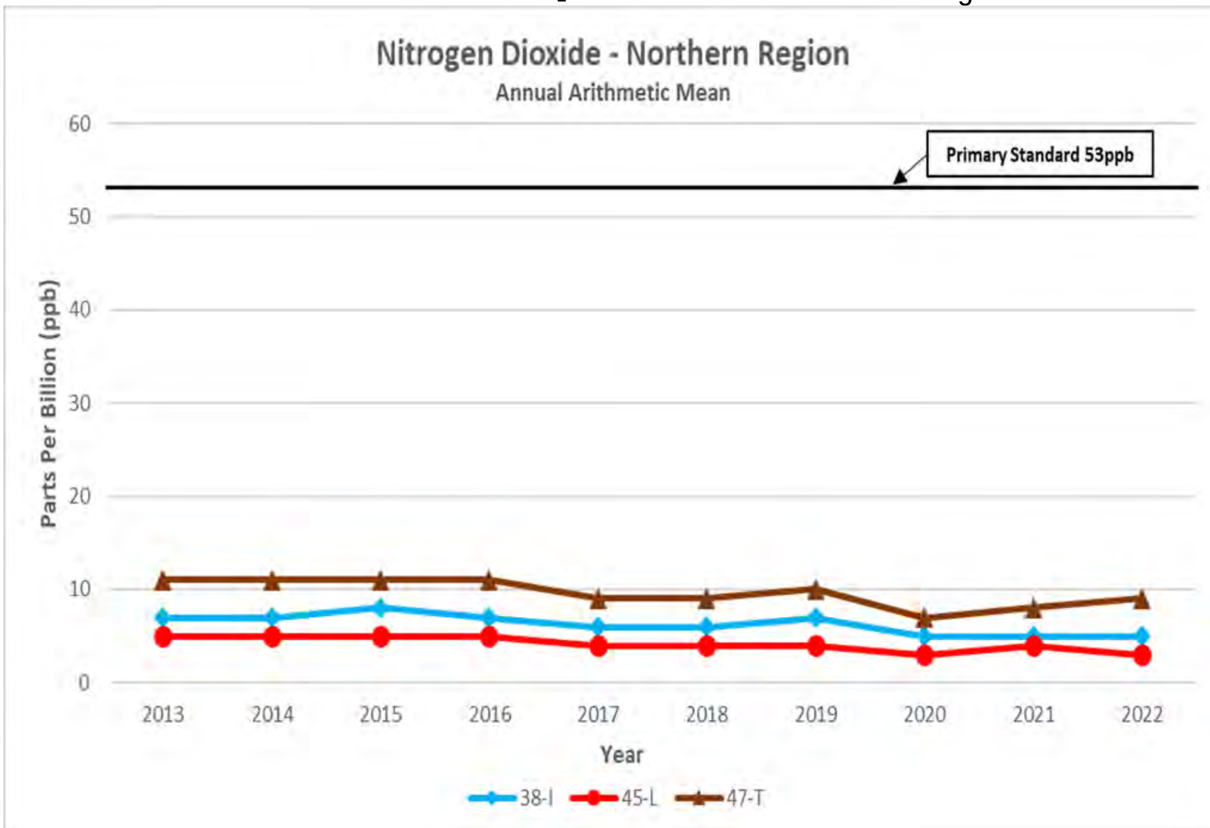
[25] See: https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2

Exhibit 2.3.10: National Trends in NO_2 Concentrations



Source: US EPA website accessed March 6, 2024. See:
https://www.epa.gov/air-trends/nitrogen-dioxide-trends

Exhibit 2.3.11: Trends in NO_2 Concentrations in Northern Virginia

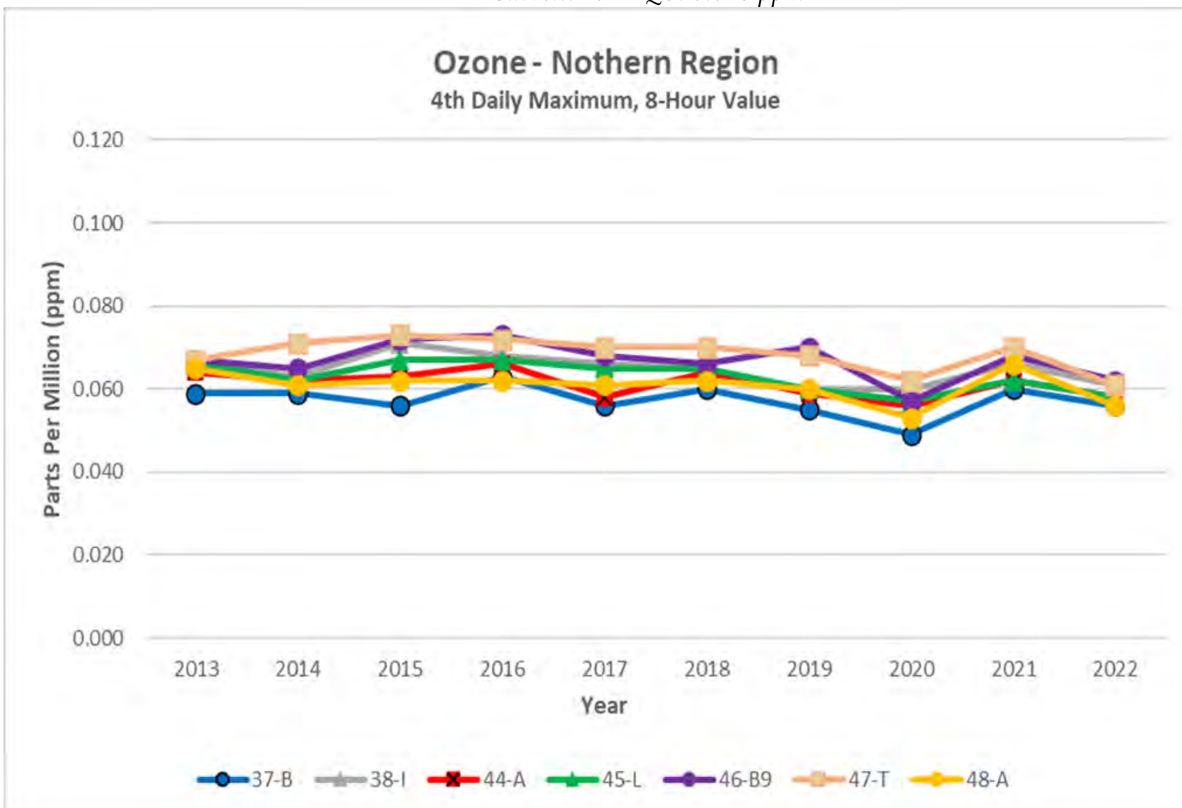


Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See: http://www.deq.virginia.gov/Programs/Air/AirMonitoring/Publications.aspx *https://www.deq.virginia.gov/our-programs/air/reports*

Ozone

Exhibit 2.3.12 presents the trend in regional ozone levels for the eight-hour standard.

Exhibit 2.3.12: Trend for the Eight-Hour Ozone Standard – Northern Region
Current NAAQS: 0.070 ppm



Source: Virginia Department of Environmental Quality, "Virginia Ambient Air Monitoring 2022 Annual Report", 2023. See: http://www.deq.virginia.gov/Programs/Air/AirMonitoring/Publications.aspx*https://www.deq.virginia.gov/our-programs/air/reports*

Air Toxics

From the VDEQ website:[26]

> *"Toxic air pollutants, also called Hazardous Air Pollutants or air toxics, are known or suspected to cause adverse health or environmental effects.*
>
> *DEQ maintains two air toxics monitoring sites: one in the Richmond area at the MathScience Innovation Center, and one in Hopewell. Among the principle objectives of these stations are assessing trends and emission reduction program effectiveness, assessing and verifying air quality models (e.g., exposure assessments, emission control strategy development, etc.), and as direct input to source-receptor models.*
>
> *At each of these sites, daily measurements are taken for dozens of pollutants, including volatile organic compounds (VOCs), carbonyls and metals, and the Richmond site also measures polyaromatic hydrocarbons (PAHs). The Hopewell site was placed in 2009 as part of a grant to study localized impacts from air toxics. The Richmond site is part of a national network to study air toxics trends. In addition to these sites, DEQ will begin collecting data as part of an air toxics study in Newport News and Norfolk in the summer of 2021.*
>
> *Find more information about these monitors in DEQ's Air Monitoring Network Plan. "*[27]

Mobile source air toxics and trends are addressed in more detail in the next section on project assessment.

[26] See: https://www.deq.virginia.gov/our-programs/air/monitoring-assessments/air-monitoring/pollutant-monitoring , accessed February 1, 2023

[27] Ibid

Project Assessment

Regulatory Requirements

The assessments presented in this section were conducted for purposes of the National Environmental Policy Act of 1969 (NEPA) and, where applicable, to meet transportation conformity rule requirements. FHWA posts guidance for NEPA on its website for project development,[28] and provides guidance specific to air quality (focusing on carbon monoxide) in its 1987 Technical Advisory 6640.8A, "*Guidance for Preparing and Processing Environmental and Section 4(f) Documents."*[29] FHWA posts separate guidance for mobile source air toxics (MSATs) along with responses to "Frequently Asked Questions" (FAQs) on its air quality webpage.[30]

EPA transportation conformity rule requirements are specified in 40 CFR Parts 51 and 93,[31] which were issued pursuant to requirements in the Clean Air Act (CAA) as amended.[32] Copies of the EPA conformity regulation and associated guidance are available on the EPA website.[33] In general, the rule requires conformity determinations for transportation plans, programs and projects in "*non-attainment or maintenance areas for transportation-related criteria pollutants for which the area is designated nonattainment or has a maintenance plan*" (40 CFR 93.102(b)).

Corresponding Commonwealth of Virginia requirements for conformity are specified in 9 VAC-5-151, which is also referred to as the state "conformity SIP" or "conformity implementation plan."[34] Note, per the federal transportation conformity regulation, its requirements apply only in the absence of corresponding requirements in the state conformity regulation.[35] The Virginia regulation incorporates by reference most of the requirements in the July 1, 2012 federal rule from 40 CFR 923.101 to 93.129, with the notable exception of 40 CFR 93.105 which addresses consultation. The Virginia regulation provides detailed requirements for consultation that are specific to Virginia but otherwise reflect the consultation requirements in 40 CFR 93.105.

---

28 See: https://www.environment.fhwa.dot.gov/nepa/nepa_projDev.aspx
29 See: https://www.environment.fhwa.dot.gov/projdev/impTA6640.asp
30 See: https://www.fhwa.dot.gov/environment/air_quality/air_toxics/
31 *EPA Transportation Conformity Regulation and Guidance*:
- https://www.epa.gov/state-and-local-transportation/current-law-regulations-and-guidance-state-and-local-transportation.

Direct links:
- https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-51#subpart-T
- https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#part-93

32 See: http://www.epa.gov/air/caa/
33 See: https://www.epa.gov/state-and-local-transportation/transportation-conformity
34 *Virginia Regulation for Transportation Conformity (9 VAC5-151)*: https://law.lis.virginia.gov/admincode/title9/agency5/chapter151/
35 40 CFR 51.390*: "…The federal conformity rules under part 93, subpart A, of this chapter… establish the conformity criteria and procedures necessary to meet the requirements of Clean Air Act section 176(c) until such time as EPA approves the conformity implementation plan revision required by this subpart… The federal conformity regulations contained in part 93, subpart A, of this chapter would continue to apply for the portion of the requirements that the state did not include in its conformity implementation plan and the portion, if any, of the state's conformity provisions that is not approved by EPA."* https://ecfr.federalregister.gov/current/title-40/chapter-I/subchapter-C/part-51.390#51.390

Application of the VDOT Resource Document

In 2016, the Department created the "VDOT Resource Document" and associated online data repository to facilitate and streamline the preparation of project-level air quality analyses for purposes of NEPA and conformity.[36] Inter-agency consultation was conducted with FHWA Division and Headquarters and other agencies (including EPA) before the Resource Document was finalized. The Resource Document was most recently updated in 2023 to address changes in applicable regulations and guidance.

With regard to this project, the models, methods/protocols and assumptions as specified or referenced in the VDOT Resource Document were applied without change or without substantive change as defined in that document.

Mobile Source Air Toxics (MSATs) Assessment

FHWA most recently updated its guidance for the assessment of MSATs in the NEPA process for highway projects in 2023.[37] It states that "*…EPA identified nine compounds with significant contributions from mobile sources that are among the national and regional-scale cancer risk drivers or contributors and non-cancer hazard contributors from the 2011 National Air Toxics Assessment (NATA).[38] These are 1,3-butadiene, acetaldehyde, acrolein, benzene, diesel particulate matter (diesel PM), ethylbenzene, formaldehyde, naphthalene, and polycyclic organic matter.*" It also specifies three possible categories or tiers of analysis, namely, 1) projects with no meaningful potential MSAT effects, or exempt projects (for which MSAT analyses are not required), 2) projects with low potential MSAT effects (requiring only qualitative analyses), and 3) projects with higher potential MSAT effects (requiring quantitative analyses).

Level of Analysis Determination

As this project involves an EA and is not exempt, it does not qualify as a Tier 1 project under FHWA MSAT Guidance. It also does not meet the criteria for a Tier 3 project in FHWA guidance, as total traffic is forecast to reach only 12 thousand ADT for the build scenario, which is below the 140-150 thousand ADT criteria specified in FHWA guidance for Tier 3 projects (i.e., ones for which quantitative analyses for MSATs would be required). Additionally, this project does not involve the creation or alteration of a major intermodal freight facility that has the potential to concentrate high levels of diesel particulate matter in a single location.

This project may therefore be categorized as a Tier 2 project, i.e., one with "Low Potential MSAT Effects." Projects in this category are addressed with a qualitative analysis, which as FHWA guidance states provides a basis for identifying and comparing potential differences for MSAT emissions, if any, from the various alternatives.

A qualitative analysis provides a basis for identifying and comparing the potential differences among MSAT emissions, if any, from the various alternatives. The qualitative assessment presented below follows FHWA guidance. It is derived in part from a study conducted by FHWA

---

36 See: https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/environmental/

37 FHWA, "*INFORMATION: Updated Interim Guidance on Mobile Source Air Toxic Analysis in NEPA Documents*", January 18, 2023. See: https://www.fhwa.dot.gov/environment/air_quality/air_toxics/
Note: While the January 2023 FHWA updated guidance was based on modeling using MOVES3, which is reflected in the background information presented here, the current version of the emission model (MOVES4.0.1 at the time of preparation for this analysis) is used for any project-specific modeling.

38 See: https://www.epa.gov/national-air-toxics-assessment

entitled "*A Methodology for Evaluating Mobile Source Air Toxic Emissions among Transportation Project Alternatives.*"[39]

Background

Controlling air toxic emissions became a national priority with the passage of the Clean Air Act Amendments (CAAA) of 1990, whereby Congress mandated that the U.S. Environmental Protection Agency (EPA) regulate 188 air toxics, also known as hazardous air pollutants. The EPA assessed this expansive list in its rule on the Control of Hazardous Air Pollutants from Mobile Sources (Federal Register, Vol. 72, No. 37, page 8430, February 26, 2007), and identified a group of 93 compounds emitted from mobile sources that are part of EPA's Integrated Risk Information System (IRIS).[40] In addition, EPA identified nine compounds with significant contributions from mobile sources that are among the national and regional-scale cancer risk drivers or contributors and non-cancer hazard contributors from the 2011 National Air Toxics Assessment (NATA).[41] These are 1,3-butadiene, acetaldehyde, acrolein, benzene, diesel particulate matter (diesel PM), ethylbenzene, formaldehyde, naphthalene, and polycyclic organic matter. While FHWA considers these the priority mobile source air toxics, the list is subject to change and may be adjusted in consideration of future EPA rules.

Motor Vehicle Emissions Simulator (MOVES)

According to EPA, MOVES3 is a major revision to MOVES2014 and improves upon it in many respects. MOVES3 includes new data, new emissions standards, and new functional improvements and features. It incorporates substantial new data for emissions, fleet, and activity developed since the release of MOVES2014. These new emissions data are for light- and heavy-duty vehicles, exhaust and evaporative emissions, and fuel effects. MOVES3 also adds updated vehicle sales, population, age distribution, and vehicle miles travelled (VMT) data. MOVES3 incorporates the effects of three new Federal emissions standard rules not included in MOVES2014. These new standards are all expected to impact MSAT emissions and include Tier 3 emissions and fuel standards starting in 2017 (79 FR 60344), heavy-duty greenhouse gas regulations that phase in during model years 2014-2018 (79 FR 60344), and the second phase of light-duty greenhouse gas regulations that phase in during model years 2017-2025 (79 FR 60344). In the November 2020 EPA issued MOVES3 Mobile Source Emissions Model Questions and Answers.[42] EPA states that for on-road emissions, MOVES3 updated heavy-duty (HD) diesel and compressed natural gas (CNG) emission running rates and updated HD gasoline emission rates. They updated light-duty (LD) emission rates for hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxide (NOx) and updated LD particulate matter rates, incorporating new data on Gasoline Direct Injection (GDI) vehicles.

Using EPA's MOVES3 model, as shown in Exhibit 3.3.1, FHWA estimates that even if VMT increases by 31 percent at a national level from 2020 to 2060 as forecast, a combined reduction of 76 percent in the total annual emissions for the priority MSAT is projected for the same time period. Diesel PM is the dominant component of MSAT emissions, making up 36 to 56 percent of all priority MSAT pollutants by mass, depending on calendar year. Users of MOVES3 will notice some differences in emissions compared with MOVES2014. MOVES3 is based on updated data on

39 https://www.fhwa.dot.gov/environment/air_quality/air_toxics/research_and_analysis/mobile_source_air_toxics/msatemissions.cfm
40 https://www.epa.gov/iris
41 https://www.epa.gov/national-air-toxics-assessment
42 https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010M06.pdf

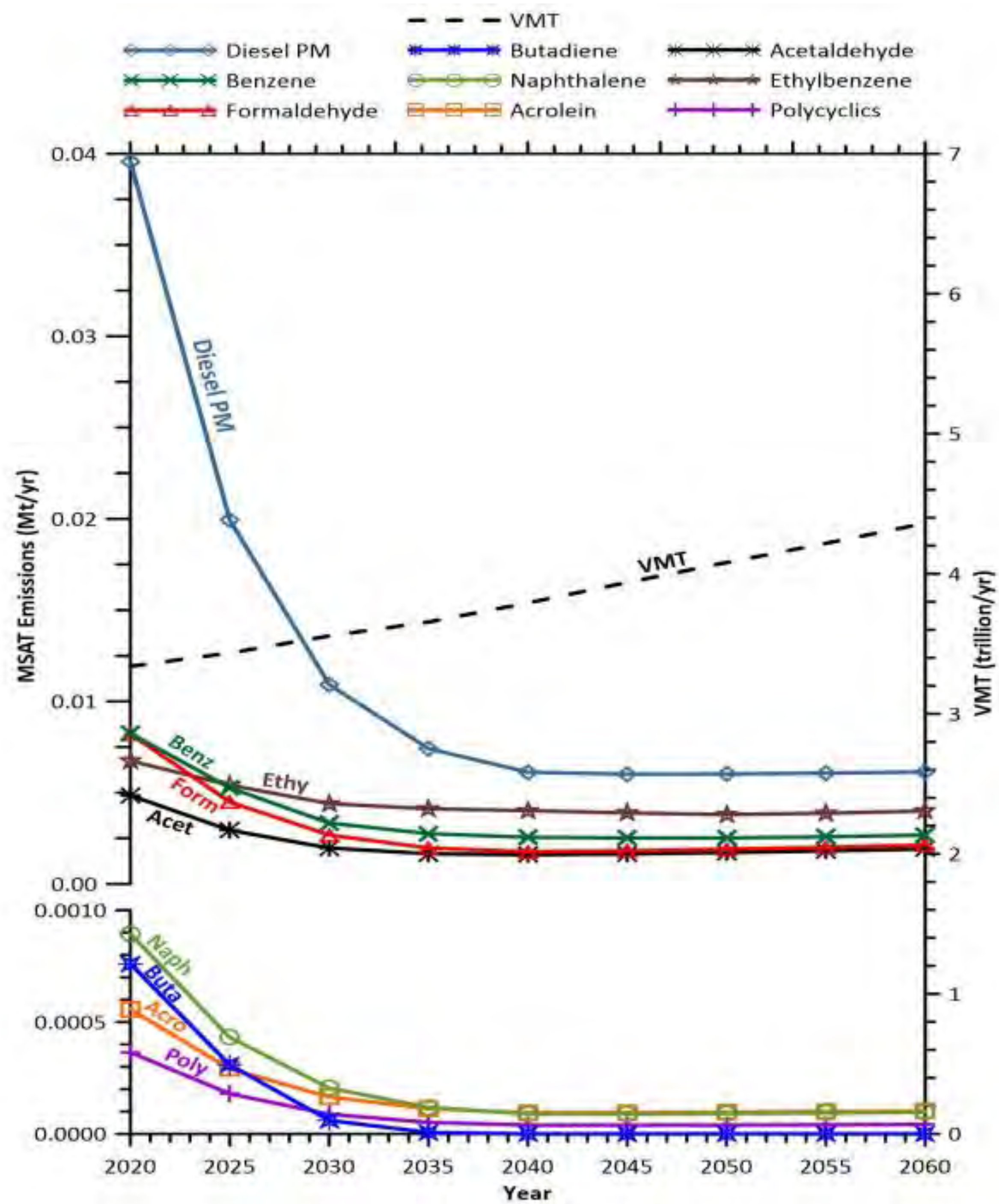
some emissions and pollutant processes compared to MOVES2014, and also reflects the latest Federal emissions standards in place at the time of its release. In addition, MOVES3 emissions forecasts are based on slightly higher VMT projections than MOVES2014, consistent with nationwide VMT trends.

MSAT Research

Air toxics analysis is a continuing area of research. While much work has been done to assess the overall health risk of air toxics, many questions remain unanswered. In particular, the tools and techniques for assessing project-specific health outcomes as a result of lifetime MSAT exposure remain limited. These limitations impede the ability to evaluate how potential public health risks posed by MSAT exposure should be factored into project-level decision-making within the context of NEPA.

Nonetheless, air toxics concerns continue to arise on highway projects during the NEPA process. Even as the science emerges, the public and other agencies expect FHWA to address MSAT impacts in its environmental documents. The FHWA, EPA, the Health Effects Institute, and others have funded and conducted research studies to try to more clearly define potential risks from MSAT emissions associated with highway projects. The FHWA will continue to monitor the developing research in this field.

Exhibit 3.3.1: FHWA Projected National MSAT Emission Trends 2020 – 2060 for Vehicles Operating on Roadways



Note: Trends for specific locations may be different, depending on locally derived information representing vehicle-miles travelled, vehicle speeds, vehicle mix, fuels, emission control programs, meteorology, and other factors.

Source: EPA MOVES3 model runs conducted by FHWA, March 2021

Qualitative Analysis

Following FHWA guidance, this project has been determined to have low potential MSAT effects, thereby requiring a qualitative MSAT analysis. A qualitative analysis provides a basis for identifying and comparing the potential differences among MSAT emissions, if any, from the various alternatives. The qualitative assessment presented below is derived in part from a study conducted by FHWA entitled *A Methodology for Evaluating Mobile Source Air Toxic Emissions among Transportation Project Alternatives*.[43]

The amount of MSATs emitted is proportional to vehicle miles traveled, or VMT, assuming that other variables such as fleet mix are the same for each alternative. The VMT estimated for the Build Alternative(s) therefore may be slightly higher than that for the No-Build Alternative because additional capacity increases the efficiency of the roadway and attracts rerouted trips from elsewhere in the transportation network. This increase in VMT could lead to higher MSAT emissions for the preferred alternative along a highway corridor, along with a corresponding decrease in MSAT emissions along parallel routes. The emissions increase is offset somewhat by lower MSAT emission rates due to increased speeds; according to the EPA MOVES3 model, emissions of all of the priority MSAT decrease as speed increases.

There may also be localized areas where VMT would increase and other areas where it would decrease. Therefore, it is possible that localized increases and decreases in MSAT emissions may occur. However, even if these increases do occur, they too will be substantially reduced in the future due to implementation of EPA's vehicle and fuel regulations. Also, regardless of the alternative chosen, emissions will likely be lower than present levels in the design year as a result of EPA's national control programs that are projected in FHWA guidance to reduce annual MSAT emissions by over 76 percent between 2020 and 2060 even with a 31 percent increase in VMT on a national level. Local conditions may differ from these national projections in terms of fleet mix and turnover, VMT growth rates, and local control measures. However, the magnitude of the EPA-projected reductions is so great (even after accounting for VMT growth) that MSAT emissions in the study area are likely to be lower in the future in nearly all cases. Any additional travel lanes contemplated as part of the project may have the effect of moving some traffic closer to nearby homes, schools, and businesses; therefore, there may be localized areas where ambient concentrations of MSATs could be higher for a Build Alternative than for the No-Build Alternative. However, the magnitude and the duration of these potential increases compared to the No-Build alternative cannot be reliably quantified due to incomplete or unavailable information in forecasting project-specific MSAT health impacts.

In sum, when capacity is added, the localized level of MSAT emissions for the Build Alternative could be higher relative to the No-Build Alternative, but this could be offset due to increases in speeds and reductions in congestion (which are associated with lower MSAT emissions). In addition, MSAT emissions will be lower in other locations when traffic shifts away from them. However, on a regional basis, EPA's vehicle and fuel regulations, coupled with fleet turnover, will over time cause substantial reductions that, in almost all cases, will cause region-wide MSAT levels to be significantly lower than today.

43 See: https://www.fhwa.dot.gov/environment/air_quality/air_toxics/research_and_analysis/mobile_source_air_toxics/msatemissions.cfm

Incomplete or Unavailable Information for Project-Specific MSAT Health Impacts Analysis

In FHWA's view, information is incomplete or unavailable to credibly predict the project-specific health impacts due to changes in MSAT emissions associated with a proposed set of highway alternatives. The outcome of such an assessment, adverse or not, would be influenced more by the uncertainty introduced into the process through assumption and speculation rather than any genuine insight into the actual health impacts directly attributable to MSAT exposure associated with a proposed action.

The EPA is responsible for protecting the public health and welfare from any known or anticipated effect of an air pollutant. They are the lead authority for administering the Clean Air Act and its amendments and have specific statutory obligations with respect to hazardous air pollutants and MSAT. The EPA is in the continual process of assessing human health effects, exposures, and risks posed by air pollutants. They maintain the Integrated Risk Information System (IRIS), which is "a compilation of electronic reports on specific substances found in the environment and their potential to cause human health effects."[44] Each report contains assessments of non-cancerous and cancerous effects for individual compounds and quantitative estimates of risk levels from lifetime oral and inhalation exposures with uncertainty spanning perhaps an order of magnitude.

Other organizations are also active in the research and analyses of the human health effects of MSAT, including the Health Effects Institute (HEI). A number of HEI studies are summarized in Appendix D of FHWA's Updated Interim Guidance on Mobile Source Air Toxic Analysis in NEPA Documents. Among the adverse health effects linked to MSAT compounds at high exposures are cancer in humans in occupational settings; cancer in animals; and irritation to the respiratory tract, including the exacerbation of asthma. Less obvious is the adverse human health effects of MSAT compounds at current environmental concentrations[45] or in the future as vehicle emissions substantially decrease.

The methodologies for forecasting health impacts include emissions modeling; dispersion modeling; exposure modeling; and then final determination of health impacts – each step in the process building on the model predictions obtained in the previous step. All are encumbered by technical shortcomings or uncertain science that prevents a more complete differentiation of the MSAT health impacts among a set of project alternatives. These difficulties are magnified for lifetime (i.e., 70 year) assessments, particularly because unsupportable assumptions would have to be made regarding changes in travel patterns and vehicle technology (which affects emissions rates) over that time frame, since such information is unavailable.

It is particularly difficult to reliably forecast 70-year lifetime MSAT concentrations and exposure near roadways; to determine the portion of time that people are actually exposed at a specific location; and to establish the extent attributable to a proposed action, especially given that some of the information needed is unavailable.

There are considerable uncertainties associated with the existing estimates of toxicity of the various MSAT, because of factors such as low-dose extrapolation and translation of occupational exposure data to the general population, a concern expressed by HEI.[46] As a result, there is no national

44 See: https://www.epa.gov/iris/

45 HEI Special Report 16. See: https://www.healtheffects.org/publication/mobile-source-air-toxics-critical-review-literature-exposure-and-health-effects

46 Ibid

consensus on air dose-response values assumed to protect the public health and welfare for MSAT compounds, and in particular for diesel PM. The EPA states that with respect to diesel engine exhaust: "[t]he absence of adequate data to develop a sufficiently confident dose-response relationship from the epidemiologic studies has prevented the estimation of inhalation carcinogenic risk (https://iris.epa.gov/static/pdfs/0642_summary.pdf)."

There is also the lack of a national consensus on an acceptable level of risk. The current context is the process used by the EPA as provided by the Clean Air Act to determine whether more stringent controls are required in order to provide an ample margin of safety to protect public health or to prevent an adverse environmental effect for industrial sources subject to the maximum achievable control technology standards, such as benzene emissions from refineries. The decision framework is a two-step process. The first step requires EPA to determine an "acceptable" level of risk due to emissions from a source, which is generally no greater than approximately 100 in a million. Additional factors are considered in the second step, the goal of which is to maximize the number of people with risks less than 1 in a million due to emissions from a source. The results of this statutory two-step process do not guarantee that cancer risks from exposure to air toxics are less than 1 in a million; in some cases, the residual risk determination could result in maximum individual cancer risks that are as high as approximately 100 in a million. In a June 2008 decision, the U.S. Court of Appeals for the District of Columbia Circuit upheld EPA's approach to addressing risk in its two-step decision framework. Information is incomplete or unavailable to establish that even the largest of highway projects would result in levels of risk greater than deemed acceptable.[47]

Because of the limitations in the methodologies for forecasting health impacts described, any predicted difference in health impacts between alternatives is likely to be much smaller than the uncertainties associated with predicting the impacts. Consequently, the results of such assessments would not be useful to decision makers, who would need to weigh this information against project benefits, such as reducing traffic congestion, accident rates, and fatalities while improving access for emergency response, that are better suited for quantitative analysis.

Conclusions

As discussed above, technical shortcomings of emissions and dispersion models and uncertain science with respect to health effects prevent meaningful or reliable estimates of MSAT emissions and effects of this project at this time. While it is possible that localized increases in MSAT emissions may occur as a result of this project, emissions will likely be lower than present levels in the design year of this project as a result of EPA's national control programs that are projected in FHWA guidance (2023) to reduce annual MSAT emissions by 76 percent between 2020 and 2060 even as VMT increases nationally by 31 percent. Although local conditions may differ from these national projections in terms of fleet mix and turnover, VMT growth rates, and local control measures, the magnitude of the EPA-projected reductions is so great (even after accounting for VMT growth) that MSAT emissions in the study area are likely to be lower in the future in nearly all cases.

47 See: https://www.cadc.uscourts.gov/internet/opinions.nsf/284E23FFE079CD59852578000050C9DA/$file/07-1053-1120274.pdf

Greenhouse Gases (GHGs)

Level of Analysis Determination

The project meets the screening criteria specified in the VDOT Resource Document (Appendix K) for a Category 2 project as one with low potential GHG effects. As such, a brief qualitative assessment is presented below for this project.

Qualitative Assessment

For each alternative in this EA, the amount of GHGs emitted would be proportional to the vehicle miles traveled (VMT), assuming that other variables such as fleet mix are the same for each alternative. The VMT estimated for each of the Build alternatives may be slightly higher than that for the No-Build alternative for each analysis year, because the additional capacity may increase the efficiency of the roadway and attract rerouted trips from elsewhere in the transportation network. An increase in VMT may lead to higher GHG emissions for the preferred action alternative compared to the No-Build alternative along the highway corridor, along with a corresponding decrease in GHG emissions along the parallel routes. The emissions increase may be offset somewhat by lower GHG emission rates due to increased speeds; according to the EPA MOVES model, emissions of GHG emissions decrease as speed increases (up to about 60 miles per hour). Because the estimated VMT under each of the alternatives are nearly the same, it is expected there would be no appreciable difference in overall GHG emissions among the various alternatives. Also, regardless of the alternative chosen, emissions will likely be lower than present levels in the design year as a result of fuel efficiency improvements and electrification policies that are projected to reduce annual statewide GHG emissions from on-road sources by nearly 50 percent between 2015 and 2040 (VDOT, Statewide Planning-Level GHG Assessment, December 2021).

Climate Change

Potential Climate Change Impacts

Greenhouse gas emissions have accumulated rapidly as the world has industrialized, with concentration of atmospheric CO_2 increasing from roughly 300 parts per million in 1900 to over 400 parts per million today according to the U.S. Global Climate Change Research Program. Over this timeframe, average temperatures have increased by roughly 1.8 degrees Fahrenheit (1 degree Celsius). If emissions continue, projected changes in global average temperature could range from 0.4°–2.7°F (0.2°–1.5°C) under a very low emissions scenario, to 4.2°–8.5°F (2.4°–4.7°C) under a higher scenario by the end of the 21^{st} century.[48]

According to information prepared by the Georgetown Climate Center, Virginia's transportation infrastructure faces risks from a changing climate including coastal flooding, inland flooding, and extreme heat.

- Coastal Flooding—Sea level rise is occurring at an accelerating rate, and five Virginia water level stations appear in the Nation's top 20 highest sea level rise trends.[49] In the next 20 to 50 years, Virginia is likely to experience at least 1.5 feet of sea level rise, with the possibility of

48 U.S. Global Climate Change Research Program (2018). Fourth National Climate Assessment.
49 City of Virginia Beach (2020). Sea Level Wise: Adaptation Strategy. https://pw.virginiabeach.gov/stormwater/sea-level-wise

even greater increases.[50] Storm surge presents major risks to Virginia's coastal areas, with over 300 bridges and structures that would face over two feet of storm surge inundation from a Category 2 hurricane.[51] By 2080, 10 percent of the roadway networks in Virginia Beach and Norfolk could be flooded by "king tides" (exceptionally high tide events) with four feet of sea level rise.[52]

- Inland Flooding—The southeastern U.S. has experienced an increase in flooding from heavy rainfall and extreme precipitation events. Virginia has seen heavy rainstorms increase by 33 percent in the last 60 years.[53] In the future, the southeastern U.S. is expected to see a continued increase in extreme rainfall events.
- Extreme Heat—Heat waves are a leading cause of weather-related deaths.[54] Anticipated more intense heat events pose dangers to human activity and human health. Extreme heat combined with drought conditions can also increase the risk of wildfires. Pavements may also contribute to heat island effects in urban locations.[55]

Project-Level Climate Strategies and Considerations

Resiliency is an important consideration for future infrastructure investments. Resiliency considerations include building in areas with minimal risk to the facility; designing infrastructure that is resilient to potential impacts that could affect its scope, function, and/or performance; and siting and designing projects to avoid or minimize impacts to natural resiliency features such as wetlands, forests, and floodplains. Resiliency strategies that are cost-effective and can be adopted during the planning, project development, construction, and/or maintenance phases of a given infrastructure project are supported. VDOT complies with all existing Federal and state laws and regulations and permitting requirements related to wetlands and water quality impacts.

VDOT, the County, and some regional and local agency partners in the state, have already engaged in efforts to plan for resiliency. As part of the development of VTrans, Virginia's Transportation Plan, the Commonwealth Transportation Board (CTB) has developed the Policy for the Development and Monitoring of VTrans Long-term Risk & Opportunity Register, which allows for quantification of impacts of 10 macrotrends, including long-term flooding risk due to sea-level rise, storm surge, and inland/riverine flooding.

The CTB has also developed a Long-term Risk & Opportunity Register, a policy document, based on an assessment of these impacts. The 2021 Risk & Opportunity Register includes the following risks and opportunities:

- Risk: A large number of the state's roadways are at risk of flooding.
- Risk: Several unknown and unquantified flooding risks are present.

---

50 Georgetown Climate Center (undated). "Understanding Virginia's Vulnerability to Climate Change." Accessed September 2021 at https://www.georgetownclimate.org/files/report/understanding-virginias-vulnerability-to-climate-change.pdf.

51 Commonwealth of Virginia, Office of the Secretary of Transportation (2020). Vulnerability Assessment.

52 Sadler, Jeffer, Nicole Haselden, Kimberly Mellon, and Allison Hackel (2017). Impact of Sea-Level Rise on Roadway Flooding in the Hampton Roads Region, Virginia. Journal of Infrastructure Systems. Accessed at: https://ascelibrary.org/doi/pdf/10.1061/%28ASCE%29IS.1943-555X.0000397.

53 Georgetown Climate Center, *ibid.*

54 Georgetown Climate Center, *ibid.*

55 Georgetown Climate Center (2012). "Adapting to Urban Heat: A Tool Kit for Local Governments." https://www.georgetownclimate.org/files/report/Urban%20Heat%20Toolkit_9.6.pdf

- Risk: Impacts of increased flooding risk are disproportionately higher for certain geographic areas and populations.
- Opportunity: Proactively eliminate or mitigate identified flooding risks.
- Opportunity: Increase the state's preparedness to address other macrotrends associated with the climate megatrend.

The CTB has also adopted the following strategic actions to mitigate the identified long-term risks and maximize opportunities.

- Collect data (e.g., right-of-way mapping, precipitation, roadway elevation, etc.) to accurately assess flooding risks for the state- and locally-maintained roadways that can be used to identify funding needs and prioritize investment.
- Develop policies based on robust data collection and analysis to ensure flooding risks are reflected in transportation asset life-cycle and/or transportation project planning processes.
- Collaborate with state/regional agencies to systematically identify solutions that facilitate consistent and systematic prioritization and support the allocation of state resources to address flooding risks.

Finally, as part of the policy, the Office of Intermodal Planning and Investment (OIPI) is required to track trends related to all macrotrends, including flooding risk, and report annually.

The Metropolitan Washington Council of Governments developed a summary of potential climate change impacts, vulnerabilities, and adaptation strategies in the region. This report describes general impacts of climate change as well as vulnerability and strategies for the transportation sector.[56]

Conclusions

Greenhouse gas emissions have accumulated rapidly as the world has industrialized. According to the U.S. Global Climate Change Research Program,[57] if emissions continue, projected changes in global average temperature could range from to 0.4° — 2.7°F (0.2°–1.5°C) under a very low emissions scenario, to 4.2°–8.5°F (2.4°–4.7°C) under a higher scenario by the end of the 21st century. Based on information developed by the Georgetown Climate Center,[58] Virginia's transportation infrastructure faces risks from a changing climate including increased levels of coastal flooding, inland flooding, and extreme heat.

Resiliency is an important consideration for VDOT when planning and designing future infrastructure investments. Resiliency considerations include siting and design of facilities both to

56 Metropolitan Washington Council of Governments. 2013. "Summary of Potential Climate Change Impacts, Vulnerabilities, and Adaptation Strategies in the Metropolitan Washington Region." https://www.mwcog.org/documents/2013/07/01/summary-of-potential-climate-change-impacts-vulnerabilities-and-adaptation-strategies-climate-change/.

57 U.S. Global Climate Change Research Program (2018). Fourth National Climate Assessment.

58 Georgetown Climate Center (undated). "Understanding Virginia's Vulnerability to Climate Change." Accessed September 2021 at https://www.georgetownclimate.org/files/report/understanding-virginias-vulnerability-to-climate-change.pdf.

minimize risk to the facility, and to minimize impacts on natural resiliency features such as wetlands, forests, and floodplains. Resiliency strategies that are cost-effective and can be adopted during the planning, project development, construction, and/or maintenance phases of a given infrastructure project are supported.

VDOT, and regional and local agency partners in the Commonwealth, have already engaged in efforts to plan for resiliency. As part of the development of VTrans, Virginia's transportation plan, the Commonwealth Transportation Board (CTB) has developed a Policy for the Development and Monitoring of VTrans Long-term Risk & Opportunity Register, which allows for quantification of impacts of ten macrotrends, including long-term flooding risk due to sea-level rise, storm surge, and inland/riverine flooding, as well as a Long-term Risk & Opportunity Register based on an assessment of these impacts. The CTB has also adopted strategic actions to mitigate the identified long-term risks and maximize opportunities, including collecting data to accurately assess flooding risks for the state- and locally-maintained roadways that can be used to identify funding needs and prioritize investment; developing policies based on robust data collection and analysis to ensure flooding risks are reflected in transportation asset life-cycle and/or transportation project planning processes; and collaborating with state and regional agencies to systematically identify solutions that facilitate consistent and systematic prioritization and support the allocation of state resources to address flooding risks. Finally, the Office of Intermodal Planning and Investment (OIPI) is required to track trends related to all macrotrends, including the flooding risk, and report annually.

Carbon Monoxide Assessment

EPA project-level ("hot-spot") transportation conformity requirements for CO do not apply as the project is located in a region that is in attainment of the NAAQS. A project-specific analysis or assessment for CO is also not needed for NEPA per the programmatic approach specified in the VDOT Resource Document (Protocol 4.2.2.2). Based on the overall weight-of-evidence, it may reasonably be concluded that the CO NAAQS will be met given:

- Continued implementation of effective emission control technology, increasingly more stringent motor vehicle emission and fuel quality standards implemented over the past few decades by the Environmental Protection Agency (EPA) that have had the combined effect of substantially reducing CO emission rates nationwide, resulting in long-term downward trends in emissions and near-road ambient concentrations of CO despite increasing vehicle-miles-travelled (VMT)
- Extensive experience in project-specific modeling for CO for a wide variety of project types, configurations and operating conditions in which compliance with the national ambient air quality standards (NAAQS) established by EPA for CO is readily demonstrated given the substantially reduced CO emission rates, and despite the use of multiple worst-case assumptions for emission and dispersion modeling that have a compounding effect such that emissions and near-road ambient concentrations are substantially over-estimated; and
- Extensive experience in programmatic agreements for project-level agreements for CO that established ever-increasing thresholds for such analyses given the substantially reduced emission rates.

Indirect Effects and Cumulative Impacts (IECI) Assessment

Indirect effects are defined by the CEQ as "effects which are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water or other natural systems, including ecosystems" (40 CFR 1508.8(b)). For transportation projects, induced growth is attributed to changes in accessibility caused by the project that influences the location and/or magnitude of future development.[59]

Cumulative impacts are "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 CFR 1508.7). According to the Federal Highway Administration's (FHWA) *Interim Guidance: Questions and Answers Regarding the Consideration of Indirect and Cumulative Impacts in the NEPA Process*, cumulative impacts include the total of all impacts to a particular resource that have occurred, are occurring, and will likely occur as a result of any action or influence, including the direct and reasonably foreseeable indirect impacts of a proposed project. Cumulative impacts include indirect effects. The potential for indirect effects or cumulative impacts to air quality that may be attributable to this project is not expected to be significant for two reasons.

First, regarding the potential for indirect effects, the quantitative assessments conducted for programmatic CO, qualitative analyses for MSAT impacts and the regional conformity analysis conducted for ozone can all be considered indirect effects analyses because they look at air quality impacts attributable to the project that occur in the future. These analyses demonstrate that, in the future: 1) air quality impacts from CO will not cause or contribute to violations of the CO NAAQS, 2) MSAT emissions will be significantly lower than they are today, and 3) conformity requirements for the transportation plan and program will be met, including the mobile source emissions budgets established for the region for purposes of meeting the ozone NAAQS.

Second, regarding the potential for cumulative impacts, the most recent conformity analysis conducted by the National Capital Region (NCR) Transportation Planning Board (TPB, which is the Metropolitan Planning Organization or MPO for the Washington, D.C. metropolitan area) represents a cumulative impact assessment for purposes of regional air quality.

- The existing air quality designations for the region are based, in part, on the accumulated mobile source emissions from past and present actions, and these pollutants serve as a baseline for the current conformity analysis.
- The conformity analysis quantifies the amount of mobile source emissions for which the area is designated nonattainment/maintenance that will result from the implementation of all reasonably foreseeable regionally significant transportation projects in the region (i.e., those proposed for construction funding over the life of the region's transportation plan).
- The most recent conformity analysis was completed in June 2022. FHWA/FTA issued a conformity finding on June 15, 2022, for the Transportation Improvement Program (TIP) and Constrained Long Range Plan (CLRP) covered by that analysis. This analysis

demonstrated that the incremental impact of the proposed project on mobile source emissions, when added to the emissions from other past, present, and reasonably foreseeable future actions, is in conformance with the SIP and will not cause or contribute to a new violation, increase the frequency or severity of any violation, or delay timely attainment of the NAAQS established by EPA.

Therefore, the indirect and cumulative effects of the project are not expected to be significant.

Project Status in the Regional Transportation Plan and Program

Federal conformity requirements at 40 CFR 93.114[60] and 40 CFR 93.115[61] (as incorporated by reference into the Virginia conformity SIP) apply as the area in which the project is located is designated as nonattainment for ozone. Accordingly, there must be a currently conforming transportation plan and program at the time of project approval, and the project must come from a conforming plan and program or otherwise meet the criteria specified in 40 CFR 93.109(b).[62] As of the date of preparation of this analysis, the project is included in the currently conforming FY 2023-2026 Transportation Improvement Program (TIP) and 2045 Long Range Transportation Plan (LRTP) developed by the designated metropolitan planning organization (MPO) for the region, the National Capital Region Transportation Planning Board (TPB).[63]

Mitigation

Historically, the continued implementation of increasingly more stringent motor vehicle emission, fuel quality and fuel economy standards has resulted in substantial reductions of emissions of both criteria pollutants and GHGs across the nation. These and other measures as identified below for GHGs that reduce VMT serve to minimize emissions across the nation.

Greenhouse Gases

The 2021 VDOT statewide GHG analysis included sixteen discrete planned state and regional rail and transit projects that will reduce automobile and truck travel and GHG emissions, as well as increases to existing service. VDOT and the Department of Rail and Public Transportation have also continued to fund other air quality and GHG mitigation strategies. These include bicycle and pedestrian projects, travel demand management (TDM) programs that seek to reduce the amount of commuting in single-occupancy vehicles, and investment in electric vehicles and charging infrastructure.

In December 2021, the Virginia State Air Pollution Control Board adopted regulations for Low-Emission Vehicle (LEV) and Zero-Emission Vehicle (ZEV) standards consistent with the California Advanced Clean Cars (ACC) program that would aggressively increase the light-duty vehicle ZEV market share beginning in 2025. California has the unique authority to maintain motor vehicle emission standards that are more stringent than federal standards. California's LEV standards control tailpipe emissions of criteria and greenhouse gas pollutants. California's ZEV program

---

60 See: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#93.114
61 See: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#93.115
62 See: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-93#93.109
63 See: http://www.mwcog.org/transportation/tpb/

requires major manufacturers of passenger cars and light trucks to produce and deliver for purchase a certain number of ZEVs. Manufacturers must increase the average fuel efficiency for light- and medium-duty vehicles, as well as increase the number of electric vehicles for sale, beginning with model year 2025.

On December 30, 2021, the EPA issued a final rule in the Federal Register that revised national GHG emissions standards for passenger cars and light trucks for Model Years 2023-2026.[64] The final standards are expected to achieve significant GHG emissions reductions along with reductions in other criteria pollutants.[65] The program will result in avoiding more than 3 billion tons of GHG emissions through 2050 which is equivalent to more than half the total U.S. CO_2 emissions in 2019. Additional benefits include reduced impacts of climate change, improved public health from lower pollution, and cost savings for vehicle owners through improved fuel efficiency.

On October 25, 2016, the EPA and the DOT National Highway Traffic Safety Administration issued the final rule in the Federal Register for jointly finalized standards for medium- and heavy-duty vehicles that would improve fuel efficiency and cut carbon pollution to reduce the impacts of climate change, while bolstering energy security and spurring manufacturing innovation.[66] The final program promotes cleaner, more fuel-efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies. The vehicle and engine performance standards cover model years 2018-2027 for certain trailers and model years 2021-2027 for semi-trucks, large pickup trucks, vans, and all types and sizes of buses and work trucks. The final standards are expected to lower CO_2 emissions by approximately 1.1 billion metric tons, save vehicle owners fuel costs of about $170 billion, and reduce oil consumption by up to two billion barrels over the lifetime of the vehicles sold under the program.[67]

Construction

Emissions may be produced in the construction of this project from heavy equipment and vehicle travel to and from the site, as well as from fugitive sources. Construction emissions are short term or temporary in nature. To mitigate these emissions, all construction activities are to be performed in accordance with VDOT *Road and Bridge Specifications*.[68]

VDEQ Requirements

The VDEQ provides general comments for projects by county that in part address mitigation.[69] For the region in which the proposed project is located, their comment is:

---

64 https://www.govinfo.gov/content/pkg/FR-2021-12-30/pdf/2021-27854.pdf
65 https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-passenger-cars-and
66 https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf
67 https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf
68 https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/technical-guidance-documents/road-and-bridge-specifications/
69 Spreadsheet entitled: "DEQ SERP Comments rev8b", March 2017

"…all reasonable precautions should be taken to limit the emissions of VOC and NOx. In addition, the following VDEQ air pollution regulations must be adhered to during the construction of this project: 9 VAC 5-130, Open Burning restrictions[70]; 9 VAC 5-45, Article 7, Cutback Asphalt restrictions[71]; and 9 VAC 5-50, Article 1, Fugitive Dust precautions.[72]"

Consultation

Public Consultation

Public consultation is generally conducted and documented within the overall NEPA process, and not separately by subject area (including air quality). Please refer to the overall NEPA documentation for a summary of public consultation activities for this project.

Conclusions

The proposed improvements were assessed for potential air quality impacts and compliance with applicable air quality regulations and requirements. All models, methods/protocols and assumptions applied in modeling and analyses were made consistent with those provided or specified in the VDOT Resource Document. The assessment indicates that the project would meet all applicable air quality requirements of the National Environmental Policy Act (NEPA) and federal and state transportation conformity regulations. As such, the project will not cause or contribute to a new violation of the NAAQS established by EPA.

70 See: https://law.lis.virginia.gov/admincode/title9/agency5/chapter130/
71 See: https://law.lis.virginia.gov/admincode/title9/agency5/chapter45/
72 See: https://law.lis.virginia.gov/admincode/title9/agency5/chapter50/

Appendix A: Traffic

Marina Way and Annapolis Way

Alternative Intersection Report

Marina Way and Annapolis Way Alternative Intersection Report DRAFT

UPC 120778

Prince William County Project #: 23C17011

Contract #: 5053661

Prepared by

Johnson, Mirmiran & Thompson

February 27, 2024

Table of Contents

List of Tables

List of Figures

Appendices

INTRODUCTION

JMT is designing the extension of Marina Way from Annapolis Way to Gordon Boulevard (Route 123) in Prince William County. This project, which will function as a main street for the proposed North Woodbridge Town Center currently under development, will connect the existing two-lane undivided Marina Way to Horner Road. The extension will be a four-lane divided roadway with pedestrian facilities. As part of the Marina Way extension project, JMT is determining the most feasible and practical-based intersection design at Marina Way extension and Annapolis Way given the available funding, right of way (ROW) constraints, lane capacity, and proximity to nearby intersections.

The purpose of this report is to evaluate the alternative designs and traffic control, including a conventional signal, for the study intersection of Marina Way and Annapolis Way. The opening year of the project is anticipated to be 2028, and the design year of the project is 2050. The opening year traffic volumes of 2028 were used for the signal warrant analysis and the design year volumes were used for the capacity analysis. To determine whether a signal is warranted, the analysis conducted in this report uses warrants outlined in the Manual on Uniform Traffic Control Devices (MUTCD, 2009 with Rev. 1 & 2), the Virginia Supplement to the MUTCD, and VDOT's IIM-TE-387.1.

BACKGROUND

The study intersection of Marina Way and Annapolis Way, located in the North Woodbridge area of Prince William County, VA, currently operates as an unsignalized intersection as two-way stop control (TWSC), with Annapolis Way operating as free flow, and Marina Way controlled by stop signs. The intersection is a four-leg intersection, as seen in **Figure 1**. In this report, Marina Way is referred to as an east-west facility, and Annapolis Way is referred to as a north-south facility.

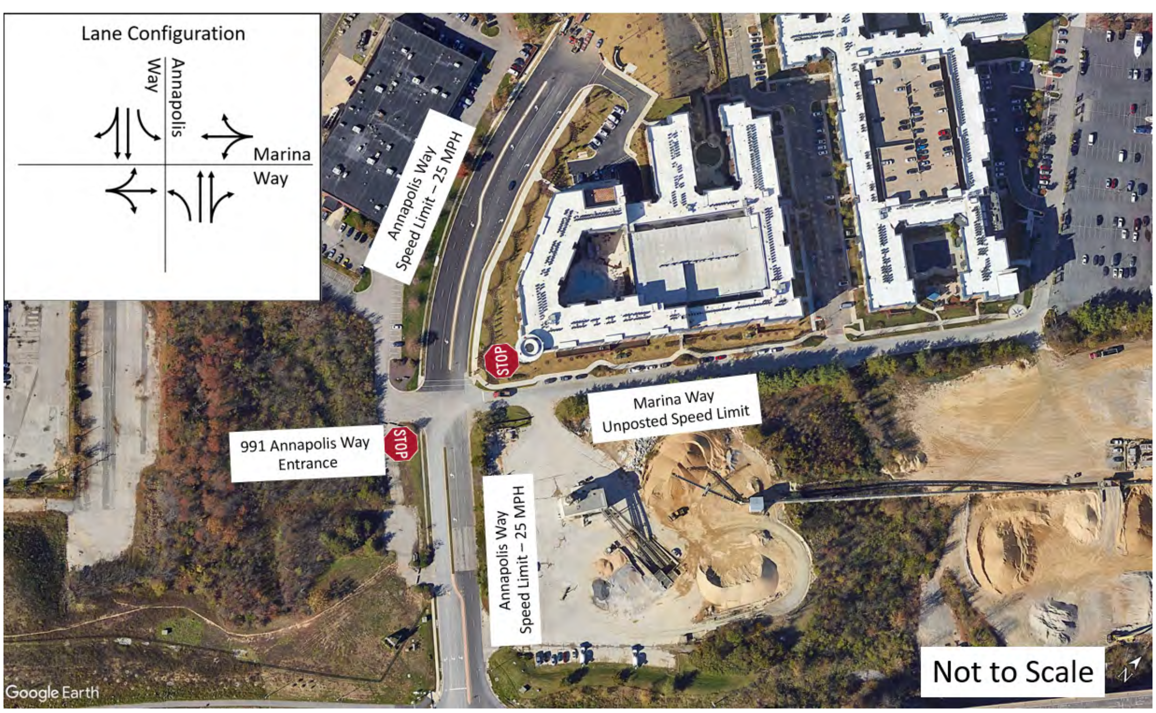


Figure 1: Study Intersection Location

For the study, Marina Way is considered the major road due to the anticipated traffic volume, and Annapolis Way is considered the minor road. The following sections details the characteristics of the intersecting roadways.

Marina Way

The existing Marina Way is a two-lane undivided roadway and classified as an avenue/street in the 2019 North Woodbridge Small Area Plan. The roadway speed limit is currently unposted. Marina Way forms the east leg of the intersection and serves as the only access point to Occoquan Harbor which includes a restaurant, the marina, apartment complexes and small businesses. Marina Way's approach to Annapolis Way (westbound approach) has a shared left/through/right lane entering the intersection.

The west leg of the intersection serves as the 991 Annapolis Way entrance. The approach (eastbound approach) has a shared left/through/right lane entering the intersection. The proposed Marina Way extension that will alter the existing west leg of the intersection will be a four-lane divided roadway with two lanes entering the intersection in the eastbound direction. It has a design speed of 30 MPH.

Annapolis Way (Route 673)

Annapolis Way is a four-lane divided roadway with a speed limit of 25 miles per hour (MPH) and classified as an avenue/street in the 2019 North Woodbridge Small Area Plan. The existing Annapolis Way in the study area extends north from Jefferson Davis Highway (US Route 1) to approximately 600 feet north of the study intersection. However, there is an on-going construction project that will connect the existing Annapolis Way alignment to another existing segment of Annapolis Way that has a signalized connection to Route 123 north of the Route 123/Horner Road intersection. Annapolis Way currently has three lanes entering the intersection in the northbound and southbound approaches. The approaches each consist of an exclusive left-turn lane, a through lane and a shared through and right lane. There is a crosswalk on the north leg of Annapolis Way at the intersection. Annapolis Way is state-maintained from Route 1 to its intersection with Marina Way and is assumed to be state-maintained (ultimately) all the way to the other Annapolis Way segment upon completion of its extension.

EXISTING CONDITION

A 24-hour turning movement count (TMC) from 12:00 AM to 12:00 AM was conducted at the study intersection on Thursday, June 8, 2023. The count collected volumes in 15-minute intervals for cars, trucks, bicycles, and pedestrians traversing the intersection. Based on the count data, the AM and PM peak hours for the intersection are 7:15 AM to 8:15 AM and 6:15 PM to 7:15 PM, respectively. Detailed counts, including total vehicles, total pedestrians, and a summary of peak hour volumes, are included in **Appendix A**. The existing peak hour traffic volumes for the intersection are shown in **Figure 2**.

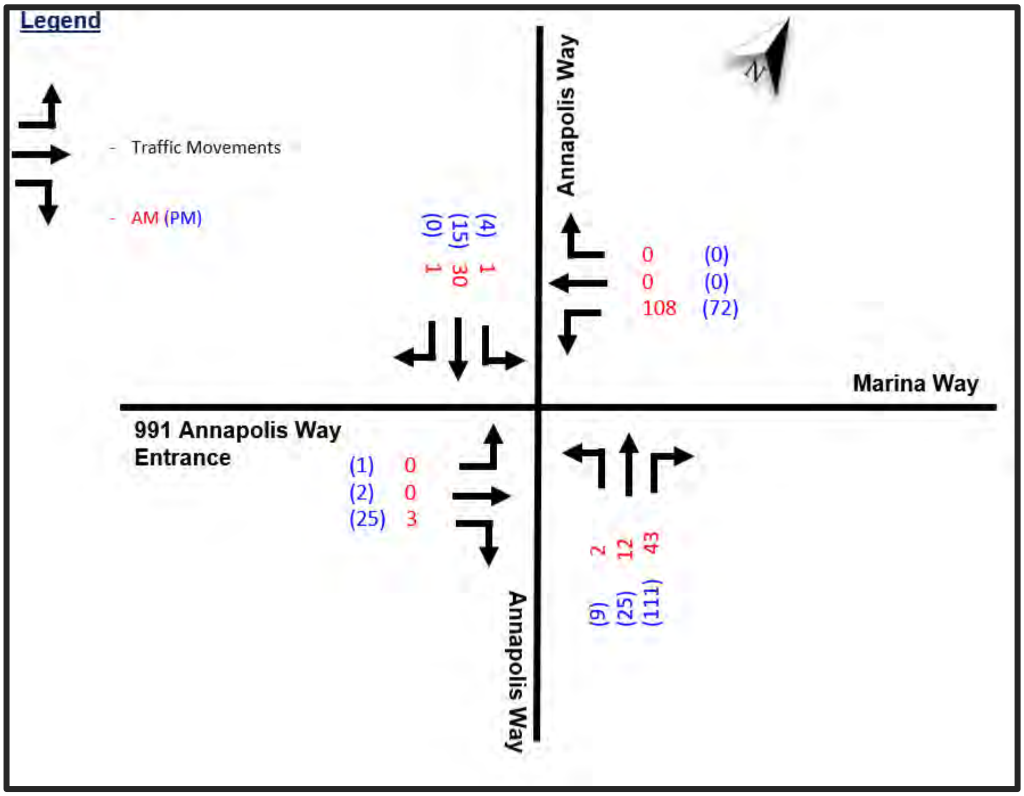


Figure 2: Existing Weekday Peak Hour Volumes

As previously mentioned, Marina Way does not extend to the west beyond the Annapolis Way intersection, therefore, the existing condition operational analysis was not needed for this study as the proposed conditions alter the 991 Annapolis Way entrance to a four-lane divided through roadway. The existing volumes were used to help develop the future volumes of the intersection with the proposed roadway alignment.

REPORT METHODOLOGY

The analysis documented in this report uses warrants outlined in the 2009 MUTCD (with Rev. 1 & 2), and the 2011 Virginia Supplement to the MUTCD (Revision 1), and VDOT's IIM-TE-387.1. Opening year 2028 volumes were used in the signal warrant analysis, and the derivation of these volumes is outlined in the following section of this report.

DEVELOPMENT OF FUTURE VOLUMES

JMT developed the future traffic volume forecasts for the anticipated Opening Year of 2028 and Design Year of 2050 using the Prince William County Travel Demand Model (PWCTD) and the approved land use data for PWC from the Metropolitan Washington Council of Governments (MWCOG) Round 10 cooperative land use forecast. The Round 10 land use data includes socio-economic/land use inputs for year 2050. In coordination with PWCDOT planning and programming division, it is assumed the PWC Round 10 cooperative land use forecasts include all the population and employment land use assumed in the North Woodbridge Small Area Plan that was approved in 2019. This includes the new developments coming into the North Woodbridge Area. The PWCTDM included a roadway network with a base year of 2015 and future year of 2045. The base year 2015 roadway network was updated to reflect the existing 2023 roadway. The Virginia Department of Transportation (VDOT) Travel Demand Modeling Policies and Procedures document was referenced to define the acceptable levels of deviation from average daily traffic (ADTs). The Percent Root Mean Square Error (%RMSE), *Table 10.5 of the travel demand modeling policies and procedures document*, was used to compare major links surrounding the study area to validate the model.

JMT ran two future models; the no-build and build model for the design year 2050. In the no-build model, the Marina Way extension was not coded in the model. For the build model, the Marina Way extension was coded in the model. The two future models were then compared to determine the traffic volume that will divert from surrounding roadways such as US 1, and Route 123 onto Marina Way. JMT also conducted a select link analysis along the centroid connector to the TAZ encompassing the North Woodbridge Area where the Marina Way extension is proposed. The select link was performed on the no-build condition to determine the distribution into and out of the centroid. The number of trips distributed was determined by performing the NCHRP Difference Method along the centroid. The AM and PM peak hour trips were then determined using the existing peak hour as a percentage of the existing daily volume. The AM and PM peak hour trips were then distributed through the network using the results of the select link analysis. JMT compared the No Build and Build conditions to divert traffic to Marina Way to determine the 2050 peak hour turning movement volume.

To develop the 2028 opening year volumes, JMT linearly interpolated between the 2025 land use and the 2030 land use provided by the County, to determine the 2028 land use. The 2028 model network was updated to reflect the conditions expected during the opening year and was sourced from the VDOT STARS study 2030 model. The updated 2028 build model was run using the interpolated 2028 land use. The 2028 build model output was compared to the 2050 build model output. The result shows that there were 30% fewer trips in the centroid representing the North Woodbridge area in 2028 as compared to 2050. Thus, a 30% reduction was applied to the developed 2050 peak hour volumes to arrive at the 2028 volumes.

The 2028 opening year and 2050 design year AM and PM peak hour volumes (along with average daily traffic (ADT) volumes) are presented in **Figure 3**, and **Figure 4**, respectively, and were approved by VDOT on October 30, 2023. The approved memorandum that details the methodology, assumptions, and traffic forecasts is in **Appendix B**.

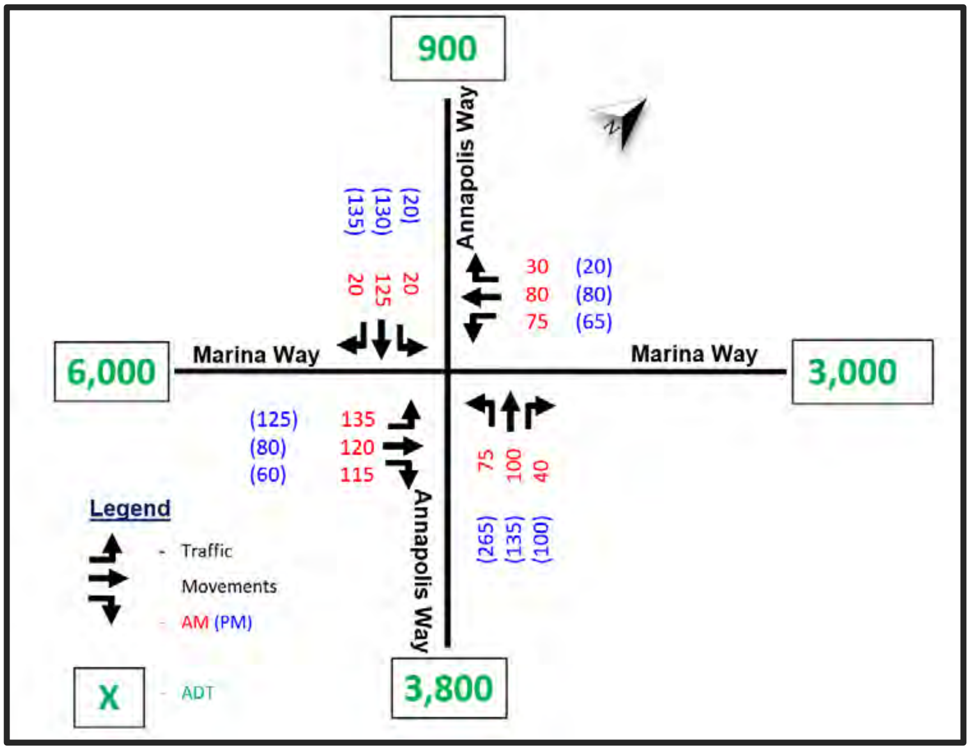


Figure 3: Opening Year 2028 Peak Hour Volumes

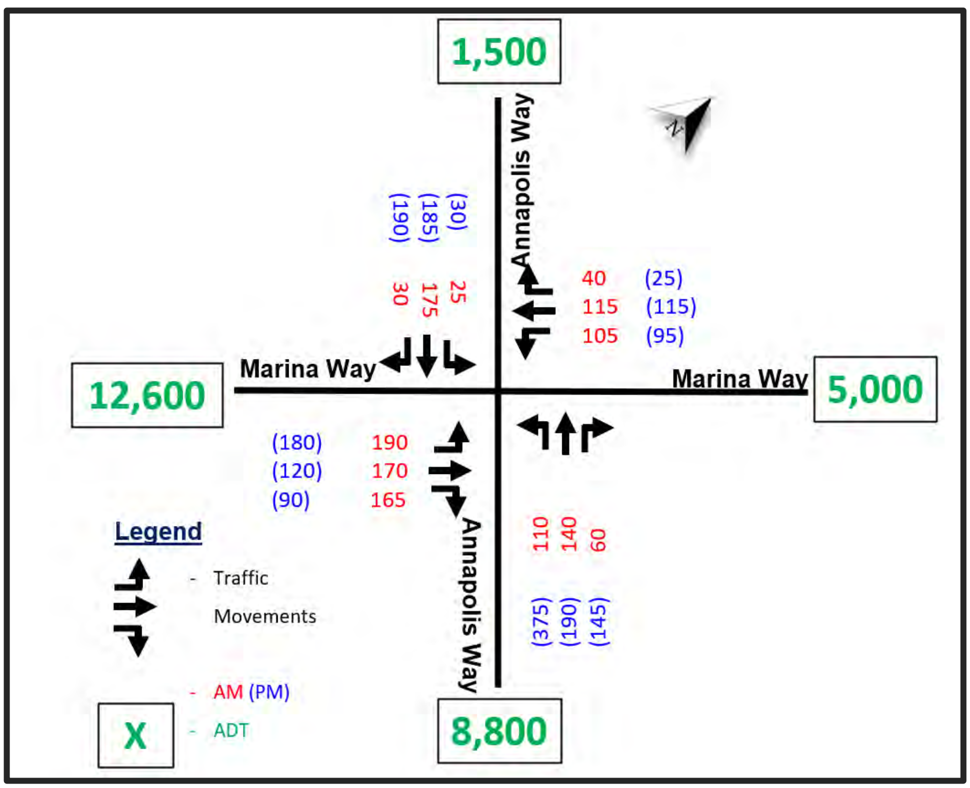


Figure 4: Design Year 2050 Peak Hour Volumes

SIGNAL WARRANT ANALYSIS (OPENING YEAR)

The signal warrants using the warrants outlined in the Manual on Uniform Traffic Control Devices (MUTCD, 2009 with Rev. 1 & 2), and the Virginia Supplement to the MUTCD. Warrant 7: Crash Experience was evaluated based on the FHWA Interim Approval #19. The study intersection includes a new roadway, therefore, there are no available hourly traffic counts that can be used for the warrant. Additionally, there are no schools, crashes, or grade crossings near the study intersection; the nearest signal is approximately 500 feet south. Due to these factors, only Warrants 1, and 8 were evaluated for this intersection. The explanation and result of the warrants are presented in the following sections.

Warrant 1: 8-hour Vehicular Volume

As mentioned above, the study intersection includes a new roadway, therefore, there are no feasible hourly traffic counts that can be used for 8-hour vehicular warrant. However, per the VDOT's 2011 Virginia Supplement to the MUTCD, ADT projections may be utilized to satisfy Warrant 1.

The need for a traffic control signal shall be considered using ADT projections if an engineering study finds that one of the following conditions exist for an average day:

A. The vehicles per day given in both of the 100 percent columns of Condition A in Table 4C-V1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or

B. The vehicles per day given in both of the 100 percent columns of Condition B in Table 4C-V1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

The volume thresholds used for this study are highlighted in **Figure 5**, taken from the Virginia Supplement to the MUTCD Table 4C-V1.

Table 4C-V1. Traffic Signal Warrant Using Average Daily Traffic Estimate

(To be used only when traffic counts are not available, such as at a future intersection)

Condition A—Minimum Vehicular Volume

Number of lines for moving traffic on each approach		Vehicles per day on major street (total of both approaches)				Vehicles per day on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	8,000	6,400	5,600	4,480	2,400	1,920	1,680	1,344
2 or more	1	9,600	7,680	6,720	5,376	2,400	1,920	1,680	1,344
2 or more	2 or more	9,600	7,680	6,720	5,376	3,200	2,560	2,240	1,792
1	2 or more	8,000	6,400	5,600	4,480	3,200	2,560	2,240	1,792

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per day on major street (total of both approaches)				Vehicles per day on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	12,000	9,600	8,400	6,720	1,200	960	850	680
2 or more	1	14,400	11,520	10,080	8,064	1,200	960	850	680
2 or more	2 or more	14,400	11,520	10,080	8,064	1,600	1,280	1,120	896
1	2 or more	12,000	9,600	8,400	6,720	1,600	1,280	1,120	896

[a] Basic minimum hourly volume for urban areas
[b] Used for combination of Conditions A and B after adequate consideration of other remedial measures in urban areas
[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000
[d] May be used for combination of Conditions A and B after adequate consideration of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Figure 5: MUTCD Table 4C-1, Warrant 1

Annapolis Way has two lanes in both directions. Marina Way has one lane in the westbound direction and will have two lanes in the eastbound direction. For this study, Marina Way is considered the major road because of its projected higher opening year volumes ADT, and Annapolis Way is considered the minor road. Based on the projected opening year 2028 volumes, Marina Way will have an approach ADT of 4,500 vehicles per day (VPD), and Annapolis Way's higher volume approach will have an ADT of 1,900 VPD. Based on the approach ADTs, Marina Way and Annapolis Way do not meet the minimum VPD under the 100% threshold for Condition A and for Condition B. Therefore, **Warrant 1 is NOT SATISFIED** in the opening year.

Warrant 8: Roadway Network

This warrant is evaluated when a traffic control signal is considered for the intersection of two or more major routes and if the intersection meets one or both of the following criteria:

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meets one or more of Warrants 1, 2, and 3 during an average weekday; or

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).

Marina Way and Annapolis Way are classified as street/avenue roadways. However, upon completion of their respective extensions, they are proposed to be important local roadway links that will alleviate traffic from Route 1 and Route 123. Also, the study intersection is projected to have at least 1,000 entering vehicles per hour during the peak hour of a typical weekday during the opening year (2028). However, projected 2033 traffic volumes (5 years after the opening year), based on this study, do not meet Warrant 1. Therefore, **Warrant 8 is NOT SATISFIED**.

Summary

The result of the opening year 2028 signal warrant analysis, presented in **Table 1,** shows that neither of the two evaluated warrants are satisfied. According to the MUTCD, only one warrant needs to be satisfied for a signal to be considered for installation at an intersection. The analysis conducted concludes that a traffic signal is not warranted at the intersection of Marina Way and Annapolis Way in the opening year. However, for the projected 2050 design year ADT, Signal Warrant 1 (with the 80% threshold for Condition A) is anticipated to be satisfied. Marina Way is projected to have an ADT of 8,800 VPD for both approaches, and Annapolis is projected to have an ADT of 4,400 VPD for the higher approach, which are over the threshold in **Figure 5**. For this reason, an evaluation of traffic signalization is included in the **Operational Analysis** later in this report.

Table 1: Signal Warrant Analysis Results (Opening Year)

Warrant #	Description	Satisfied
1	8-hour Vehicular Volume	Not Satisfied
8	Roadway Network	Not Satisfied

ALTERNATIVE INTERSECTION ANALYSIS

Alternative intersection analysis was conducted using VDOT's Junction Screening Tool (VJuST) to select the best practical design for the intersection based on available funding, ROW constraints, lane capacity, and proximity to nearby intersections. This alternative screening was based on the projected year 2050 volumes. VJuST was used to evaluate multiple intersection designs based on traffic volumes, lane configurations, and number of lanes. This tool evaluates at-grade and grade-separated intersection designs. This intersection is not planned for any future interchange or overpass. Therefore, this study focused on at-grade intersection designs. **Table 2** shows the alternative intersections from VJuST that were considered along with the alternative intersection types that were *not* considered (including the most applicable justification).

Table 2: VJuST Possible Alternatives

#	Intersections	Information	Consider?	Justification
	VDOT Junction Screening Tool			
	Possible Configurations			
	Indicate with a "Y" or "N" if each intersection or interchange configuration should or should not be considered. Use the information links for guidance. Then, click the "Show/Hide Configurations button" to hide the worksheets for the configurations that will not be considered.			
	Signalized Intersections			
1	Conventional	-	Y	
2	Bowtie	Link	N	Insufficient intersection spacing
3	Center Turn Overpass	Link	N	Not feasible for roadway facility type
4	Continuous Green-T	Link	N	Not feasible for roadway facility type
5	Echelon	Link	N	Not feasible for roadway facility type
6	Full Displaced Left Turn	Link	N	Not feasible for roadway facility type
7	Median U-Turn	Link	N	Unable to accommodate traffic patterns
8	Partial Displaced Left Turn	Link	N	Not feasible for roadway facility type
9	Partial Median U-Turn	Link	N	Unable to accommodate traffic patterns
10	Quadrant Roadway N-E	Link	N	Right-of-way restrictions identified
11	Quadrant Roadway N-W	Link	N	Right-of-way restrictions identified
12	Quadrant Roadway S-E	Link	N	Right-of-way restrictions identified
13	Quadrant Roadway S-W	Link	N	Right-of-way restrictions identified
14	Restricted Crossing U-Turn	Link	N	Unable to accommodate traffic patterns
15	Single Loop	Link	N	Right-of-way restrictions identified
16	Split Intersection	Link	N	Right-of-way restrictions identified
17	Thru-Cut	Link	N	Unable to accommodate traffic patterns
	Unsignalized Intersections			
18	50 Mini Roundabout	Link	Y	
19	75 Mini Roundabout	Link	Y	
20	Roundabout	Link	Y	
21	Two-Way Stop Control	-	Y	
#	**Interchanges**	**Information**	**Consider?**	**Justification**
22	Traditional Diamond	Link	N	Not feasible for roadway facility type
23	Contraflow Left	Link	N	Not feasible for roadway facility type
24	Displaced Left Turn	Link	N	Not feasible for roadway facility type
25	Diverging Diamond	Link	N	Not feasible for roadway facility type
26	Double Roundabout	Link	N	Not feasible for roadway facility type
27	Michigan Urban Diamond	Link	N	Not feasible for roadway facility type
28	Partial Cloverleaf	Link	N	Not feasible for roadway facility type
29	Single Point	Link	N	Not feasible for roadway facility type
30	Single Roundabout	Link	N	Not feasible for roadway facility type

As seen in the **Table 2**, five possible alternatives were considered for this study: a 50 feet mini roundabout, a 75 feet mini roundabout, a full roundabout, a two-way stop control, and a conventional traffic signal. It is noted that the conventional traffic signal option was still considered as part of the alternatives, even though it wasn't warranted in the opening year, to determine how it would operate in the ultimate (2050) design year. The other alternative designs were not considered because they either require acquisition of additional right-of-way (ROW), they are unable to accommodate the traffic volume, there are no existing roadway networks to detour traffic to, or the existing roadway characteristics do not meet the alternative's criteria. For example, the median U-turn, partial median U-turn, restricted crossing U-turn, and thru-cut alternatives all require median openings for a U-turn. Along Annapolis Way, the closest opening to the south of the study intersection is at the intersection of Route 1 and Annapolis Way. Route 1 and Annapolis Way intersection will need to be modified to accommodate the U-turn movements, especially for heavy vehicles. Additionally, the existing Marina Way is a two-lane undivided roadway with a width of approximately 26 feet. The type of roadway cannot accommodate U-turns. Modifications of intersection are constrained to the study intersection. The VJuST results are presented in **Figure 6** and **Figure 7** for the AM and PM peak hours, respectively.

Intersection Results						
		Congestion	Pedestrian	Safety	Planning Level Costs	Notes
Type	Dir	Maximum V/C	Accommodation Compared to Conventional	Weighted Total Conflict Points	Planning Level Cost Category	
Conventional	-	0.51		48	$	
50 Mini Roundabout	-	0.78		8	$	
75 Mini Roundabout	-	0.74		8	$	
Roundabout	-	0.37		8	$$	
Two-Way Stop Control	-	0.96		48	$	

*The continuous green-T is the only three-legged innovative intersection in this tool. To compare the continuous green-T to other innovative intersections, conflicts corresponding with the fourth leg must be removed. This has been done for the conventional intersection. Conflict point diagrams for three-legged and four-legged conventional intersections have been provided on the conventional intersection worksheet for reference.

Figure 6: VJuST AM Peak Hour Intersection Result

Intersection Results						
		Congestion	Pedestrian	Safety	Planning Level Costs	Notes
Type	Dir	Maximum V/C	Accommodation Compared to Conventional	Weighted Total Conflict Points	Planning Level Cost Category	
Conventional	-	0.72		48	$	
50 Mini Roundabout	-	1.09		8	$	
75 Mini Roundabout	-	1.03		8	$	
Roundabout	-	0.59		8	$$	
Two-Way Stop Control	-	N/A*		48	$	

*The continuous green-T is the only three-legged innovative intersection in this tool. To compare the continuous green-T to other innovative intersections, conflicts corresponding with the fourth leg must be removed. This has been done for the conventional intersection. Conflict point diagrams for three-legged and four-legged conventional intersections have been provided on the conventional intersection worksheet for reference.

Figure 7: VJuST PM Peak Hour Intersection Result

The results of the VJuST analysis show that the roundabout will operate the best with the lowest volume to capacity (v/c) ratio during both peaks, followed by the convention signal alternative. The mini roundabouts and two-way stop control alternatives will be over capacity in the design year during the PM peak hour. The AM and PM VJuST worksheets are in **Appendix C,** and **Appendix D**, respectively.

All-Way Stop Control (AWSC)

In addition to the alternative intersection analysis, all-way stop control (AWSC) was also considered for the intersection. The installation of an all-way stop was determined using the applicable criteria listed in Section 2B.07 of the Manual on Uniform Traffic Control Devices (MUTCD, 2009 with Rev. 1 & 2).

Criteria A

Criteria A states that an all-way stop is justified as an interim measure for an intersection where a traffic control signal is justified while arrangements are being made for traffic signal installation.

Analysis findings: A signal warrant analysis shows a signal is not warranted at this intersection in the opening year, so this criterion was **not evaluated** as part of this study.

Criteria B

Criteria B states that an all -way stop is justified by the occurrence of 5 or more crashes in a 12-month period that are potentially correctable by an all-way stop installation, including turning movement collisions and right-angle collisions.

Analysis findings: According to the VDOT Virginia Crash Map, no crash has occurred at the study intersection. Also, the intersection design will include a new roadway, and so this criterion was **not evaluated** as part of this study.

Criteria C

Criteria C is based on minimum hourly traffic volumes and delay and consists of two parts and must be satisfied by meeting the requirements of both C.1 and C.2 together. Furthermore, the volume requirements of C.1 and C.2 can be reduced if the major roadway approach speed exceeds 40 MPH. ***Criteria C.1*** states that the total vehicular volume of both major street approaches must average at least 300 vehicles per hour (VPH) for any 8 hours of an average day, which can be reduced to 210 VPH. ***Criterion C.2*** states that the total number of units (vehicles, bicycles, and pedestrians) on the minor street approaches must average at least 200 units per hour (UPH) for the same 8 hours used to satisfy C.1.

Analysis findings: The hourly volume for Marina Way and Annapolis Way were derived from the percentage difference between the peak hour volume and each hourly volume for each approach at the intersection of Gordon Boulevard and Horner Road. The percentage differences were then applied to the opening year forecasted peak hour volumes at Marina Way/Annapolis way. The forecasted AM peak hour was used to derive the hourly volume from 6 AM to 12 PM, except 7 AM, which was assumed to be the AM peak hour. The forecasted PM peak hour was used to derive the hourly volume from 12 PM to 6 PM, except 5 PM, which was assumed to be the PM peak hour. The diurnal data from the intersection of Gordon Boulevard and Horner Road was used since existing counts at the Marina Way and Annapolis Way intersection would not be representative of the daily traffic flow in the future. It was assumed that the daily flow through the intersection of Gordon Boulevard and Horner Road will be seen at the altered Marina Way and Annapolis Way intersection.

Analysis of volume data indicate that nine (9) (highlighted in green) of the 12 hourly volumes on the major street and minor street meet the volume requirements set for Criteria C is presented in **Table 3.** Therefore, the Volume Criterion for Criteria C is MET.

Table 3: Hourly Volume Analysis Criteria

Time	Major Street (Marina Way)		Minor Street (Annapolis Way)	
	Total Vehicles	*Criteria Requirement (100%)*	*Total Units*	*Criteria Requirement (100%)*
6:00 – 7:00 AM	579	300 Vehicles	256	200 Units
7:00 – 8:00 AM	510		380	
8:00 – 9:00 AM	262		300	
9:00 – 10:00 AM	182		276	
10:00 – 11:00 AM	155		266	
11:00 – 12:00 PM	135		299	
12:00 – 1:00 PM	425		394	
1:00 – 2:00 PM	435		407	
2:00 – 3:00 PM	417		527	
3:00 – 4:00 PM	412		703	
4:00 – 5:00 PM	403		745	
5:00 – 6:00 PM	430		785	

Criteria C.2 also requires an average delay of at least 30 seconds per vehicle (sec/veh) on the minor street approaches for the busiest hour.

Analysis findings: The intersection includes a new roadway, the proposed Marina Way extension, that will alter the existing west leg of the intersection, which will be a four-lane divided roadway with two lanes entering the intersection in the eastbound direction. This will require a new intersection control, and the existing intersection control, two-way stop control, will be void. Also, the VJuST analysis indicated the intersection with the proposed extension will operate over capacity under the existing control, in the design year. Therefore, Criteria C2 does not apply and is not evaluated.

Criteria D

Criteria D states that where no single criterion is met, an all-way stop may still be justified if all of Criteria B, C.1, and C.2 are satisfied to 80 percent of the minimum values.

Analysis findings: Since Criteria C1 is already satisfied, Criteria D does not apply and is not evaluated.

Other Criteria:

Other criteria listed in MUTCD were also considered as listed below:

A. *The need to control left turn conflicts*

Analysis findings: Due to the new roadway that will alter the intersection from existing condition, this criterion was not evaluated.

B. *The need to control vehicle/pedestrian conflicts near locations that generate high pedestrian volumes.*
Analysis findings: Due to the new roadway that will alter the intersection from existing condition, this criterion was not evaluated.

C. *Locations where a road user, after stopping, cannot see conflicting traffic and is not able to negotiate the intersection unless conflicting cross traffic is also required to stop.*
Analysis findings: Due to the new roadway that will alter the intersection from existing condition, this criterion was not evaluated.

D. *An intersection of two residential neighborhood collector streets where all-way stop control would improve traffic operational characteristics of the intersection.*
Analysis findings: According to the 2019 North Woodbridge Small Area Plan, Marina Way and Annapolis Way are classified as avenue/street. The VJuST analysis indicated the intersection with the proposed extension will operate over capacity under the existing control (TWSC) in the design year. A Synchro operational analysis of the all-way stop control indicated that the intersection is expected to operate at acceptable LOS during the opening and design years. The operational results for the all-way stop control Synchro analysis are in the **All-Way Stop Control Section**.

The analysis provided in this study shows that an all-way stop control is justified since two of the Criteria (Criterion C & traffic operations improvement Criterion) listed in the MUTCD were satisfied.

OPERATIONAL ANALYSIS

The intersection was evaluated as a conventional signal, 50 feet mini roundabout, 75 feet mini roundabout, a full roundabout, and a two-way stop control. Further operational analysis was not conducted for the mini roundabouts and two-way stop control alternatives because they will not be able to accommodate the traffic volume in the design year based on the VJuST result. Operational analysis was conducted for the conventional signal and roundabout alternatives. In addition to the two alternatives, an all-way stop control (AWSC) was also analyzed for the intersection. An AWSC configuration is not included as an option in the VJuST tool; however, it was deemed a reasonable alternative, and also justified for analysis in this study given that traffic signal warrants are not initially satisfied (refer to previous section: **Signal Warrant Analysis (Opening Year)**).

The operational analysis of the conventional signal and AWSC alternatives was conducted using Synchro/SimTraffic, Version 11, implementing the built-in Highway Capacity Manual Methodology (HCM 6). The operational analysis of the roundabout was conducted using SIDRA Intersection 9.0. The measures of effectiveness (MOEs) reported are control delay (seconds per vehicle (s/veh)), level of service (LOS), and 95^{th} percentile queue length. The analysis was conducted for the AM and PM peak hours under the design year 2050 condition, with a peak hour factor of 0.92. According to the 2022 Prince William County Mobility Plan, a LOS E is acceptable for intersections, specifically in areas designated within Small Area Plans.

Conventional Signalized Intersection

The lane configuration for the signalized intersection alternative for the 2050 design year is presented in **Figure 8**. This lane configuration is based on the VJuST analysis, while considering ROW constraints.

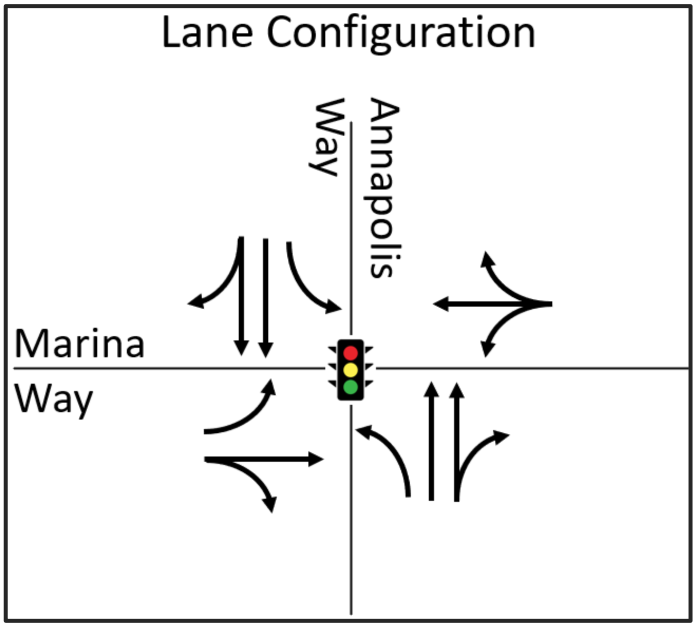


Figure 8: Proposed Signalized Lane Configuration

The result of the signalized intersection analysis for the 2050 design year is presented in **Table 4**. The Synchro and SimTraffic reports are presented in **Appendix E**.

Table 4: Proposed Signalized Operational Results (2050 Design Year)

ROADWAY	DIRECTION	LANE	STORAGE LENGTH (feet)	AM PEAK			PM PEAK		
				Delay (s/veh)	LOS	95th Percentile Queue length (feet)	Delay (s/veh)	LOS	95th Percentile Queue length (feet)
Marina Way	Eastbound	L	Continuous	15.6	B	132	17.1	B	137
		TR		15.9	B	180	15.7	B	119
	Approach Delay			**15.8**	**B**	-	**16.3**	**B**	-
	Westbound	LTR		24.0	C	196	24.9	C	178
	Approach Delay			**24.0**	**C**	-	**24.9**	**C**	-
Annapolis Way	Northbound	L	225	10.5	B	82	15.2	B	192
		TR		11.8	B	80	11.6	B	101
	Approach Delay			**11.3**	**B**	-	**13.5**	**B**	-
	Southbound	L	250	11.4	B	31	12.6	B	34
		TR		13.5	B	78	17.7	B	92
	Approach Delay			**13.2**	**B**	-	**16.9**	**B**	-
OVERALL DELAY				***15.9***	***B***	-	***16.4***	***B***	-

As shown in **Table 4**, the conventional signal is expected to operate at an acceptable overall LOS B during both peak hours. All the approaches and lane movements are expected to operate at an acceptable LOS C or better during both peaks. In addition, the queues are not expected to exceed the storage lengths for all the turn lanes for the approaches, based on the 95th percentile queue lengths presented in **Table 4**.

Roundabout

Singe-Lane Roundabout

A single-lane configuration with slip lanes was evaluated for the roundabout alternative. Annapolis Way is currently a four-lane roadway with two lanes each in the northbound and southbound approaches, which is in accordance with the 2019 North Woodbridge Small Area Plan. To maintain the existing four-lane roadway configuration along Annapolis Way and analyze for a single-lane roundabout, one of the two lanes in each approach was converted to a slip lane for the right-turn movement. The proposed eastbound approach two lane configuration along Marina Way was also assumed to be converted to a shared through and left-turn lane, and a slip lane for the right-turn movement (similar to the Annapolis Way approaches). The existing westbound approach single-lane configuration will be maintained. A screen-capture from SIDRA showing the lane configuration and intersection control for this alternative is presented in **Figure 9**.

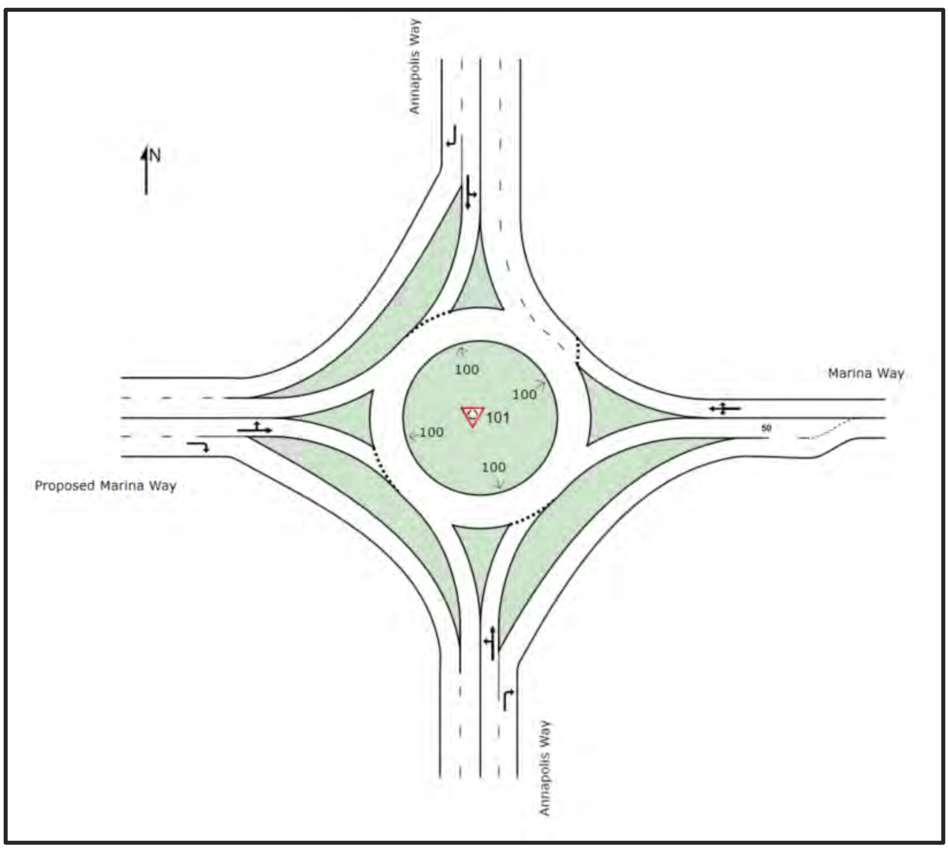


Figure 9: Proposed Single-Lane Roundabout Lane Configuration

The result of the roundabout analysis is presented in **Table 5.** The SIDRA result output is presented in **Appendix F**.

Table 5: Proposed Single-Lane Roundabout Operational Results

ROADWAY	DIRECTION	LANE	AM PEAK			PM PEAK		
			Delay (S/Veh)	LOS	95th Percentile Queue (feet)	Delay (S/Veh)	LOS	95th Percentile Queue (feet)
Marina Way	Eastbound	L	11.3	B	83.5	10.1	B	56.1
		T	14.3	B	83.5	13.1	B	56.1
		R	0	A	-	0	A	-
	Approach Delay		**8.8**	**A**	**-**	**8.7**	**A**	**-**
	Westbound	L	12.7	B	67.1	25.1	D	88.4
		T	12.7	B	67.1	25.1	D	88.4
		R	12.7	B	67.1	25.1	D	88.4
	Approach Delay		**12.7**	**B**	**-**	**25.1**	**D**	**-**
Annapolis Way	Northbound	L	9.8	A	43.9	24.9	C	349.8
		T	9.7	A	43.9	24.9	C	349.8
		R	0	A	-	0	A	-
	Approach Delay		**7.9**	**A**	**-**	**19.8**	**C**	**-**
	Southbound	L	11	B	30.5	16.8	C	56.4
		T	8	A	30.5	13.8	B	56.4
		R	0	A	-	0	A	-
	Approach Delay		**7.3**	**A**	**-**	**7.6**	**A**	**-**
OVERALL DELAY			***9.1***	***A***	***-***	***15.1***	***C***	***-***

The result of the analysis shows the roundabout is expected to perform at an acceptable overall LOS during both peaks. The movements and approaches are expected to operate at an acceptable LOS of D or better during both peak hours. In addition, the queues are not expected to spill to the downstream intersections, based on the 95th percentile queue lengths. It is noted that the northbound 95th percentile queue during the PM peak hour extends to approximately 50 feet from the downstream signalized intersection, without interfering or blocking.

Hybrid (2 x 1) Roundabout

VDOT requested that in addition to analyzing the single-lane configuration with slip lanes roundabout alternative, a hybrid configuration, with two lanes along Annapolis Road, and one lane along Marina Way, should be analyzed. This will ensure that all feasible alternatives have been evaluated under the roundabout alternative while still maintaining the existing four-lane roadway configuration along Annapolis Way, and also address the potential northbound queue that is expected to occur (and to extend within approximately 50' of the upstream signalized intersection) under the single-lane roundabout alternative. A screen-capture from SIDRA showing the lane configuration and intersection control for this alternative is presented in **Figure 10**.

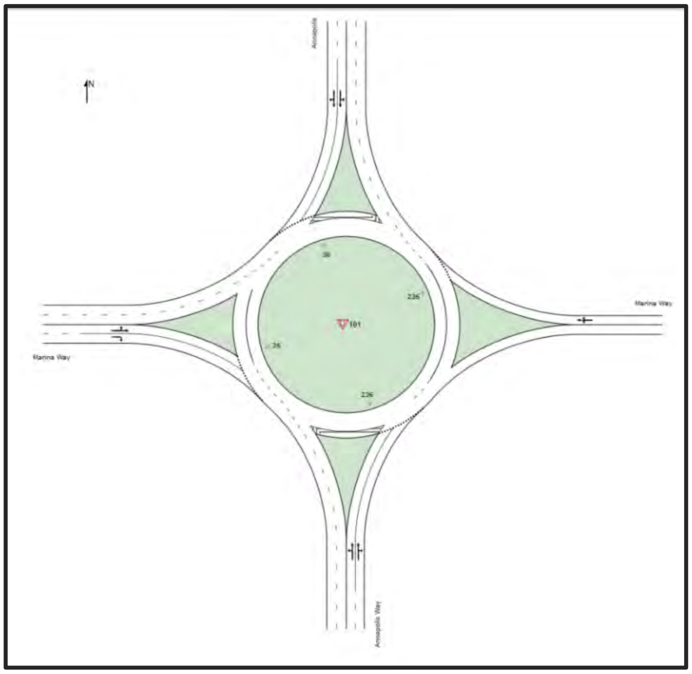


Figure 10: Proposed Hybrid Roundabout Lane Configuration

The result of the hybrid roundabout analysis is presented in **Table 6.** The SIDRA result output is presented in **Appendix F**.

Table 6: Proposed Hybrid Roundabout Operational Results

ROADWAY	DIRECTION	LANE	AM PEAK			PM PEAK		
			Delay (S/Veh)	LOS	95^{th} Percentile Queue (feet)	Delay (S/Veh)	LOS	95^{th} Percentile Queue (feet)
Marina Way	Eastbound	L	10.8	A	74.4	9.6	A	59.2
		T	10.8	B	74.4	9.6	A	59.2
		R	7.4	A	22.9	6.3	A	59.2
	Approach Delay		**9.8**	**A**	**-**	**8.9**	**A**	**-**
	Westbound	L	10.5	B	48.2	16.3	C	49.1
		T	10.5	B	48.2	16.3	C	49.1
		R	10.5	B	48.2	16.3	C	12.1
	Approach Delay		**10.5**	**B**	**-**	**16.3**	**C**	**-**
Annapolis Way	Northbound	L	7.6	A	22.6	12.5	B	100.7
		T	7.6	A	22.6	11.2	B	75.7
		R	7.6	A	22.6	11.2	B	75.7
	Approach Delay		**7.6**	**A**	**-**	**11.9**	**B**	**-**
	Southbound	L	6.4	A	15.5	12.6	B	47.9
		T	6.4	A	15.5	12.6	B	47.9
		R	6.4	A	15.5	12.6	B	47.9
	Approach Delay		**6.4**	**A**	**-**	**12.6**	**B**	**-**
OVERALL DELAY			***8.8***	***A***	***-***	***11.9***	***B***	***-***

The result of the analysis shows the roundabout is expected to perform at an acceptable overall LOS during both peaks. The movements and approaches are expected to operate an acceptable LOS of C or better during both peak hours. In addition, the 95th percentile queues are minimal (four vehicles or less) and are not expected to spill to near the downstream intersections.

All-Way Stop Control (AWSC)

An AWSC alternative was analyzed in the opening year 2028, and design year 2050 for the study intersection. Under this alternative, the existing lane configuration entering the intersection along Annapolis Way was modified from three lanes to two lanes to be within the HCM AWSC analysis standard. As seen in **Figure 11**, the northbound approach was converted to an exclusive left-turn lane and shared through and right lane, and the southbound approach was converted to a shared left and through lane and an exclusive right-turn lane. The proposed eastbound approach will be an exclusive left-turn lane and shared through and right lane.

The result of the AWSC analysis for the opening year is presented in **Table 7.** The opening year synchro output is presented in **Appendix G**.

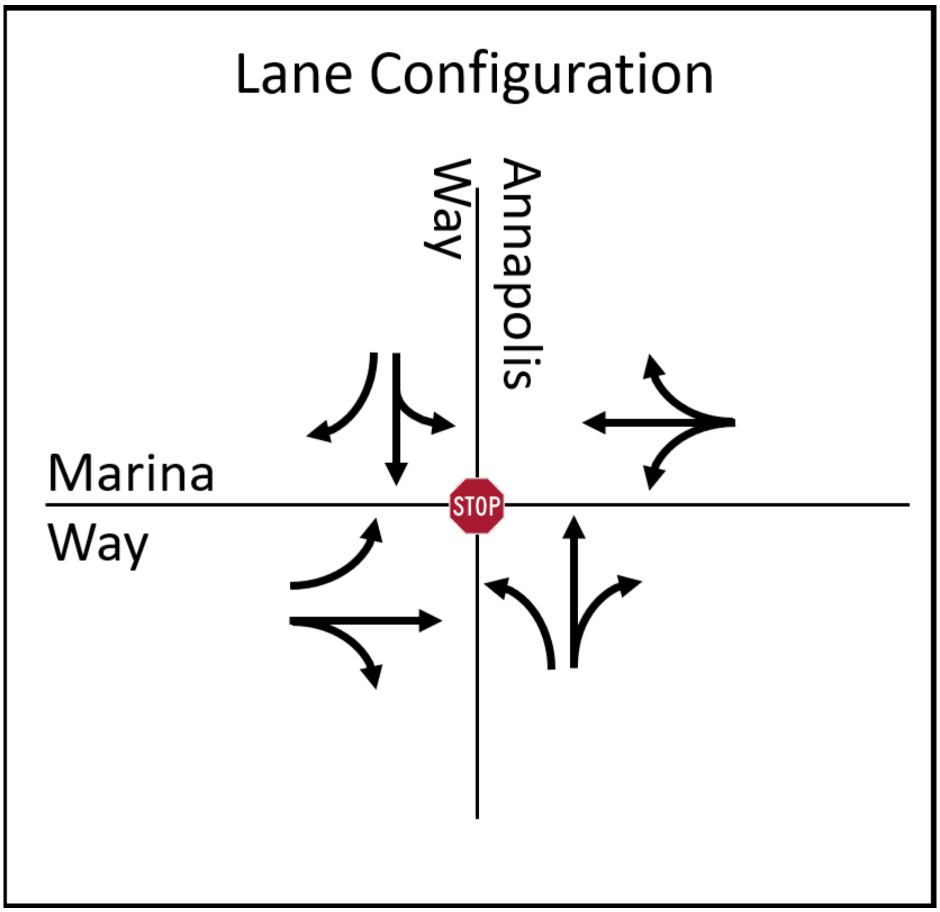


Figure 11: Proposed AWSC Lane Configuration

Table 7: Proposed AWSC Operational Results for the Opening Year 2028

ROADWAY	DIRECTION	LANE	AM PEAK			PM PEAK		
			Delay (S/Veh)	LOS	95th Percentile Queue (feet)	Delay (S/Veh)	LOS	95th Percentile Queue (feet)
Marina Way	Eastbound	L	12.0	B	28	14.1	B	33
		TR	12.7	B	50	13	B	33
	Approach Delay		**12.4**	**B**	-	**13.5**	**B**	-
	Westbound	LTR	13.2	B	40	15.4	C	45
	Approach Delay		**13.2**	**B**	-	**15.4**	**C**	-
Annapolis Way	Northbound	L	11.3	B	15	20.0	C	93
		TR	11.6	B	28	14.8	B	60
	Approach Delay		**11.5**	**B**	-	**17.6**	**C**	-
	Southbound	LT	12.4	B	30	13.6	B	35
		R	9.0	A	3	11.6	B	28
	Approach Delay		**12.0**	**B**	-	**12.7**	**B**	-
OVERALL DELAY			***12.3***	***B***	-	***15.3***	***C***	-

The opening year result shows the intersection is expected to perform at an acceptable overall LOS B and LOS C during the AM and PM peak hours, respectively. Additionally, all the lane movements and approaches are expected to operate at acceptable LOS.

The result of the AWSC analysis for the design year is presented in **Table 8**. The design year synchro output is presented in **Appendix H**.

Table 8: Proposed AWSC Operational Results for the Design Year 2050

ROADWAY	DIRECTION	LANE	AM PEAK			PM PEAK		
			Delay (S/Veh)	LOS	95th Percentile Queue (feet)	Delay (S/Veh)	LOS	95th Percentile Queue (feet)
Marina Way	Eastbound	L	17.2	C	58	21.8	C	70
		TR	25.7	D	143	21.3	C	78
	Approach Delay		**22.6**	**C**	-	**21.5**	**C**	-
	Westbound	LTR	22.9	C	103	28.1	D	110
	Approach Delay		**22.9**	**C**	-	**28.1**	**D**	-
Annapolis Way	Northbound	L	14.6	B	28	77	F	313
		TR	17.3	C	63	38	E	190
	Approach Delay		**16.3**	**C**	-	**58.6**	**F**	-
	Southbound	LT	18.9	C	68	23.3	C	88
		R	10.7	B	0	18.1	C	63
	Approach Delay		**17.8**	**C**	-	**20.9**	**C**	-
OVERALL DELAY			***20.4***	***C***	-	***37.5***	***E***	-

The result of the AWSC operational analysis shows the intersection is expected to perform at an acceptable overall LOS C and LOS E during the AM and PM peak hours, respectively. During the AM peak hour, the movements and approaches are expected to operate an acceptable LOS of D. During the PM peak hour, three of the four approaches operate with acceptable LOS D (or better); however, the northbound approach is expected to operate with failing LOS F and delay of 58.6 s/veh. The approach delay and LOS are driven by the northbound left-turn movement, which operates at LOS F and a delay of 77 s/veh.

RECOMMENDATIONS AND CONCLUSIONS

JMT evaluated the intersection of Marina Way and Annapolis Way as part of the Marina Way extension project to determine the most feasible and practical-based intersection design and traffic control given the available funding, right of way (ROW) constraints, lane capacity, and proximity to nearby intersections. Opening year 2028 and design year 2050 volumes were developed for this study. The opening year traffic volumes of 2028 were used for the signal warrant analysis and the design year 2050 volumes were used for the capacity analysis. The signal warrant analysis was conducted to determine whether a signal will be justified at the intersection during the opening year.

The signal warrant analysis showed that neither of the signal warrants evaluated herein (Warrant 1 and Warrant 8) are anticipated to be satisfied under opening year 2028 conditions. Other alternative intersection configurations were considered. VDOT's Junction Screening Tool (VJuST) was used to select the best practical design for the intersection based on available funding, ROW constraints, lane capacity, and proximity to nearby intersections. Using the year 2050 volumes, the VJuST analysis showed five alternative designs are practical and feasible at the study intersection: a 50 feet mini roundabout, 75 feet mini roundabout, a full roundabout, two-way stop control, and a conventional traffic signal. Based on projected 2050 design year volumes, a conventional traffic signal was still considered as part of the alternatives (even though it wasn't warranted in the opening year) to determine how it would operate in the design year. The other alternative designs were not considered because they either require acquisition of additional right-of-way (ROW), they are unable to accommodate the traffic volume, there are no existing roadway networks to detour traffic to, or the existing roadway characteristics do not meet the alternative's criteria. In the design year, the roundabout will operate with the lowest volume to capacity (v/c) ratio during both peaks, followed by the conventional signal alternative. The mini roundabouts and two-way stop control alternatives will be over capacity in the design year during the PM peak hour. Additionally, an all-way stop control (AWSC) warrant analysis was performed which indicated that an AWSC was justified at the intersection.

Operational analysis was conducted for the conventional signal, a single-lane roundabout, a hybrid (2 x 1) roundabout, and AWSC alternatives using the design year 2050 volumes. The lane configuration for all the alternatives conformed with the County's 2019 North Woodbridge Small Area Plan. The AWSC lane configuration was within the HCM AWSC analysis standard. The results showed the conventional signal and both roundabout alternatives are expected to operate at an acceptable LOS C or better. Additionally, all the movements and approaches are expected to operate at LOS D or better during the projected 2050 design year AM and PM peak hour.

The AWSC is expected to operate at an overall LOS C and LOS E during the AM and PM peak hours, respectively, in the design year. However, during the PM peak hour, the northbound approach is expected to operate with a failing LOS F and delay of 58.6 s/veh. Additionally, the northbound left-turn movement is expected to fail with a LOS F and delay of 77 s/veh. A sensitivity analysis was conducted to determine when the AWSC NB left-turn movement and approach will first experience a LOS F. A linear interpolation of the intersection PM peak volume was conducted between the year 2028 and year 2050, to determine the PM peak volume for the years in between. The sensitivity analysis showed that the northbound left-turn movement is anticipated to first experience a LOS F in the year 2045, and the approach in year 2049.

Based on the operational results presented above, a roundabout would be expected to provide the best overall intersection operations. However, given the following implications and physical constraints, a roundabout is not considered a feasible option:

ROW Impacts

The existing intersection is surrounded by a newly constructed apartment complex on the northwest corner, an existing facility parking lot on the SW corner, and a concrete facility on the northeast corner of the intersection. This presents major footprint constraints and acquisition challenges for the County. The concrete facility currently accesses the eastern leg of Marina Way to gain full access to Annapolis Way. Implementing a roundabout would potentially eliminate this access point, not to mention the fact that this section of Marina Way is currently privately owned. Access for the property owner on the northwest corner would be situated within the footprint of the roundabout and will have to be accommodated. This will require a new access point onto Annapolis Way for this property owner as well as parking remediation and potential impacts to their existing storm sewer system.

Proximity to Route 1 & Rivergate Apartments Intersection

To further expand on the physical constraints, given the surrounding land use, the design vehicle that would govern the design of a roundabout at this location would be a WB-67. This vehicle would significantly increase the footprint of this roundabout which would situate the roundabout at an offset from the original intersection. This would require major reconfiguration of the approaching roadways, which would not be feasible given the proximity of only 400' to these existing intersections. In addition, the existing 4-lane roadway approaches will have to be reduced to single lane approaches. This would also cause implications for a future double-left from northbound Route 1 (turning onto Annapolis Way), which has already been constructed and is striped out for future use.

Access Management

There are multiple partial and full access entrances and exits within the proximity of this intersection. Installing a roundabout would trigger entrance spacing requirements to be met. This will result in multiple entrances being closed or relocated away from the roundabout. This will ultimately cause major liquidated damages to the County.

Adjacent Redevelopment

The owner of Parcel 003 (Ashna LLC), which is located in the southwest corner, is planning to redevelop their property in the near future and is currently in coordination with the County. Installing a roundabout will indefinitely encroach onto their property and may result in their parcel being undevelopable. This would require the County to perform a total acquisition and expend the ROW budget for litigation efforts with this owner.

Schedule

The County is on a stringent schedule to deliver this project and have Marina Way extension in operation before the redevelopment of the Gordon Plaza (Home Depot and Aldi) towards Route 123 is completed. Incorporating additional ROW impacts and potential remediation efforts for larger acquisitions at the Annapolis Way intersection would put the project delivery schedule in jeopardy.

In conclusion, an AWSC alternative is recommended for this intersection in the opening (and foreseeable future) years, because it is expected to operate at an acceptable level of service (and with acceptable 95^{th} percentile queue lengths) during both peaks. In addition, a traffic signal is not warranted in the opening year, and a roundabout is not feasible for the intersection due to the constraints mentioned above.

It is recommended that the County consider further analysis and potential implementation of a traffic signal (or other types of traffic control improvements) by year 2045 (five years before the design year of 2050) because the northbound approach is expected to start failing under the AWSC configuration in year 2049. Traffic signal warrants under Warrant 1 with the 80% threshold for Condition A are expected to be satisfied by the year 2045. Marina Way is projected to have an ADT of 7,800 VPD for both approaches, and Annapolis Way is projected to have an ADT of 3,800 VPD for the higher approach, which are over the signal warrant thresholds in **Figure 5**.

Appendix A

Vehicular and Pedestrian Count Data

1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC

Thu Jun 8, 2023
Full Length (12 AM-12 AM (+1))
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

PEGGY MALONE & ASSOCIATES TRAFFIC DATA COLLECTION
Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345, Jacksonville Beach, FL, 32250, US

Leg	Business Driveway						Marina Way						Annapolis Way						Annapolis Way						
Direction	Eastbound						Westbound						Northbound						Southbound						
Time	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	**Int**
2023-06-08 12:00AM	0	0	2	0	**2**	0	2	0	0	0	**2**	0	2	0	0	0	**2**	0	0	0	0	0	**0**	0	**6**
12:15AM	0	0	0	0	**0**	0	3	0	0	0	**3**	0	0	0	1	0	**1**	0	0	1	0	0	**1**	0	**5**
12:30AM	0	0	0	0	**0**	0	2	0	0	0	**2**	0	0	0	2	0	**2**	0	0	0	0	0	**0**	0	**4**
12:45AM	0	0	0	0	**0**	0	3	0	0	0	**3**	0	0	1	4	0	**5**	0	0	0	0	0	**0**	0	**8**
Hourly Total	0	0	2	0	**2**	0	10	0	0	0	**10**	0	2	1	7	0	**10**	0	0	1	0	0	**1**	0	**23**
1:00AM	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	1	2	0	**3**	0	0	0	0	0	**0**	0	**3**
1:15AM	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	4	0	**4**	0	0	0	0	0	**0**	0	**4**
1:30AM	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	1	0	**1**	0	0	0	0	0	**0**	0	**1**
1:45AM	0	0	0	0	**0**	0	2	0	0	0	**2**	0	0	0	2	0	**2**	0	0	0	0	0	**0**	0	**4**
Hourly Total	0	0	0	0	**0**	0	2	0	0	0	**2**	0	0	1	9	0	**10**	0	0	0	0	0	**0**	0	**12**
2:00AM	0	0	0	0	**0**	0	1	0	0	0	**1**	0	1	0	2	0	**3**	0	0	0	0	0	**0**	0	**4**
2:15AM	0	0	1	0	**1**	0	0	0	0	0	**0**	0	0	0	2	0	**2**	0	0	1	0	0	**1**	0	**4**
2:30AM	0	0	0	0	**0**	0	1	0	0	0	**1**	0	0	1	1	0	**2**	0	0	0	0	0	**0**	0	**3**
2:45AM	0	1	0	0	**1**	0	1	0	0	0	**1**	0	1	1	1	0	**3**	0	0	0	0	0	**0**	0	**5**
Hourly Total	0	1	1	0	**2**	0	3	0	0	0	**3**	0	2	2	6	0	**10**	0	0	1	0	0	**1**	0	**16**
3:00AM	0	0	0	0	**0**	0	1	0	0	0	**1**	0	0	1	0	0	**1**	0	0	0	0	0	**0**	0	**2**
3:15AM	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	1	0	0	**1**	0	0	0	0	0	**0**	0	**1**
3:30AM	0	0	0	0	**0**	0	1	0	0	0	**1**	0	0	0	0	0	**0**	0	0	1	0	0	**1**	0	**2**
3:45AM	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	1	0	**1**	0	0	0	0	0	**0**	0	**1**
Hourly Total	0	0	0	0	**0**	0	2	0	0	0	**2**	0	0	2	1	0	**3**	0	0	1	0	0	**1**	0	**6**
4:00AM	1	0	0	0	**1**	0	7	0	0	0	**7**	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	**8**
4:15AM	0	0	0	0	**0**	0	10	0	0	0	**10**	0	0	0	1	0	**1**	0	0	0	0	0	**0**	0	**11**
4:30AM	0	0	0	0	**0**	0	2	0	0	0	**2**	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	**2**
4:45AM	0	0	0	0	**0**	0	3	0	0	0	**3**	0	0	0	3	0	**3**	0	0	3	0	0	**3**	0	**9**
Hourly Total	1	0	0	0	**1**	0	22	0	0	0	**22**	0	0	0	4	0	**4**	0	0	3	0	0	**3**	0	**30**
5:00AM	0	0	0	0	**0**	1	5	0	0	0	**5**	0	0	0	1	0	**1**	0	0	0	0	0	**0**	1	**6**
5:15AM	0	0	0	0	**0**	0	5	0	0	0	**5**	0	0	0	2	1	**3**	0	0	1	0	0	**1**	0	**9**
5:30AM	0	0	0	0	**0**	0	30	0	0	0	**30**	0	0	0	10	0	**10**	0	0	4	0	0	**4**	0	**44**
5:45AM	0	0	0	0	**0**	0	19	0	0	0	**19**	0	0	0	5	0	**5**	0	0	3	0	0	**3**	0	**27**
Hourly Total	0	0	0	0	**0**	1	59	0	0	0	**59**	0	0	0	18	1	**19**	0	0	8	0	0	**8**	1	**86**
6:00AM	0	0	1	0	**1**	0	12	1	0	0	**13**	0	0	3	1	0	**4**	0	0	6	0	0	**6**	0	**24**
6:15AM	0	0	0	0	**0**	0	21	0	0	0	**21**	0	0	1	8	1	**10**	0	0	5	0	1	**6**	0	**37**
6:30AM	0	0	0	0	**0**	0	23	0	0	0	**23**	0	0	3	4	0	**7**	0	0	6	0	0	**6**	1	**36**
6:45AM	0	0	0	0	**0**	0	14	0	0	0	**14**	0	0	3	5	0	**8**	0	1	11	0	0	**12**	0	**34**
Hourly Total	0	0	1	0	**1**	0	70	1	0	0	**71**	0	0	10	18	1	**29**	0	1	28	0	1	**30**	1	**131**
7:00AM	0	0	0	0	**0**	0	25	1	0	0	**26**	0	0	1	6	1	**8**	0	0	4	0	0	**4**	0	**38**
7:15AM	0	0	1	0	**1**	3	22	0	0	0	**22**	0	0	3	8	0	**11**	0	0	9	0	0	**9**	11	**43**
7:30AM	0	0	1	0	**1**	0	29	0	0	0	**29**	0	0	3	9	1	**13**	0	0	7	1	0	**8**	1	**51**
7:45AM	0	0	0	0	**0**	0	30	0	0	0	**30**	0	0	3	9	0	**12**	0	1	6	0	0	**7**	0	**49**
Hourly Total	0	0	2	0	**2**	3	106	1	0	0	**107**	0	0	10	32	2	**44**	0	1	26	1	0	**28**	12	**181**
8:00AM	0	0	1	0	**1**	0	27	0	0	0	**27**	0	1	3	17	0	**21**	0	0	8	0	0	**8**	0	**57**
8:15AM	0	0	0	0	**0**	0	16	0	0	0	**16**	0	1	4	7	0	**12**	0	0	9	0	0	**9**	0	**37**
8:30AM	0	0	0	0	**0**	1	15	0	1	0	**16**	0	1	3	11	0	**15**	0	0	10	0	0	**10**	0	**41**
8:45AM	0	0	0	0	**0**	0	17	0	0	0	**17**	0	1	3	12	0	**16**	0	2	7	0	0	**9**	0	**42**
Hourly Total	0	0	1	0	**1**	1	75	0	1	0	**76**	0	4	13	47	0	**64**	0	2	34	0	0	**36**	0	**177**
9:00AM	0	0	0	0	**0**	0	19	0	1	0	**20**	1	1	3	11	1	**16**	0	0	3	0	0	**3**	0	**39**
9:15AM	0	0	1	0	**1**	0	20	0	1	0	**21**	0	6	3	10	2	**21**	0	1	0	0	0	**1**	0	**44**
9:30AM	0	0	0	0	**0**	1	26	0	0	0	**26**	0	3	3	11	0	**17**	0	0	3	0	0	**3**	0	**46**
9:45AM	0	0	2	0	**2**	0	17	1	1	0	**19**	0	10	2	18	1	**31**	0	0	2	1	0	**3**	0	**55**
Hourly Total	0	0	3	0	**3**	1	82	1	3	0	**86**	1	20	11	50	4	**85**	0	1	8	1	0	**10**	0	**184**
10:00AM	1	0	0	0	**1**	0	15	0	0	0	**15**	0	12	3	14	0	**29**	0	0	3	0	0	**3**	0	**48**
10:15AM	0	0	1	0	**1**	0	13	0	0	0	**13**	0	1	4	17	0	**22**	0	0	1	0	0	**1**	0	**37**
10:30AM	0	0	1	0	**1**	0	11	0	1	0	**12**	0	3	1	11	0	**15**	0	0	8	0	0	**8**	0	**36**
10:45AM	1	0	1	0	**2**	1	23	0	1	0	**24**	0	1	0	17	0	**18**	0	0	4	1	0	**5**	0	**49**
Hourly Total	2	0	3	0	**5**	1	62	0	2	0	**64**	0	17	8	59	0	**84**	0	0	16	1	0	**17**	0	**170**
11:00AM	0	0	1	0	**1**	1	13	0	0	0	**13**	0	1	2	10	2	**15**	0	0	1	1	0	**2**	0	**31**
11:15AM	0	0	0	0	**0**	0	12	0	1	0	**13**	0	2	2	13	0	**17**	0	1	3	0	0	**4**	0	**34**
11:30AM	0	0	1	0	**1**	0	23	0	0	0	**23**	0	0	6	19	0	**25**	0	3	5	0	0	**8**	0	**57**
11:45AM	0	0	2	0	**2**	0	14	0	0	0	**14**	2	1	4	20	0	**25**	0	3	3	0	0	**6**	0	**47**
Hourly Total	0	0	4	0	**4**	1	62	0	1	0	**63**	2	4	14	62	2	**82**	0	7	12	1	0	**20**	0	**169**
12:00PM	0	0	2	0	**2**	1	13	0	2	0	**15**	0	3	4	14	0	**21**	0	0	8	0	0	**8**	1	**46**
12:15PM	0	0	2	0	**2**	2	18	0	0	0	**18**	0	0	3	7	1	**11**	0	1	3	0	0	**4**	1	**35**

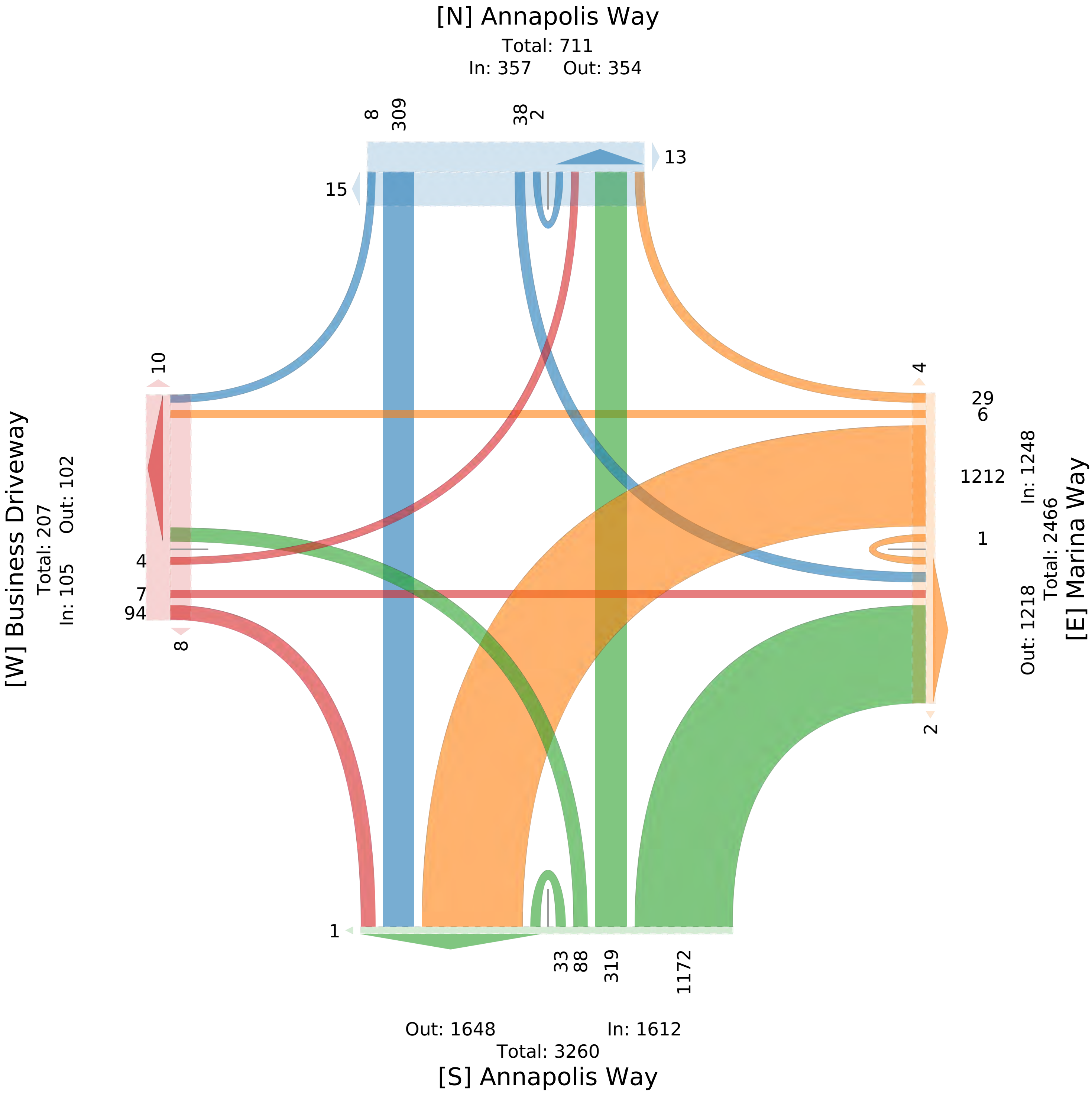
Leg	Business Driveway						Marina Way						Annapolis Way						Annapolis Way						
Direction	Eastbound						Westbound						Northbound						Southbound						
Time	L	T	R	U	App	Ped*	L	T	R	U	App	Ped*	L	T	R	U	App	Ped*	L	T	R	U	App	Ped*	Int
12:30PM	0	0	0	0	**0**	0	12	0	0	0	**12**	0	0	3	18	1	**22**	0	1	5	0	0	**6**	0	**40**
12:45PM	0	1	2	0	**3**	0	9	0	1	0	**10**	0	0	5	17	0	**22**	0	1	1	1	0	**3**	0	**38**
Hourly Total	0	1	6	0	**7**	3	52	0	3	0	**55**	0	3	15	56	2	**76**	0	3	17	1	0	**21**	2	**159**
1:00PM	0	0	2	0	**2**	0	13	0	0	0	**13**	0	0	5	17	0	**22**	0	0	1	0	0	**1**	0	**38**
1:15PM	0	0	2	0	**2**	0	19	0	0	0	**19**	0	1	2	11	0	**14**	0	0	1	0	0	**1**	0	**36**
1:30PM	0	0	7	0	**7**	0	18	0	1	0	**19**	0	0	5	20	2	**27**	0	1	4	1	0	**6**	1	**59**
1:45PM	0	0	0	0	**0**	1	13	0	1	0	**14**	0	3	7	16	0	**26**	0	2	4	0	0	**6**	0	**46**
Hourly Total	0	0	11	0	**11**	1	63	0	2	0	**65**	0	4	19	64	2	**89**	0	3	10	1	0	**14**	1	**179**
2:00PM	0	0	0	0	**0**	0	14	0	0	0	**14**	0	1	5	11	1	**18**	0	0	5	0	0	**5**	0	**37**
2:15PM	0	0	1	0	**1**	0	13	0	1	0	**14**	0	2	5	16	1	**24**	0	1	4	0	0	**5**	0	**44**
2:30PM	0	0	4	0	**4**	0	22	0	0	0	**22**	0	4	4	19	0	**27**	0	1	9	0	0	**10**	0	**63**
2:45PM	0	0	0	0	**0**	0	18	1	0	0	**19**	0	1	5	12	0	**18**	0	0	7	0	0	**7**	0	**44**
Hourly Total	0	0	5	0	**5**	0	67	1	1	0	**69**	0	8	19	58	2	**87**	0	2	25	0	0	**27**	0	**188**
3:00PM	0	0	0	0	**0**	0	19	0	1	0	**20**	3	1	6	18	4	**29**	0	0	4	0	0	**4**	1	**53**
3:15PM	0	0	1	0	**1**	0	17	0	2	0	**19**	0	3	10	23	1	**37**	0	0	5	0	0	**5**	5	**62**
3:30PM	0	0	2	0	**2**	1	12	0	1	0	**13**	0	2	8	23	1	**34**	0	2	2	1	0	**5**	0	**54**
3:45PM	0	0	2	0	**2**	0	14	0	1	0	**15**	0	1	4	33	2	**40**	0	0	3	0	0	**3**	0	**60**
Hourly Total	0	0	5	0	**5**	1	62	0	5	0	**67**	3	7	28	97	8	**140**	0	2	14	1	0	**17**	6	**229**
4:00PM	0	0	1	0	**1**	0	10	0	0	0	**10**	0	0	6	21	1	**28**	1	1	2	0	0	**3**	0	**42**
4:15PM	0	0	1	0	**1**	0	21	0	1	0	**22**	0	0	6	29	0	**35**	0	2	4	0	0	**6**	0	**64**
4:30PM	0	0	0	0	**0**	1	18	0	0	0	**18**	0	0	2	28	1	**31**	0	0	0	0	0	**0**	0	**49**
4:45PM	0	0	1	0	**1**	0	8	0	0	0	**8**	0	1	13	21	2	**37**	0	1	6	0	0	**7**	0	**53**
Hourly Total	0	0	3	0	**3**	1	57	0	1	0	**58**	0	1	27	99	4	**131**	1	4	12	0	0	**16**	0	**208**
5:00PM	0	0	2	0	**2**	1	15	0	0	0	**15**	0	0	5	30	0	**35**	0	0	7	0	0	**7**	1	**59**
5:15PM	0	0	0	0	**0**	0	16	0	0	0	**16**	0	0	5	21	0	**26**	0	0	6	0	0	**6**	0	**48**
5:30PM	0	0	1	0	**1**	1	15	0	0	0	**15**	0	1	11	25	0	**37**	0	1	4	0	0	**5**	0	**58**
5:45PM	0	0	1	0	**1**	0	15	0	1	0	**16**	0	0	7	27	0	**34**	0	0	7	0	0	**7**	0	**58**
Hourly Total	0	0	4	0	**4**	2	61	0	1	0	**62**	0	1	28	103	0	**132**	0	1	24	0	0	**25**	1	**223**
6:00PM	0	0	4	0	**4**	0	16	0	1	0	**17**	0	1	6	21	1	**29**	0	0	3	0	0	**3**	0	**53**
6:15PM	0	0	2	0	**2**	0	18	0	0	0	**18**	0	1	6	31	1	**39**	0	1	2	0	0	**3**	0	**62**
6:30PM	1	0	2	0	**3**	0	18	0	0	0	**18**	0	3	7	30	0	**40**	0	0	3	0	0	**3**	0	**64**
6:45PM	0	0	1	0	**1**	0	16	0	0	0	**16**	0	4	8	25	0	**37**	0	2	5	0	1	**8**	0	**62**
Hourly Total	1	0	9	0	**10**	0	68	0	1	0	**69**	0	9	27	107	2	**145**	0	3	13	0	1	**17**	0	**241**
7:00PM	0	2	20	0	**22**	0	20	0	0	0	**20**	0	0	4	25	0	**29**	0	0	5	0	0	**5**	0	**76**
7:15PM	0	0	3	0	**3**	0	13	0	1	0	**14**	0	2	7	23	1	**33**	0	1	5	0	0	**6**	0	**56**
7:30PM	0	0	3	0	**3**	1	17	0	1	0	**18**	0	0	1	24	0	**25**	0	0	4	0	0	**4**	1	**50**
7:45PM	0	0	1	0	**1**	0	13	0	0	0	**13**	0	0	7	19	0	**26**	0	1	5	0	0	**6**	1	**46**
Hourly Total	0	2	27	0	**29**	1	63	0	2	0	**65**	0	2	19	91	1	**113**	0	2	19	0	0	**21**	2	**228**
8:00PM	0	0	2	0	**2**	0	16	1	1	0	**18**	0	1	6	23	0	**30**	0	1	4	0	0	**5**	0	**55**
8:15PM	0	1	2	0	**3**	0	10	1	0	0	**11**	0	2	14	15	0	**31**	0	2	3	0	0	**5**	0	**50**
8:30PM	0	0	1	0	**1**	0	19	0	1	0	**20**	0	0	3	20	1	**24**	0	1	2	0	0	**3**	0	**48**
8:45PM	0	1	0	0	**1**	0	13	0	1	0	**14**	0	0	3	18	0	**21**	0	0	5	0	0	**5**	0	**41**
Hourly Total	0	2	5	0	**7**	0	58	2	3	0	**63**	0	3	26	76	1	**106**	0	4	14	0	0	**18**	0	**194**
9:00PM	0	0	0	0	**0**	0	7	0	0	0	**7**	0	0	5	13	0	**18**	0	0	0	0	0	**0**	0	**25**
9:15PM	0	0	0	0	**0**	0	13	0	0	0	**13**	0	0	3	12	0	**15**	0	0	3	0	0	**3**	0	**31**
9:30PM	0	0	0	0	**0**	0	10	0	0	0	**10**	0	0	7	14	0	**21**	0	0	0	0	0	**0**	1	**31**
9:45PM	0	0	1	0	**1**	0	9	0	0	0	**9**	0	0	2	10	0	**12**	0	0	2	0	0	**2**	0	**24**
Hourly Total	0	0	1	0	**1**	0	39	0	0	0	**39**	0	0	17	49	0	**66**	0	0	5	0	0	**5**	1	**111**
10:00PM	0	1	0	0	**1**	1	14	0	2	1	**17**	0	0	6	16	0	**22**	0	1	4	0	0	**5**	1	**45**
10:15PM	0	0	0	0	**0**	0	12	0	0	0	**12**	0	0	2	11	0	**13**	0	1	4	0	0	**5**	0	**30**
10:30PM	0	0	1	0	**1**	0	8	0	0	0	**8**	0	1	4	5	0	**10**	0	0	1	1	0	**2**	0	**21**
10:45PM	0	0	0	0	**0**	0	5	0	0	0	**5**	0	0	3	6	0	**9**	0	0	2	0	0	**2**	0	**16**
Hourly Total	0	1	1	0	**2**	1	39	0	2	1	**42**	0	1	15	38	0	**54**	0	2	11	1	0	**14**	1	**112**
11:00PM	0	0	0	0	**0**	0	9	0	1	0	**10**	0	0	3	5	0	**8**	0	0	3	0	0	**3**	0	**21**
11:15PM	0	0	0	0	**0**	0	9	0	0	0	**9**	0	0	0	2	0	**2**	0	0	1	0	0	**1**	0	**12**
11:30PM	0	0	0	0	**0**	0	4	0	0	0	**4**	0	0	4	6	0	**10**	0	0	2	0	0	**2**	0	**16**
11:45PM	0	0	0	0	**0**	0	6	0	0	0	**6**	0	0	0	8	1	**9**	0	0	1	0	0	**1**	0	**16**
Hourly Total	0	0	0	0	**0**	0	28	0	1	0	**29**	0	0	7	21	1	**29**	0	0	7	0	0	**7**	0	**65**
Total	4	7	94	0	**105**	18	1212	6	29	1	**1248**	6	88	319	1172	33	**1612**	1	38	309	8	2	**357**	28	**3322**
% Approach	3.8%	6.7%	89.5%	0%	**-**	-	97.1%	0.5%	2.3%	0.1%	**-**	-	5.5%	19.8%	72.7%	2.0%	**-**	-	10.6%	86.6%	2.2%	0.6%	**-**	-	-
% Total	0.1%	0.2%	2.8%	0%	**3.2%**	-	36.5%	0.2%	0.9%	0%	**37.6%**	-	2.6%	9.6%	35.3%	1.0%	**48.5%**	-	1.1%	9.3%	0.2%	0.1%	**10.7%**	-	-
Lights and Motorcycles	4	7	85	0	**96**	-	1089	6	26	1	**1122**	-	81	306	1078	29	**1494**	-	36	297	6	2	**341**	-	3053
% Lights and Motorcycles	100%	100%	90.4%	0%	**91.4%**	-	89.9%	100%	89.7%	100%	**89.9%**	-	92.0%	95.9%	92.0%	87.9%	**92.7%**	-	94.7%	96.1%	75.0%	100%	**95.5%**	-	91.9%
Heavy	0	0	9	0	**9**	-	123	0	3	0	**126**	-	7	13	94	4	**118**	-	2	12	2	0	**16**	-	269
% Heavy	0%	0%	9.6%	0%	**8.6%**	-	10.1%	0%	10.3%	0%	**10.1%**	-	8.0%	4.1%	8.0%	12.1%	**7.3%**	-	5.3%	3.9%	25.0%	0%	**4.5%**	-	8.1%
Pedestrians	-	-	-	-	-	16	-	-	-	-	-	6	-	-	-	-	-	1	-	-	-	-	-	26	
% Pedestrians	-	-	-	-	-	88.9%	-	-	-	-	-	100%	-	-	-	-	-	100%	-	-	-	-	-	92.9%	-

Leg	Business Driveway						Marina Way						Annapolis Way						Annapolis Way						
Direction	Eastbound						Westbound						Northbound						Southbound						
Time	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	**Int**
Bicycles on Crosswalk	-	-	-	-	-	2	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	2	
% Bicycles on Crosswalk	-	-	-	-	-	11.1%	-	-	-	-	-	0%	-	-	-	-	-	0%	-	-	-	-	-	7.1%	-

*Pedestrians and Bicycles on Crosswalk. L: Left, R: Right, T: Thru, U: U-Turn

1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC
Thu Jun 8, 2023
Full Length (12 AM-12 AM (+1))
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US



1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC

Thu Jun 8, 2023
AM Peak (7:15 AM - 8:15 AM)
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

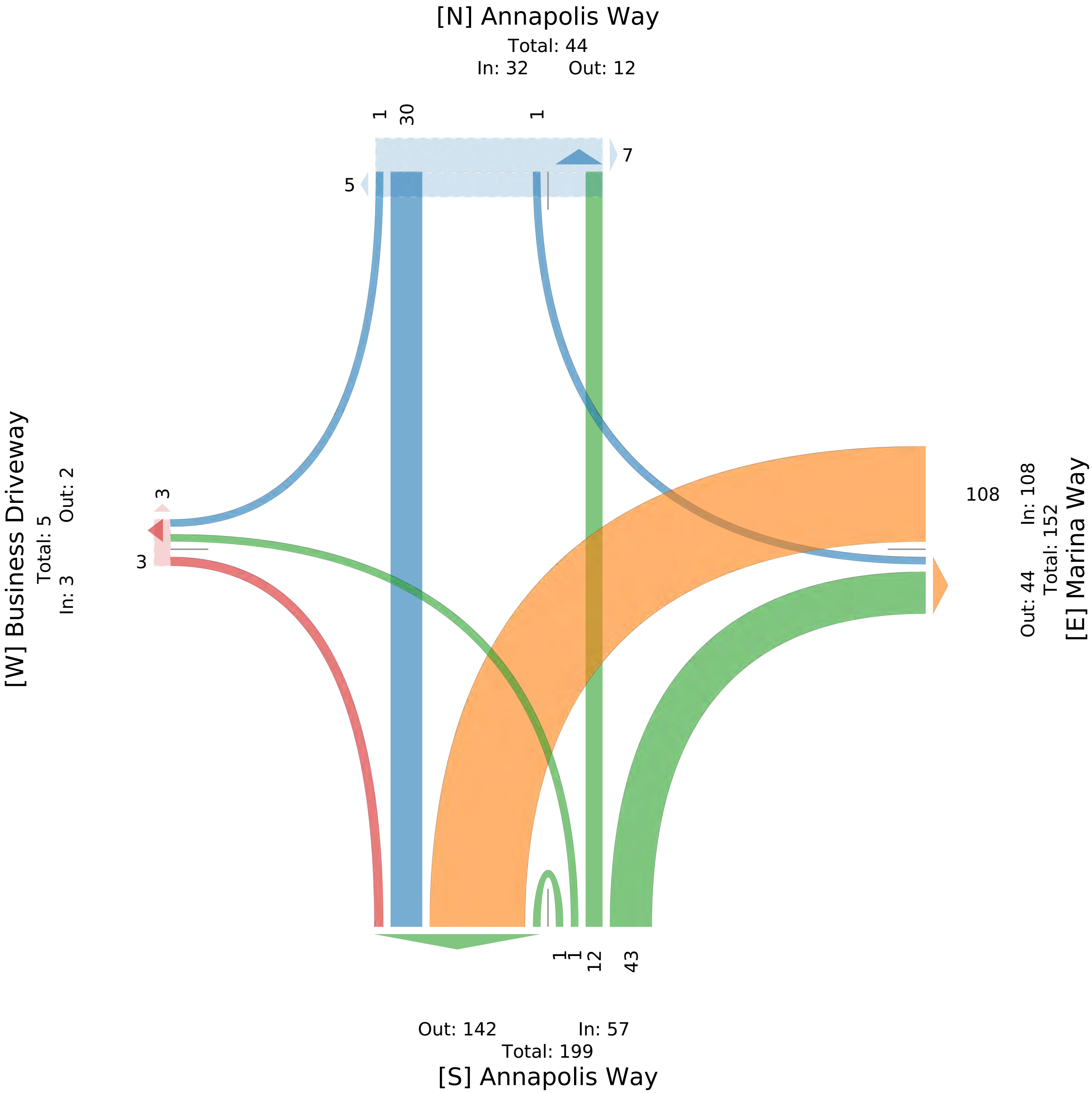
Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US

Leg	Business Driveway						Marina Way						Annapolis Way						Annapolis Way						
Direction	Eastbound						Westbound						Northbound						Southbound						
Time	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	**Int**
2023-06-08 7:15AM	0	0	1	0	**1**	3	22	0	0	0	**22**	0	0	3	8	0	**11**	0	0	9	0	0	**9**	11	**43**
7:30AM	0	0	1	0	**1**	0	29	0	0	0	**29**	0	0	3	9	1	**13**	0	0	7	1	0	**8**	1	**51**
7:45AM	0	0	0	0	**0**	0	30	0	0	0	**30**	0	0	3	9	0	**12**	0	1	6	0	0	**7**	0	**49**
8:00AM	0	0	1	0	**1**	0	27	0	0	0	**27**	0	1	3	17	0	**21**	0	0	8	0	0	**8**	0	**57**
Total	0	0	3	0	**3**	3	108	0	0	0	**108**	0	1	12	43	1	**57**	0	1	30	1	0	**32**	12	**200**
% Approach	0%	0%	100%	0%	-	-	100%	0%	0%	0%	-	-	1.8%	21.1%	75.4%	1.8%	-	-	3.1%	93.8%	3.1%	0%	-	-	-
% Total	0%	0%	1.5%	0%	**1.5%**	-	54.0%	0%	0%	0%	**54.0%**	-	0.5%	6.0%	21.5%	0.5%	**28.5%**	-	0.5%	15.0%	0.5%	0%	**16.0%**	-	-
PHF	-	-	0.750	-	**0.750**	-	0.900	-	-	-	**0.900**	-	0.250	1.000	0.632	0.250	**0.679**	-	0.250	0.833	0.250	-	**0.889**	-	0.877
Lights and Motorcycles	0	0	1	0	**1**	-	92	0	0	0	**92**	-	0	9	31	0	**40**	-	1	28	0	0	**29**	-	162
% Lights and Motorcycles	0%	0%	33.3%	0%	**33.3%**	-	85.2%	0%	0%	0%	**85.2%**	-	0%	75.0%	72.1%	0%	**70.2%**	-	100%	93.3%	0%	0%	**90.6%**	-	81.0%
Heavy	0	0	2	0	**2**	-	16	0	0	0	**16**	-	1	3	12	1	**17**	-	0	2	1	0	**3**	-	38
% Heavy	0%	0%	66.7%	0%	**66.7%**	-	14.8%	0%	0%	0%	**14.8%**	-	100%	25.0%	27.9%	100%	**29.8%**	-	0%	6.7%	100%	0%	**9.4%**	-	19.0%
Pedestrians	-	-	-	-	-	3	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	12	
% Pedestrians	-	-	-	-	-	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100%	-
Bicycles on Crosswalk	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	
% Bicycles on Crosswalk	-	-	-	-	-	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	-

*Pedestrians and Bicycles on Crosswalk. L: Left, R: Right, T: Thru, U: U-Turn

1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC
Thu Jun 8, 2023
AM Peak (7:15 AM - 8:15 AM)
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US



1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC

Thu Jun 8, 2023
Midday Peak (11:30 AM - 12:30 PM)
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

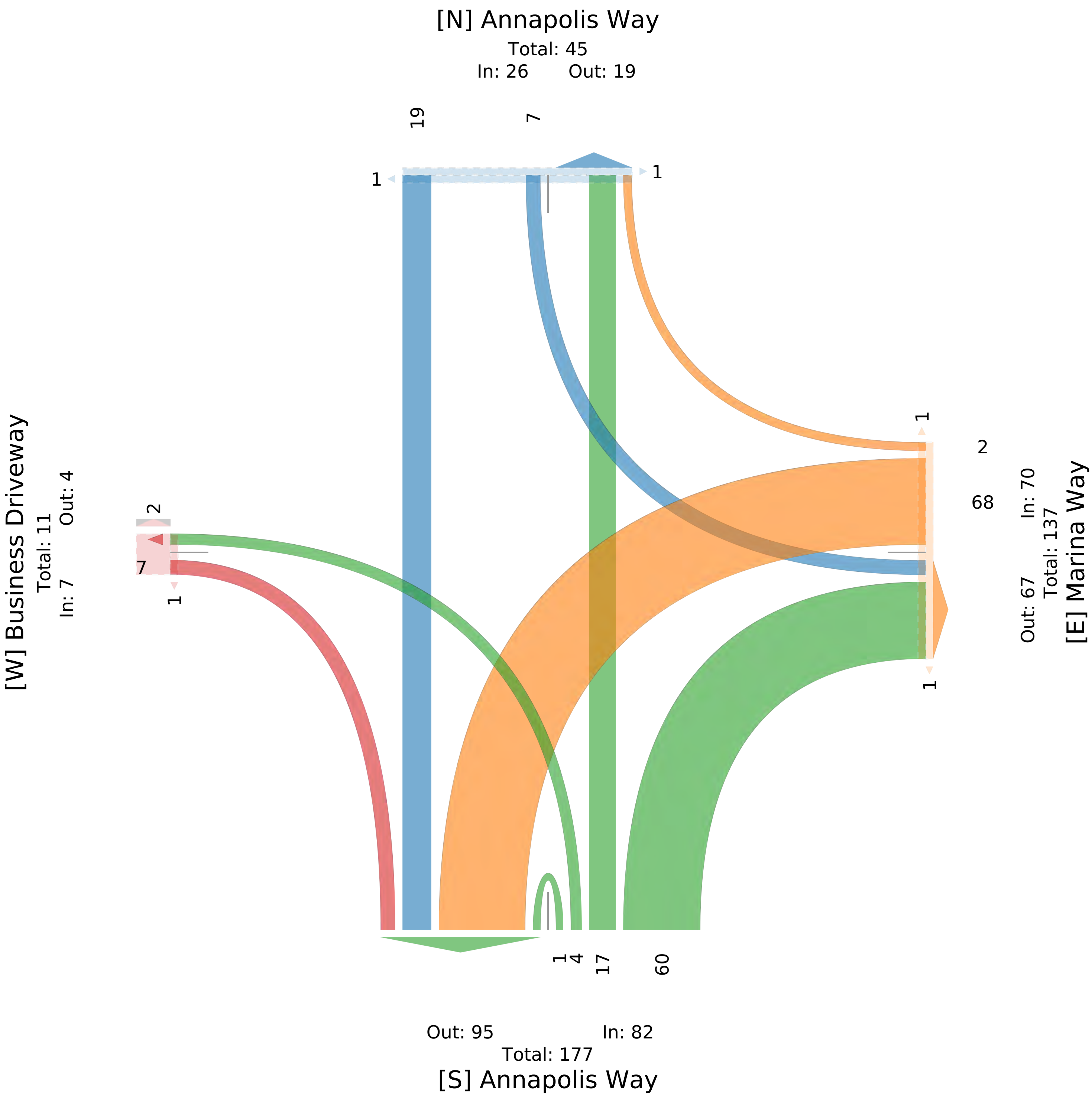
Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US

Leg	Business Driveway						Marina Way						Annapolis Way						Annapolis Way						
Direction	Eastbound						Westbound						Northbound						Southbound						
Time	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	**Int**
2023-06-08 11:30AM	0	0	1	0	**1**	0	23	0	0	0	**23**	0	0	6	19	0	**25**	0	3	5	0	0	**8**	0	**57**
11:45AM	0	0	2	0	**2**	0	14	0	0	0	**14**	2	1	4	20	0	**25**	0	3	3	0	0	**6**	0	**47**
12:00PM	0	0	2	0	**2**	1	13	0	2	0	**15**	0	3	4	14	0	**21**	0	0	8	0	0	**8**	1	**46**
12:15PM	0	0	2	0	**2**	2	18	0	0	0	**18**	0	0	3	7	1	**11**	0	1	3	0	0	**4**	1	**35**
Total	0	0	7	0	**7**	3	68	0	2	0	**70**	2	4	17	60	1	**82**	0	7	19	0	0	**26**	2	**185**
% Approach	0%	0%	100%	0%	-	-	97.1%	0%	2.9%	0%	-	-	4.9%	20.7%	73.2%	1.2%	-	-	26.9%	73.1%	0%	0%	-	-	-
% Total	0%	0%	3.8%	0%	**3.8%**	-	36.8%	0%	1.1%	0%	**37.8%**	-	2.2%	9.2%	32.4%	0.5%	**44.3%**	-	3.8%	10.3%	0%	0%	**14.1%**	-	-
PHF	-	-	0.875	-	**0.875**	-	0.739	-	0.250	-	**0.761**	-	0.333	0.708	0.750	0.250	**0.820**	-	0.583	0.594	-	-	**0.813**	-	0.811
Lights and Motorcycles	0	0	6	0	**6**	-	56	0	2	0	**58**	-	3	16	50	1	**70**	-	7	18	0	0	**25**	-	159
% Lights and Motorcycles	0%	0%	85.7%	0%	**85.7%**	-	82.4%	0%	100%	0%	**82.9%**	-	75.0%	94.1%	83.3%	100%	**85.4%**	-	100%	94.7%	0%	0%	**96.2%**	-	85.9%
Heavy	0	0	1	0	**1**	-	12	0	0	0	**12**	-	1	1	10	0	**12**	-	0	1	0	0	**1**	-	26
% Heavy	0%	0%	14.3%	0%	**14.3%**	-	17.6%	0%	0%	0%	**17.1%**	-	25.0%	5.9%	16.7%	0%	**14.6%**	-	0%	5.3%	0%	0%	**3.8%**	-	14.1%
Pedestrians	-	-	-	-	-	3	-	-	-	-	-	2	-	-	-	-	-	0	-	-	-	-	-	2	
% Pedestrians	-	-	-	-	-	100%	-	-	-	-	-	100%	-	-	-	-	-	-	-	-	-	-	-	100%	-
Bicycles on Crosswalk	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	
% Bicycles on Crosswalk	-	-	-	-	-	0%	-	-	-	-	-	0%	-	-	-	-	-	-	-	-	-	-	-	0%	-

*Pedestrians and Bicycles on Crosswalk. L: Left, R: Right, T: Thru, U: U-Turn

1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC
Thu Jun 8, 2023
Midday Peak (11:30 AM - 12:30 PM)
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US



1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC

Thu Jun 8, 2023
PM Peak (6:15 PM - 7:15 PM) - Overall Peak Hour
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

PEGGY MALONE & ASSOCIATES TRAFFIC DATA COLLECTION
Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US

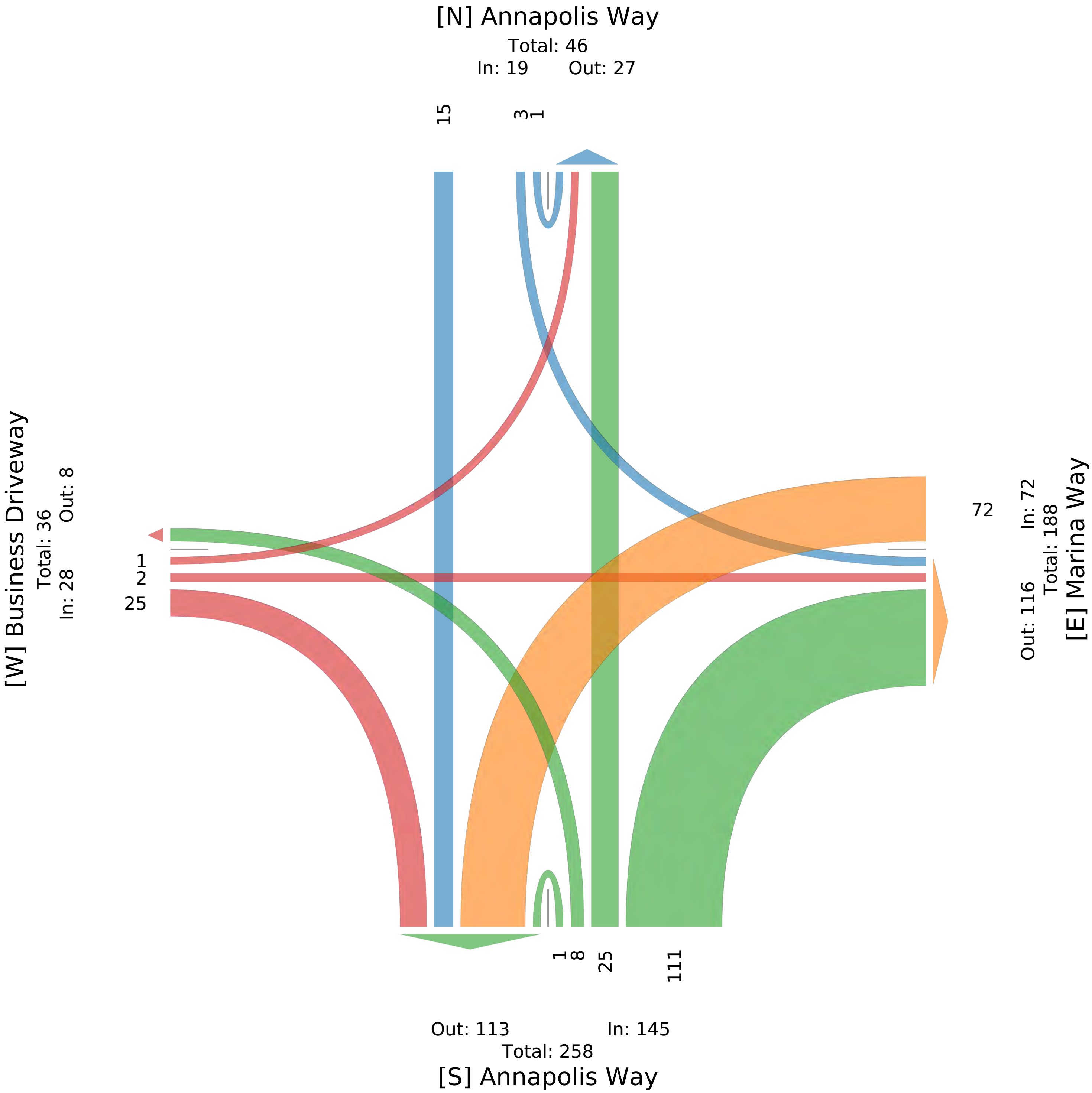
Leg	Business Driveway						Marina Way						Annapolis Way						Annapolis Way						
Direction	Eastbound						Westbound						Northbound						Southbound						
Time	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	L	T	R	U	**App**	Ped*	**Int**
2023-06-08 6:15PM	0	0	2	0	**2**	0	18	0	0	0	**18**	0	1	6	31	1	**39**	0	1	2	0	0	**3**	0	**62**
6:30PM	1	0	2	0	**3**	0	18	0	0	0	**18**	0	3	7	30	0	**40**	0	0	3	0	0	**3**	0	**64**
6:45PM	0	0	1	0	**1**	0	16	0	0	0	**16**	0	4	8	25	0	**37**	0	2	5	0	1	**8**	0	**62**
7:00PM	0	2	20	0	**22**	0	20	0	0	0	**20**	0	0	4	25	0	**29**	0	0	5	0	0	**5**	0	**76**
Total	1	2	25	0	**28**	0	72	0	0	0	**72**	0	8	25	111	1	**145**	0	3	15	0	1	**19**	0	**264**
% Approach	3.6%	7.1%	89.3%	0%	-	-	100%	0%	0%	0%	-	-	5.5%	17.2%	76.6%	0.7%	-	-	15.8%	78.9%	0%	5.3%	-	-	-
% Total	0.4%	0.8%	9.5%	0%	**10.6%**	-	27.3%	0%	0%	0%	**27.3%**	-	3.0%	9.5%	42.0%	0.4%	**54.9%**	-	1.1%	5.7%	0%	0.4%	**7.2%**	-	-
PHF	0.250	0.250	0.313	-	**0.318**	-	0.900	-	-	-	**0.900**	-	0.500	0.781	0.895	0.250	**0.906**	-	0.375	0.750	-	0.250	**0.594**	-	0.868
Lights and Motorcycles	1	2	24	0	**27**	-	69	0	0	0	**69**	-	7	24	107	1	**139**	-	3	15	0	1	**19**	-	254
% Lights and Motorcycles	100%	100%	96.0%	0%	**96.4%**	-	95.8%	0%	0%	0%	**95.8%**	-	87.5%	96.0%	96.4%	100%	**95.9%**	-	100%	100%	0%	100%	**100%**	-	96.2%
Heavy	0	0	1	0	**1**	-	3	0	0	0	**3**	-	1	1	4	0	**6**	-	0	0	0	0	**0**	-	10
% Heavy	0%	0%	4.0%	0%	**3.6%**	-	4.2%	0%	0%	0%	**4.2%**	-	12.5%	4.0%	3.6%	0%	**4.1%**	-	0%	0%	0%	0%	**0%**	-	3.8%
Pedestrians	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	
% Pedestrians	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bicycles on Crosswalk	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	
% Bicycles on Crosswalk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Pedestrians and Bicycles on Crosswalk. L: Left, R: Right, T: Thru, U: U-Turn

1-Annapolis Way & Mariana Way - Weekday (VA2... - TMC

Thu Jun 8, 2023
PM Peak (6:15 PM - 7:15 PM) - Overall Peak Hour
All Classes (Lights and Motorcycles, Heavy, Pedestrians, Bicycles on Crosswalk)
All Movements
ID: 1072154, Location: 38.666122, -77.24545

Provided by: Peggy Malone & Associates
14286 Beach Blvd, 19-345,
Jacksonville Beach, FL, 32250, US



Appendix B

VDOT Approved Travel Forecast Memorandum

MEMORANDUM

TO: Jeffrey Daily, P.E
DATE: 10/27/2023
FROM: Olaoluwa Dairo, PE, PTOE, JMT
PROJECT NAME: Marina Way Extension (UPC 120778)
JMT PROJECT NO.: 19-01549-019
CONTRACT NO.: 5053661
RE: Traffic Forecast

JMT was contracted by the Prince William County Department of Transportation (PWCDOT) to design the extension of Marina Way to connect the existing Marina Way to Horner Road, passing through Annapolis Way, and Gordon Boulevard (Route 123). The Marina Way extension will be a four-lane divided roadway. The project is near the I-95 at the Route 123 interchange. The opening year for the project is 2028, and the design year is 2050. The project location is presented in **Figure 1**.

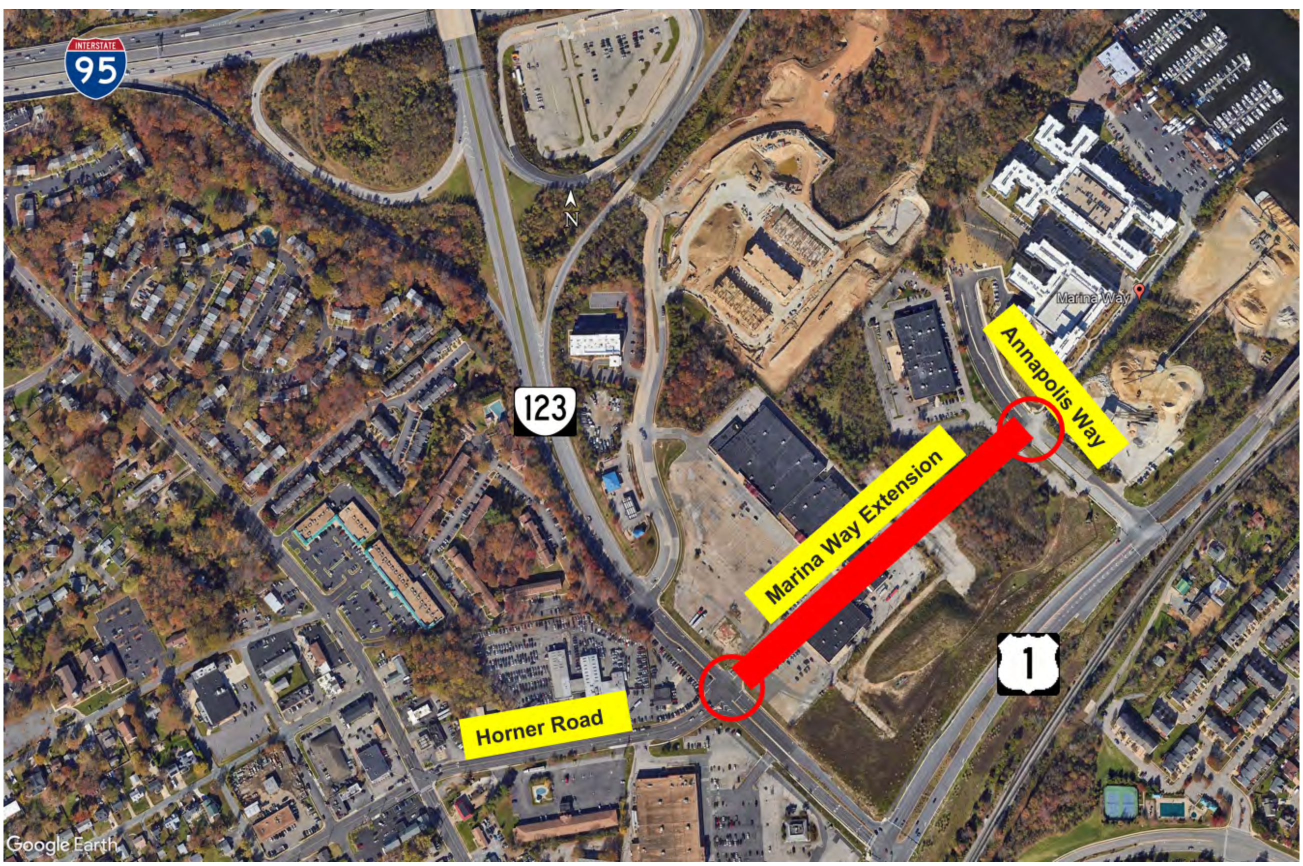


Figure 1: Marina Way Extension Project Location

For this project, two intersections will be analyzed. The intersections are located at both ends of the extension, circled in **Figure 1**. The intersections are Route 123 at Horner Road (the west terminus) and Annapolis Way at Marina Way (the east terminus). The eastern leg of Route 123 at Horner Road intersection currently leads to the Gordon Plaza Shopping Mall. The eastern leg marks the western terminus of the project limits. The western leg of the Annapolis Way at Marina Way intersection is an access to the Royalhouse Chapel International, Breakthrough Center. The western leg marks the eastern terminus of the extension. A 24-hour turning movement count was conducted at the intersection of Route 123 and Horner Road on Thursday, June 8, 2023. This memorandum describes the approach JMT used to develop the AM and PM peak hour volumes at the two study intersections.

During the scope development of this project, PWCDOT indicated a VDOT STARS study was conducted for the I-95 at Route 123 interchange. The study used the Prince William County Travel Demand Model (PWCTDM) to develop the traffic forecast for the project. The calibrated STARS study PWCTDM was provided to JMT by PWCDOT, which was used to develop the traffic forecast for this study. In addition to this, the approved land use data for PWC from the Metropolitan Washington Council of Governments (MWCOG) Round 10 cooperative land use forecast was provided by the County to be used for the model runs. The Round 10 land use data includes socio-economic/land use inputs for year 2050. In coordination with PWCDOT planning and programming division, it is assumed the PWC Round 10 cooperative land use forecasts include all the population and employment land use assumed in the North Woodbridge Small Area Plan that was approved in 2019. This includes the new developments coming into the North Woodbridge Area.

The PWCTDM included a roadway network with a base year of 2015 and future year of 2045. The base year 2015 roadway network was updated to reflect the existing 2023 roadway. The VDOT Travel Demand Modeling Policies and Procedures document was referenced to define the acceptable levels of deviation from ADTs. The Percent Root Mean Square Error (%RMSE), *Table 10.5 of the travel demand modeling policies and procedures document*, was used to compare major links surrounding the study area. The model was run and validated using existing volume data. **Table 1** presents the model validation results for the major roadways surrounding the study area. The result shows the model meets the validation criteria.

Table 1: Model Validation Check

Location	Exiting Data (VPD)	Model Output (VPD)	%RMSE Guideline	%RMSE
US 1 over Occoquan River[1]	39,000	35,988	25	7.72
Horner Road South of VA 123[2]	11,115	11,722	35	5.46
Occoquan Road[1]	13,000	11,947	35	8.10
VA 123 (Gordon Boulevard) Between US 1 and Horner[1]	19,000	18,657	30	1.81
VA 294 Between I-95 and US 1[1]	29,333	23,469	27	19.99
I-95 at Between VA 294 and Fairfax County Line[1]	230,000	209,500	19	8.91

1-ADT from VDOT 2019 Database
2-Existing 2023 turning movement count (24 hours)

As seen in **Table 1**, the numbers highlighted in green show that the daily volumes produced by the model are within the acceptable thresholds set in the VDOT Travel Demand Modeling Policies and Procedures document, when compared to the existing ADTs.

It is assumed the 2045 model encompasses the PWC transportation plan. Additional verification was done to confirm if the potential roadway projects are included in the model, such as the widening of Route 123 to six lanes from US 1 to Annapolis Way. JMT included the Annapolis Way connector which will connect Annapolis Way from US 1 to Route 123. In coordination with the County, no additional roadway or transit projects have been approved for 2050. Therefore, the model was not updated from 2045 to 2050 with any roadway or transit projects except for the Annapolis Way connector. JMT ran two future models; the no-build and build model for the design year 2050. In the no-build model, the Marina Way extension was not coded in the model. For the build model, the Marina Way extension was coded in the model. Both networks can be seen in **Figure 2**.

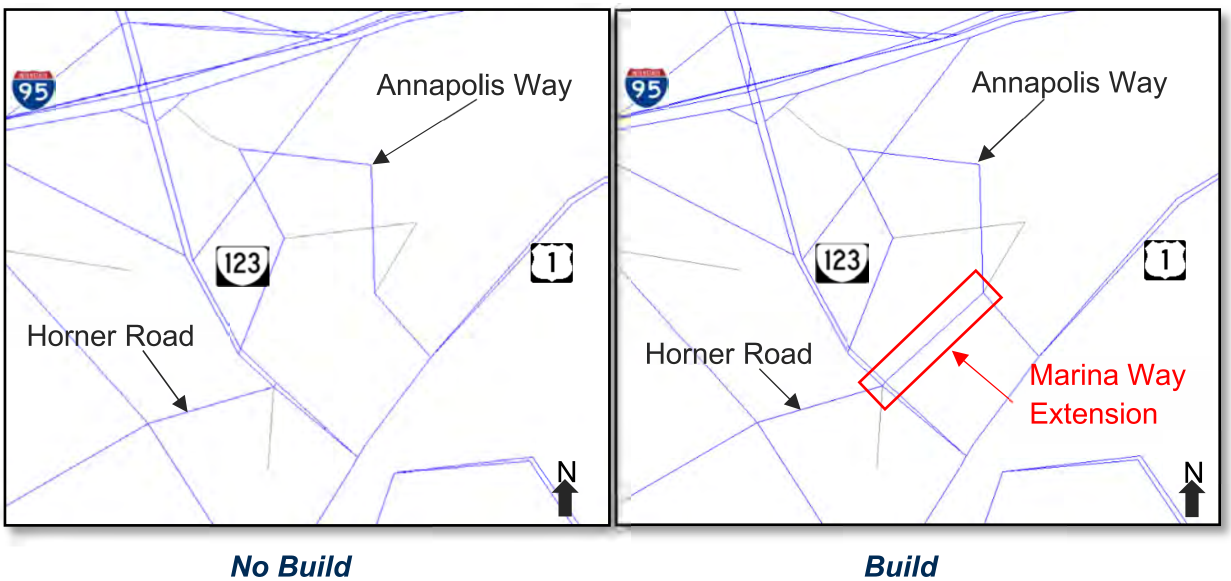


Figure 2: Marina Way Extension 2050 Networks

The two future models were then compared to determine the traffic volume that will divert from surrounding roadways such as US 1, and Route 123 onto Marina Way.

JMT also conducted a select link analysis along the centroid connector to the TAZ encompassing the North Woodbridge Area where the Marina Way extension is proposed. The select link was performed on the no-build condition to determine the distribution into and out of the centroid. The number of trips distributed was determined by performing the NCHRP Difference Method along the centroid. The calculation can be found in **Table 2**.

Table 2: North Woodbridge Area Centroid Growth

	Trips In	Trips Out	Total
Existing (Count)	3,613	3,777	7,390
Base Year Model	665	643	1,308
2028 Build	2,453	2,416	4,869
2050 Build	4,390	4,337	8,727
2050 Difference Method ADT (Rounded)	**7,400**	**7,500**	**14,900**
2028 Difference Method ADT	**5,400**	**5,600**	**11,000**

The AM and PM peak hour trips were then determined using the existing peak hour as a percentage of the existing daily volume. The AM and PM peak hour trips were then distributed through the network using the results of the select link analysis. To develop the forecasts for the movements that are not destined to or originating from the centroid, such as the through movements along Route 123, the growth from the base year model to the future year model was applied. The turning movement distribution from the existing condition was applied to the future condition for the movements not originating or destined to the select link centroid. JMT also compared the No Build and Build conditions to divert traffic to Marina Way. The spreadsheet used to determine the 2050 turning movements is attached to this memorandum.

To develop the 2028 opening year volumes, JMT linearly interpolated between the 2025 land use and the 2030 land use provided by the County, to determine the 2028 land use. The 2028 model network was updated to reflect the conditions expected during the opening year and was sourced from the VDOT STARS study 2030 model. The updated 2028 build model was run using the interpolated 2028 land use. The 2028 build model output was compared to the 2050 build model output. The result shows that there was a 30% reduction in trips in the centroid representing the North Woodbridge area. The reduction can be found in **Table 2**. This reduction was then applied to the developed 2050 peak hour volumes to arrive at the 2028 volumes. The resulting 2028 AM and PM peak hour volumes are displayed in **Figure 3**, and the 2050 volumes are displayed in **Figure 4**.

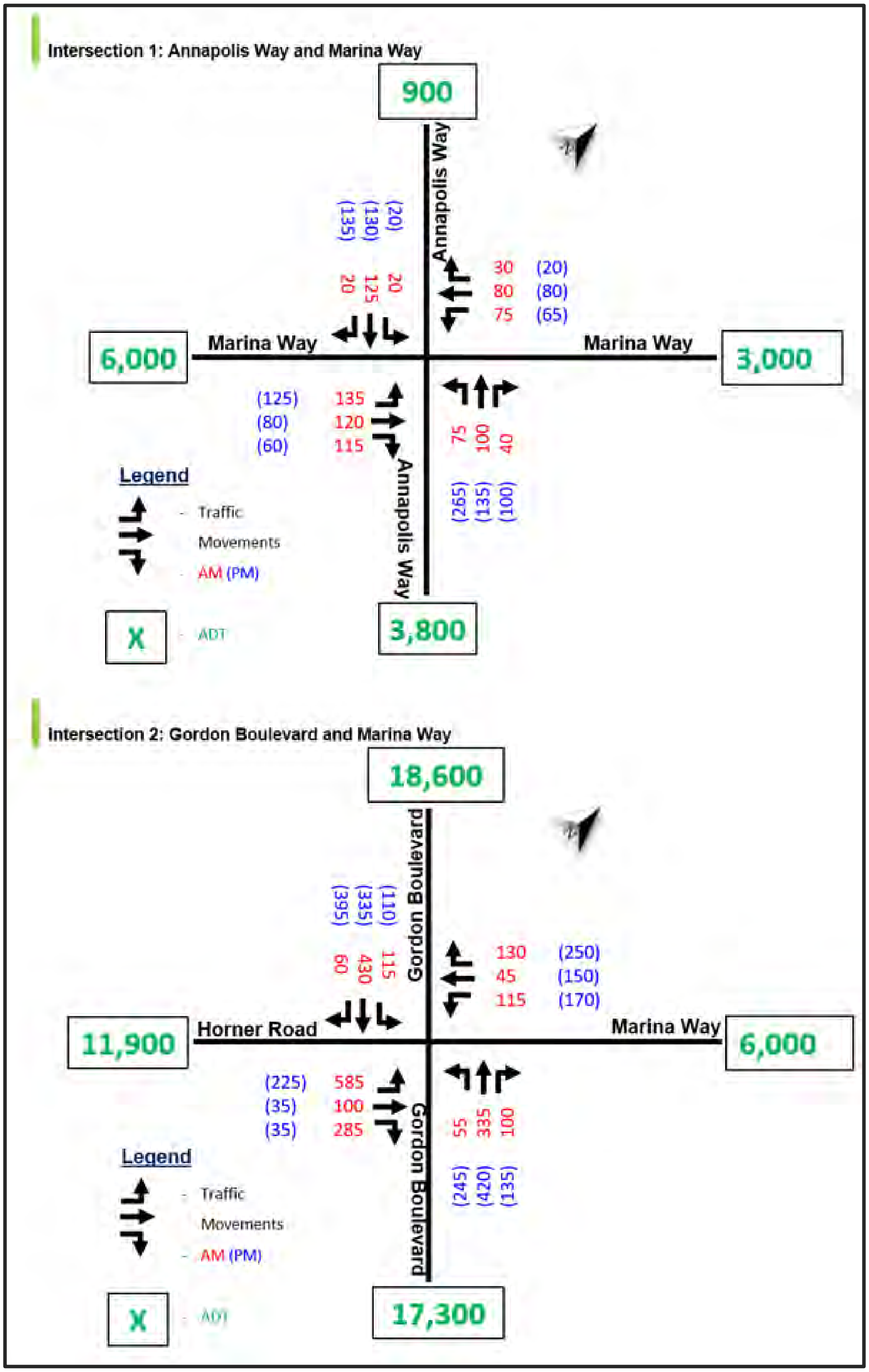


Figure 3: 2028 AM and PM Peak Hour Volumes

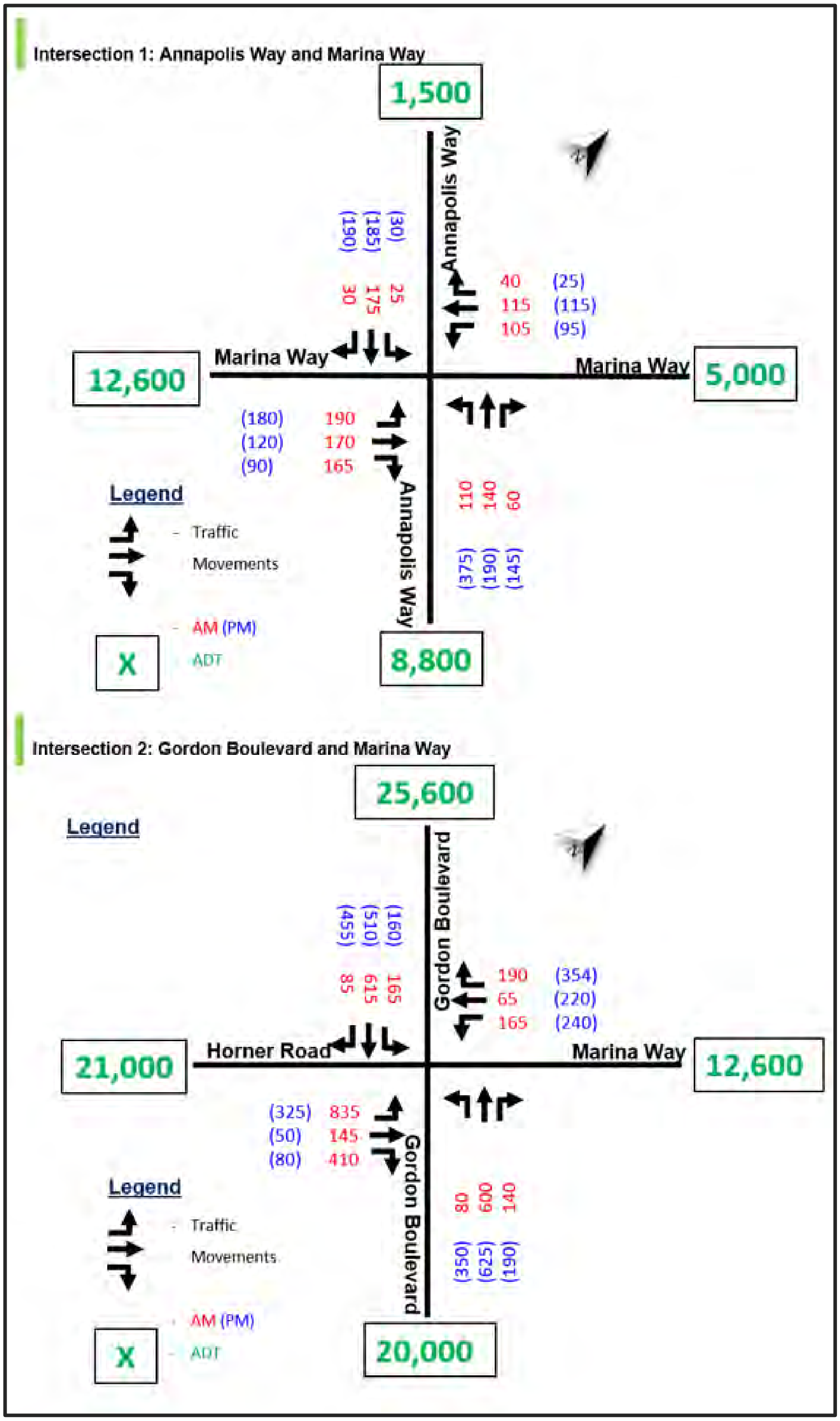
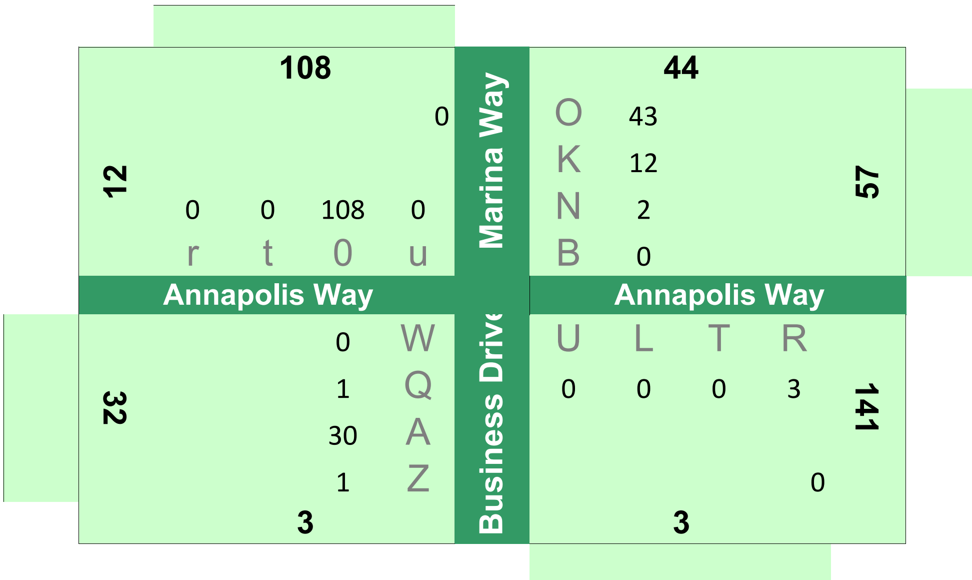
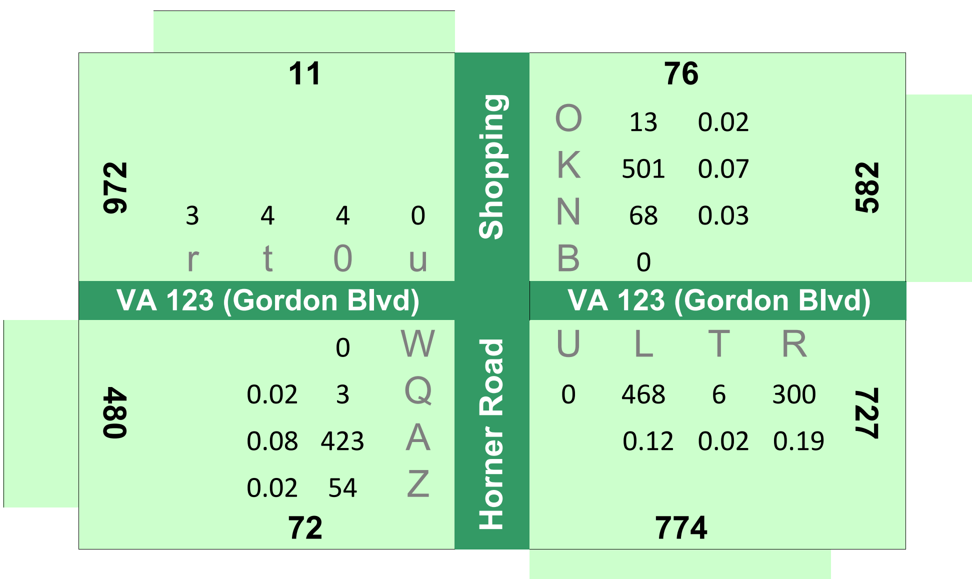


Figure 4: 2050 AM and PM Peak Hour Volumes

ATTACHMENT
Excerpt from Computation Spreadsheet

Existing Volume AM





2050 No-Build AM IN

7400 in
AM Pk Hour =7.5% of ADT
555 trips in

0 | **Marina Way** | **138**

O 52
K 126
N 32
B 0

277 0 0 0 0 **210**
r t 0 u

Annapolis Way | **Annapolis Way**

0 W | U L T R
23 Q | 0 151 63 0
0 A
13 Z

36 | **Business Driv** | **0**

45 | **214**

Origin	Select Link Percentage
US 1 SB	15%
US 1 NB	45%
VA 123 EB	33%
Horner NB	7%

Destination*	Percentage
Annapolis Way WB	60%
Existing Marina Way	25%
Marina Way	15%

*Based on North Woodbridge Plan

0 | **Shopping** | **252**

O 125
K 0
N 0
B 0

0 0 0 0 0 **125**
r t 0 u

VA 123 (Gordon Blvd) | **VA 123 (Gordon Blvd)**

0 W | U L T R
92 Q | 0 0 35 0
0 A
0 Z

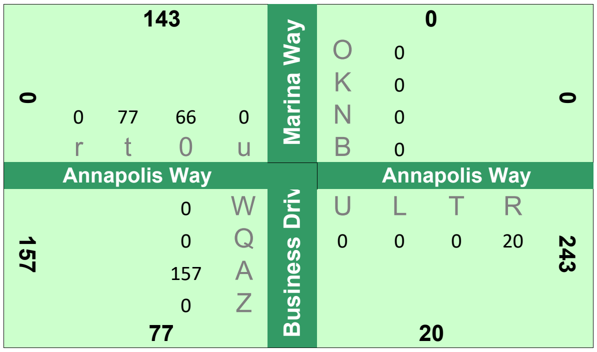
92 | **Horner Road** | **0**

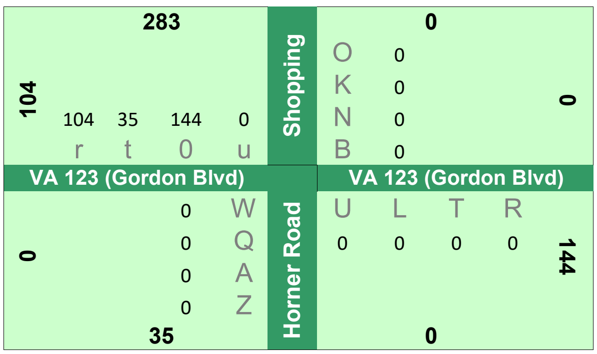
0 | **35**

Some
trips (93)
use
Annapolis

2050 No-Build AM OUT

7500 out
AM Pk Hour =7.5% of ADT
570 trips out



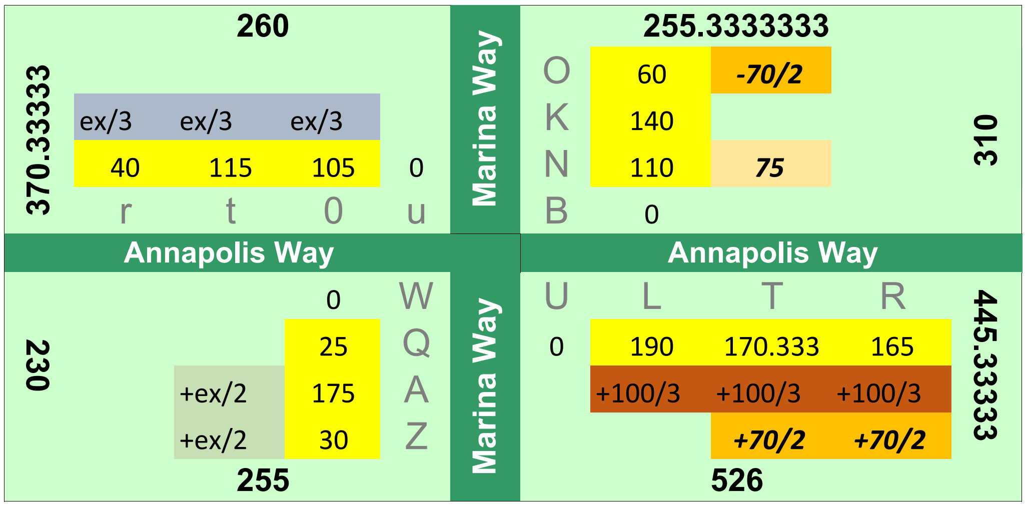


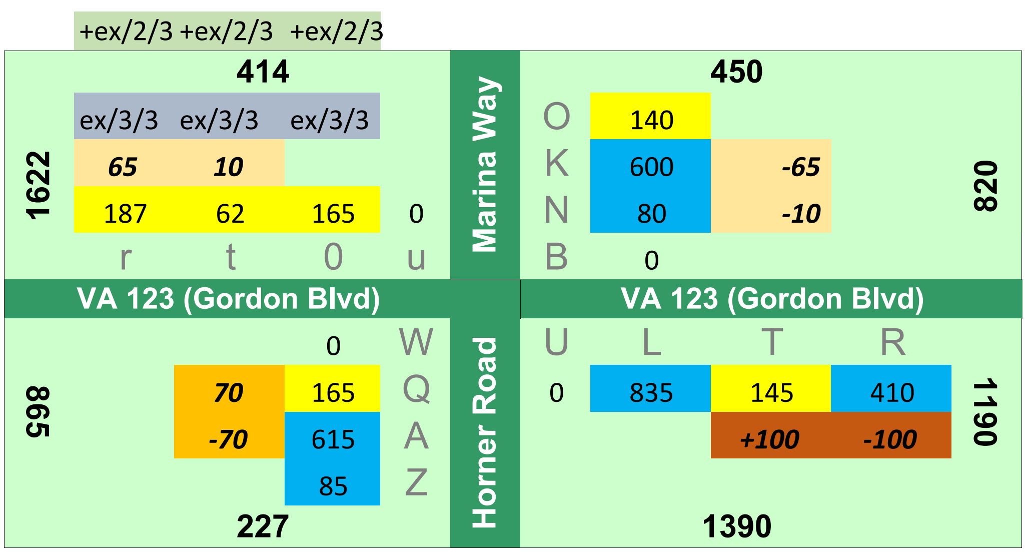
Destination	Select Link Percentage
US 1 SB	44%
US 1 NB	24%
VA 123 WB	26%
Horner SB	6%

Origin*	Percentage
Annapolis Way WB	60%
Existing Marina Way	25%
Marina Way	15%

*Based on North Woodbridge Plan

2050 Build AM

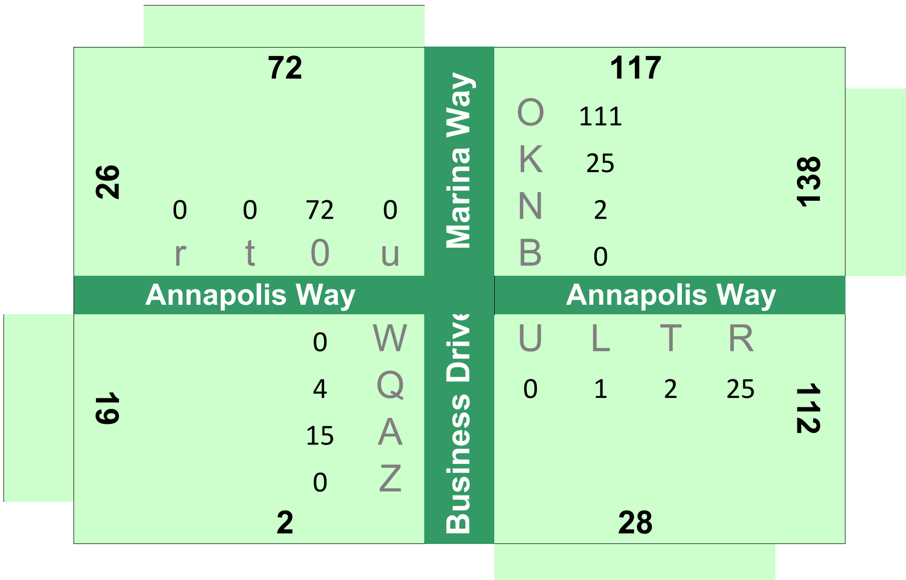


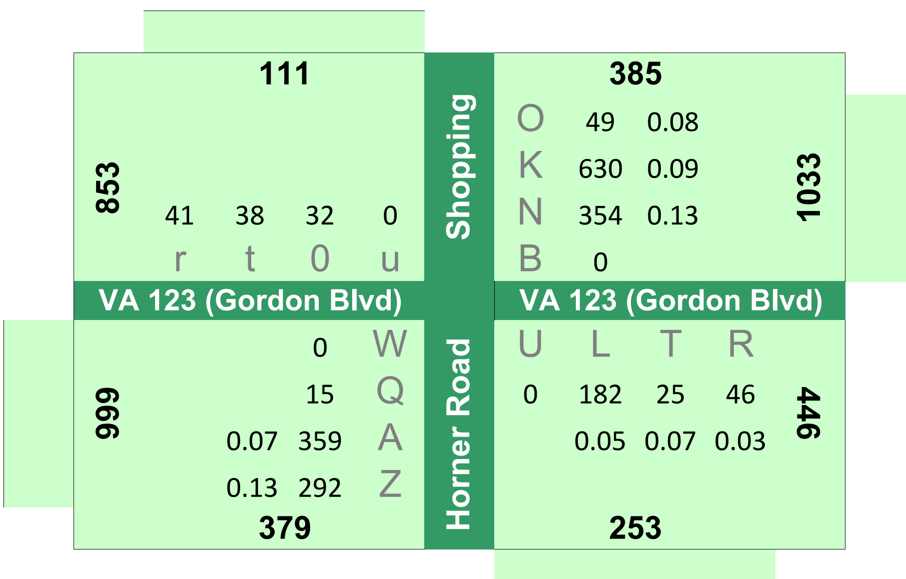


KEY

Colour	Meaning
Yellow	SLA in + SLA out + Existing
Blue	2050 build/NoBuild x existing turning distribtion

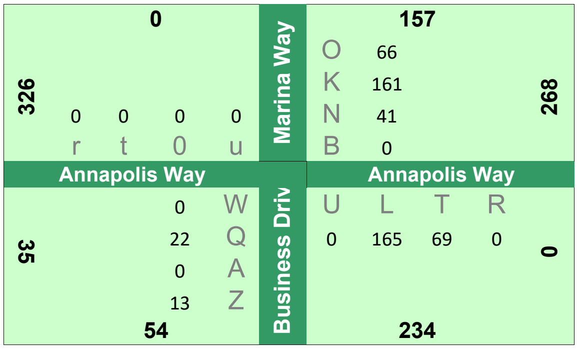
Existing Volume PM





2050 No Build PM IN

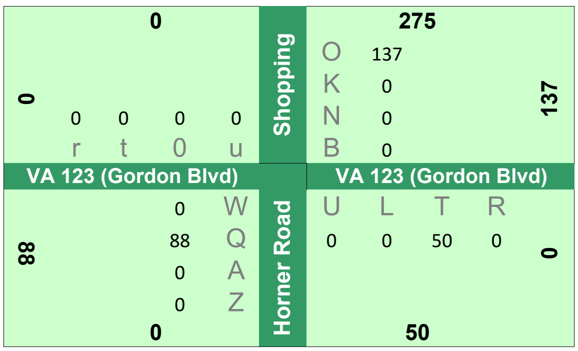
7400 in
PM Pk Hour =8.5% of ADT
630 trips in



Origin	Select Link Percentage
US 1 SB	21%
US 1 NB	44%
VA 123 EB	28%
Horner NB	7%

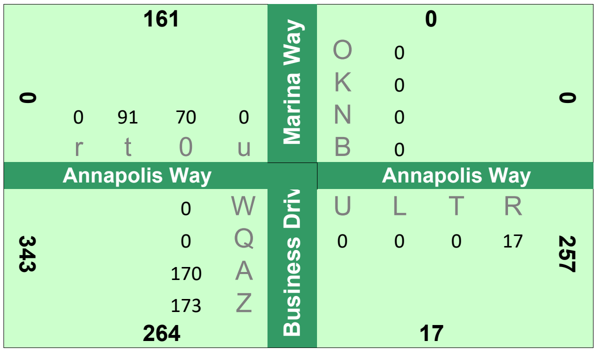
Destination*	Percentage
Annapolis Way WB	60%
Existing Marina Way	25%
Marina Way	15%

*Based on North Woodbridge Plan



2050 No Build PM OUT

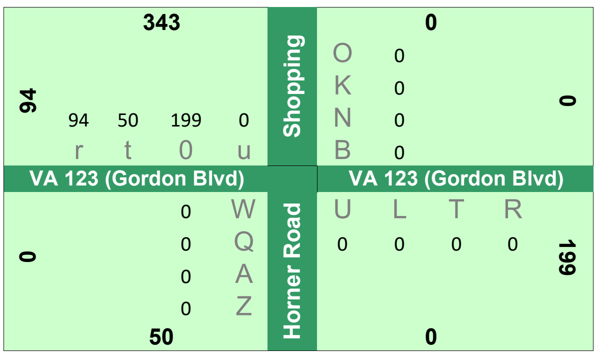
7500 out
PM Pk Hour =8.5% of ADT
640 trips out



Destination	Select Link Percentage
US 1 SB	54%
US 1 NB	17%
VA 123 WB	21%
Horner SB	8%

Origin*	Percentage
Annapolis Way WB	60%
Existing Marina Way	25%
Marina Way	15%

*Based on North Woodbridge Plan



2050 Build PM

Marina Way / Annapolis Way

					Marina Way					
		235					291.6666667			
391.66667						O	145	-70/2		710
	+ex/3	+ex/3	+ex/3			K	190			
	25	115	95	0		N	375	+330		
	r	t	0	u		B	0			
	Annapolis Way						Annapolis Way			
			0	W		U	L	T	R	
405			30	Q		0	176.7	116.667	86.6667	366.66667
			185	A				+70/2	+70/2	
			190	Z			+20/3	+20/3	+20/3	
		680			Marina Way			380		

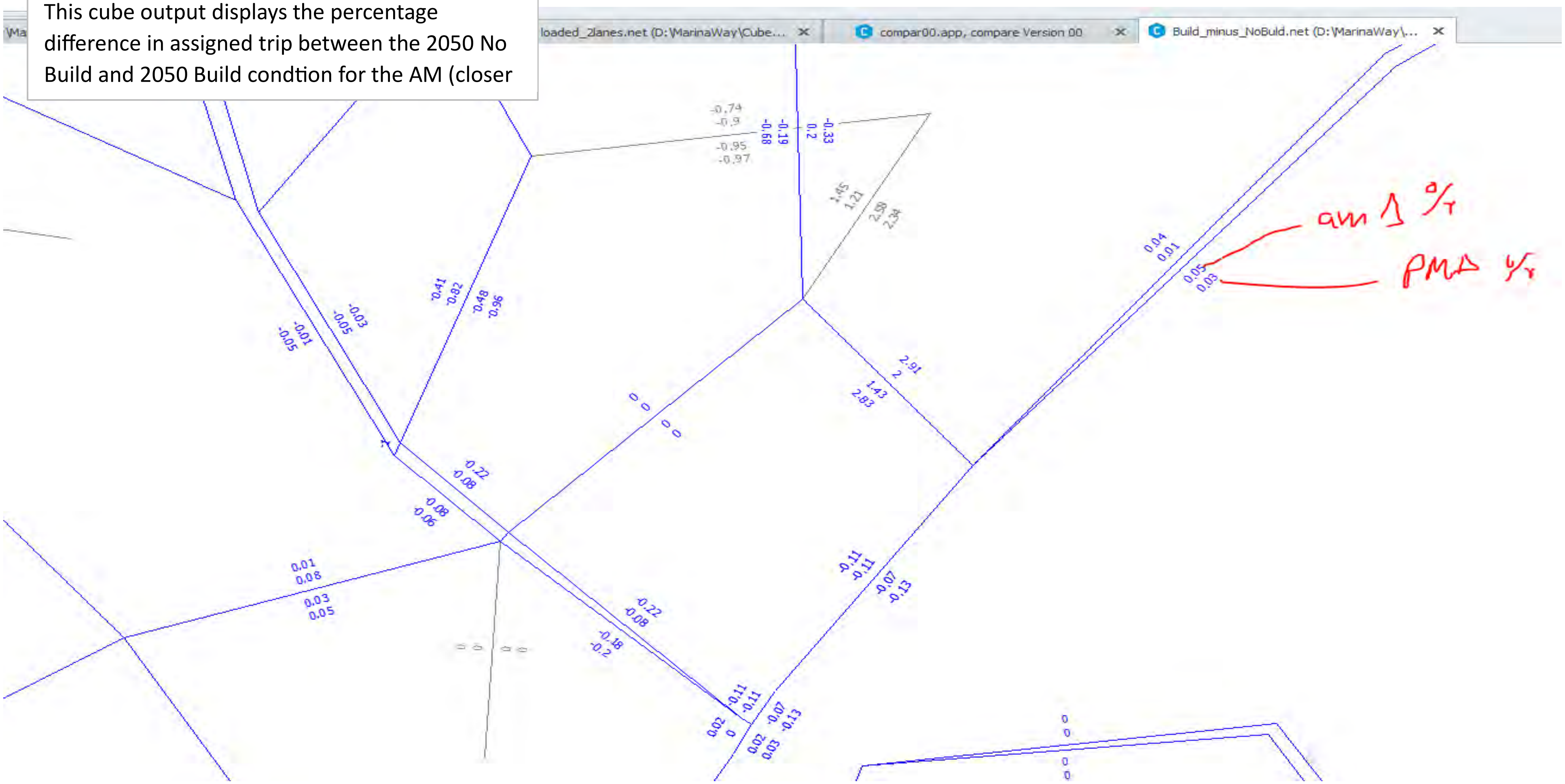
Marina Way / Horner Road / VA 123 (Gordon Blvd)

					Marina Way					
		810					400			
1304	+ex/3/3	+ex/3/3	+ex/3/3			O	190			1165
	210	120				K	625	-210		
	354	216	240	0		N	350	-120		
	r	t	0	u		B	0			
	VA 123 (Gordon Blvd)						VA 123 (Gordon Blvd)			
			0	W		U	L	T	R	
1125		70	160	Q		0	325	50	80	830
		-70	510	A				+20	-20	
			455	Z						
		1021			Horner Road			455		

KEY

- SLA in + SLA out + Existing
- 2050 build x existing turning distribtion

This cube output displays the percentage difference in assigned trip between the 2050 No Build and 2050 Build condtion for the AM (closer



Appendix C

AM VJuST Worksheets

VDOT Junction Screening Tool

Input Worksheet

Project Title:	*Marina Way Extension*
E-W Facility:	*Marina Way*
N-S Facility:	*Annapolis Way*
Date:	*November 4, 2023*

Traffic Volume Demand

Direction	Volume (veh/hr)				Truck Percent (%)
	U-Turn / Left		Through	Right	
Eastbound	190		170	165	2.00%
Westbound	105		115	40	2.00%
Northbound	110		140	60	2.00%
Southbound	25		175	30	2.00%
Adjustment Factor	0.80	0.95		0.85	
Suggested	**U - 0.8**	**L - 0.95**		**0.85**	
Truck to PCE Factor			**Suggested = 2.00**		2.00
Critical Lane Volume			1600		

Equivalent Passenger Car Volume

	Volume (pc/hr)			
	U-Turn / Left	Through	Right	Approach
Eastbound	194	173	168	535
Westbound	107	117	41	265
Northbound	112	143	61	316
Southbound	26	179	31	236

Notes:

Left-turn Adjustment Factor	*Conversion of left-turning vehicles to equivalent through vehicles*
Right-turn Adjustment Factor	*Conversion of right-turning vehicles to equivalent through vehicles*
U-turn Adjustment Factor	*Conversion of U-turning vehicles to equivalent through vehicles*
Truck to PCE Factor	*1 truck = X Passenger Car Equivalents*
Critical Lane Volume Sum Limit	*Saturation value for critical lane volume sum at an intersection*

VDOT Junction Screening Tool

Possible Configurations

Indicate with a "Y" or "N" if each intersection or interchange configuration should or should not be considered. Use the information links for guidance. Then, click the "Show/Hide Configurations button" to hide the worksheets for the configurations that will not be considered.

#	Intersections	Information	Consider?	Justification
	Signalized Intersections			
1	Conventional	-	Y	
2	Bowtie	Link	N	Insufficient intersection spacing
3	Center Turn Overpass	Link	N	Not feasible for roadway facility type
4	Continuous Green-T	Link	N	Not feasible for roadway facility type
5	Echelon	Link	N	Not feasible for roadway facility type
6	Full Displaced Left Turn	Link	N	Not feasible for roadway facility type
7	Median U-Turn	Link	N	Unable to accommodate traffic patterns
8	Partial Displaced Left Turn	Link	N	Not feasible for roadway facility type
9	Partial Median U-Turn	Link	N	Unable to accommodate traffic patterns
10	Quadrant Roadway N-E	Link	N	Right-of-way restrictions identified
11	Quadrant Roadway N-W	Link	N	Right-of-way restrictions identified
12	Quadrant Roadway S-E	Link	N	Right-of-way restrictions identified
13	Quadrant Roadway S-W	Link	N	Right-of-way restrictions identified
14	Restricted Crossing U-Turn	Link	N	Unable to accommodate traffic patterns
15	Single Loop	Link	N	Right-of-way restrictions identified
16	Split Intersection	Link	N	Right-of-way restrictions identified
17	Thru-Cut	Link	N	Unable to accommodate traffic patterns
	Unsignalized Intersections			
18	50 Mini Roundabout	Link	Y	
19	75 Mini Roundabout	Link	Y	
20	Roundabout	Link	Y	
21	Two-Way Stop Control	-	Y	
#	**Interchanges**	**Information**	**Consider?**	**Justification**
22	Traditional Diamond	Link	N	Not feasible for roadway facility type
23	Contraflow Left	Link	N	Not feasible for roadway facility type
24	Displaced Left Turn	Link	N	Not feasible for roadway facility type
25	Diverging Diamond	Link	N	Not feasible for roadway facility type
26	Double Roundabout	Link	N	Not feasible for roadway facility type
27	Michigan Urban Diamond	Link	N	Not feasible for roadway facility type
28	Partial Cloverleaf	Link	N	Not feasible for roadway facility type
29	Single Point	Link	N	Not feasible for roadway facility type
30	Single Roundabout	Link	N	Not feasible for roadway facility type

VDOT Junction Screening Tool

Directional Questions and Base Lane Configurations

Before entering a base number of through lanes for each direction, answer all applicable directional question for each intersection or interchange configuration selected for consideration. Navigate to the lane configuration worksheet for example diagrams, if provided.

Intersections	Question	Direction
Bowtie	N/A	N/A
Continuous Green-T	N/A	N/A
Echelon	N/A	N/A
Median U-Turn	N/A	N/A
Partial Displaced Left Turn	N/A	N/A
Partial Median U-Turn	N/A	N/A
Restricted Crossing U-Turn	N/A	N/A
Single Loop	N/A	N/A
Split Intersection	N/A	N/A
Thru-Cut	N/A	N/A
Interchanges	**Question**	**Direction**
All	N/A	N/A

Base Number of Through Lanes

Enter a base number of through lanes for each direction. The number of through lanes entered will populate on each non-roundabout lane configuration worksheet. This tool also allows the user to enter the number of through lanes on the lane configuration worksheets directly. This base number may be overwritten on individual lane configuration worksheets. Turn lanes, shared lanes, and channelized lanes must still be entered in each lane configuration worksheet.

Eastbound	1
Westbound	1
Northbound	2
Southbound	2

VDOT Junction Screening Tool

Results Worksheet

VJuST
VDOT Junction Screening Tool

General Information	
Project Title:	Marina Way Extension
EW Facility:	Marina Way
NS Facility:	Annapolis Way
Date:	November 4, 2023

Volumes (veh/hr)	U-Turn / Left	Through		Right
Eastbound	190	170	190	165
Westbound	105	115	190	40
Northbound	110	140	190	60
Southbound	25	175	190	30

General Instructions: All intersection and interchange configurations have a default assumption of one exclusive lane per movement. No results shall be interpreted until the user has verified the lane configurations on each worksheet.

Intersection Results

		Congestion	Pedestrian	Safety	Planning Level Costs	Notes
Type	**Dir**	**Maximum V/C**	**Accommodation Compared to Conventional**	**Weighted Total Conflict Points**	**Planning Level Cost Category**	
Conventional	-	0.51		48	$	
50 Mini Roundabout	-	0.78		8	$	
75 Mini Roundabout	-	0.74		8	$	
Roundabout	-	0.37		8	$$	
Two-Way Stop Control	-	0.96		48	$	

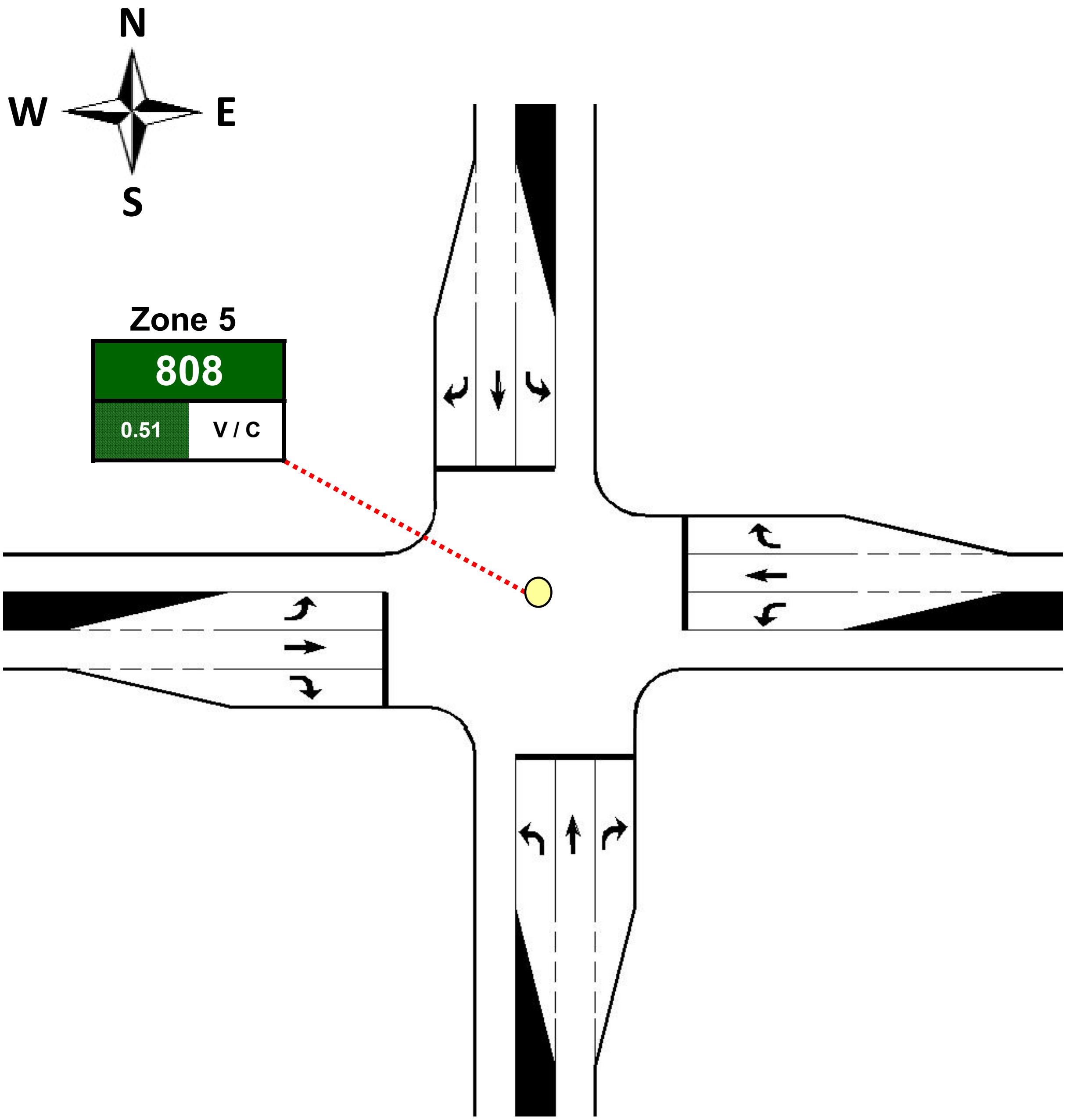
*The continuous green-T is the only three-legged innovative intersection in this tool. To compare the continuous green-T to other innovative intersections, conflicts corresponding with the fourth leg must be removed. This has been done for the conventional intersection. Conflict point diagrams for three-legged and four-legged conventional intersections have been provided on the conventional intersection worksheet for reference.

Conventional

DESIGN AND RESULTS

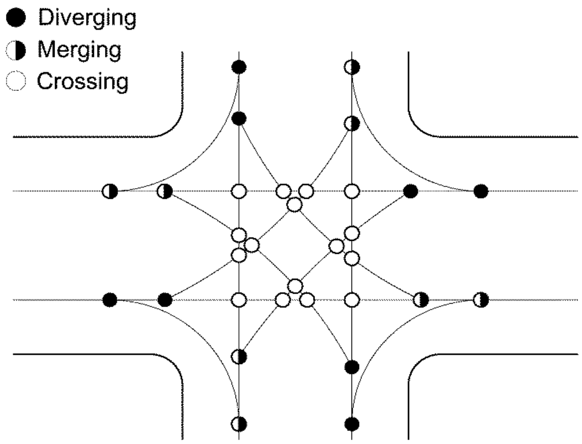
Project Name:	*Marina Way Extension*	
EW Facility:	*Marina Way*	
NS Facility:	*Annapolis Way*	
Date:	*November 4, 2023*	

Critical Lane Volume Sum			
< 1200	1200 - 1399	1400 - 1599	≥ 1600
VOLUME / CAPACITY RATIO:		0.51	



Note: This diagram does not reflect the actual lane configuration of the intersection

Safety - Conflict Point Diagram



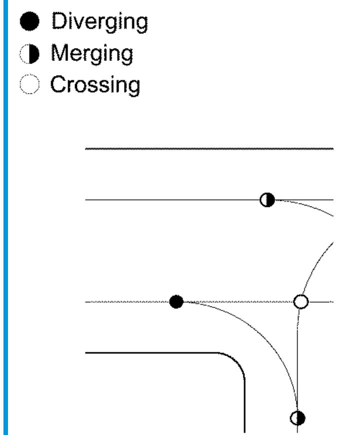
Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

48

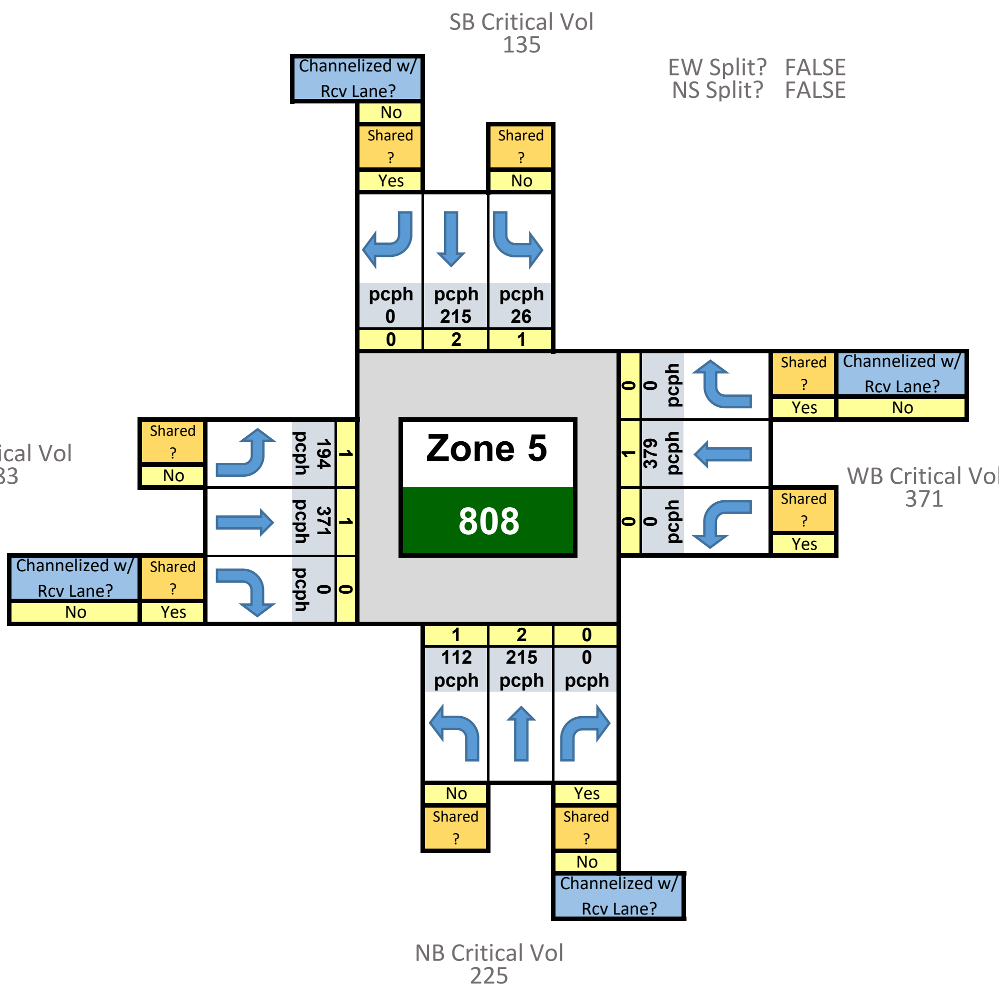
Safety - Cor



Conventional

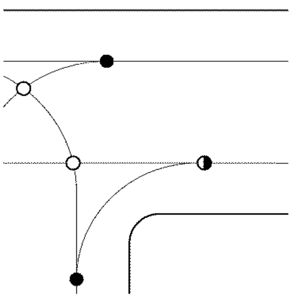
DATA INPUT AND CONFIGURATION

Enter the lane configurations in the yellow cells.



Back to Results

nflict Point Diagram (Three Legs)



Conflict Type	Count
Crossing	3
Merging	3
Diverging	3
Total	**9**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

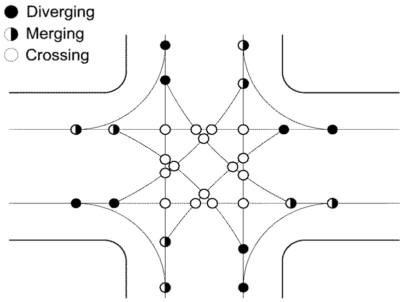
12

Planning Level Cost

$ $ $ $ $ **1**

- Are new lanes and/or pavement needed? **No**
- Cost category 1 if no new pavement needed, else cost cateogry 2.
- Assumes existing two-way stop contol or all-way stop control

Safety - Conflict Point Diagram



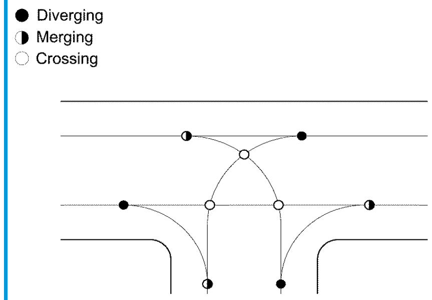
Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

48

Safety - Conflict Point Diagram (Three Legs)



Conflict Type	Count
Crossing	3
Merging	3
Diverging	3
Total	**9**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

12

Planning Level Cost

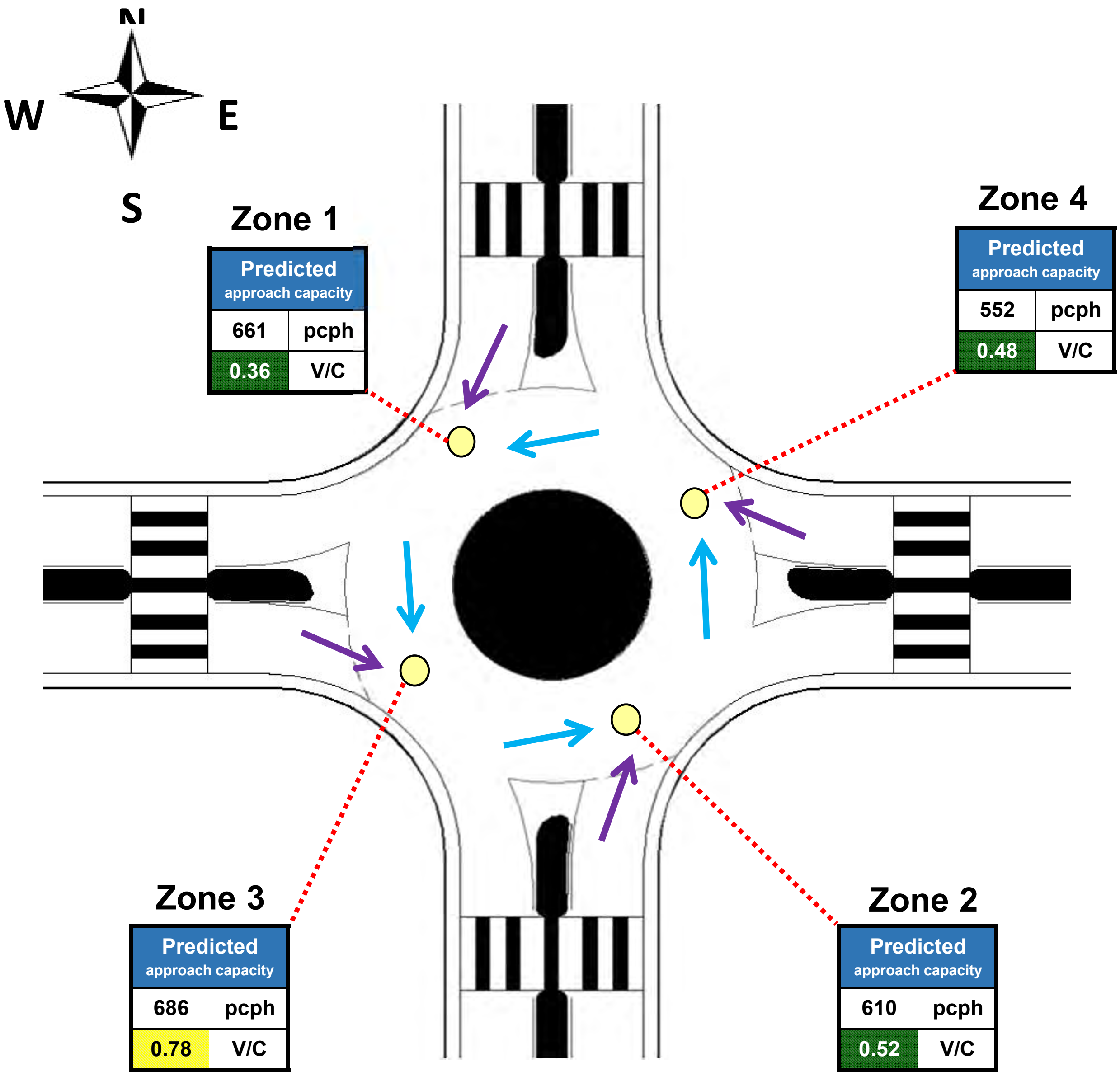
$ $ $ $ $ **1**

- Are new lanes and/or pavement needed? **No**
- Cost category 1 if no new pavement needed, else cost cateogry 2.
- Assumes existing two-way stop contol or all-way stop control

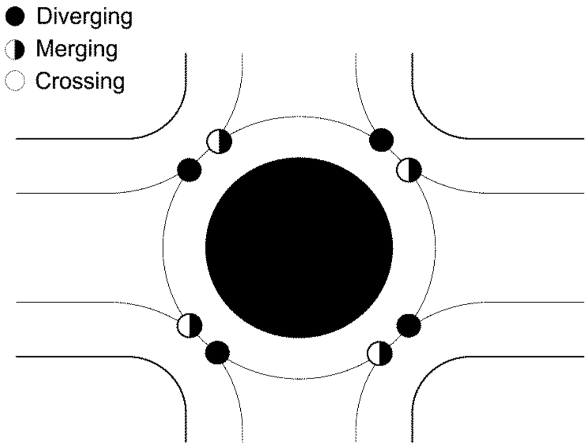
50' ICD Mini-Roundabout

DESIGN AND RESULTS

Project Name:	*Marina Way Extension*	***Critical Lane Volume Sum***			
EW Facility:	*Marina Way*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
NS Facility:	*Annapolis Way*	VOLUME / CAPACITY RATIO:	0.78		
Date:	*November 4, 2023*				



Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

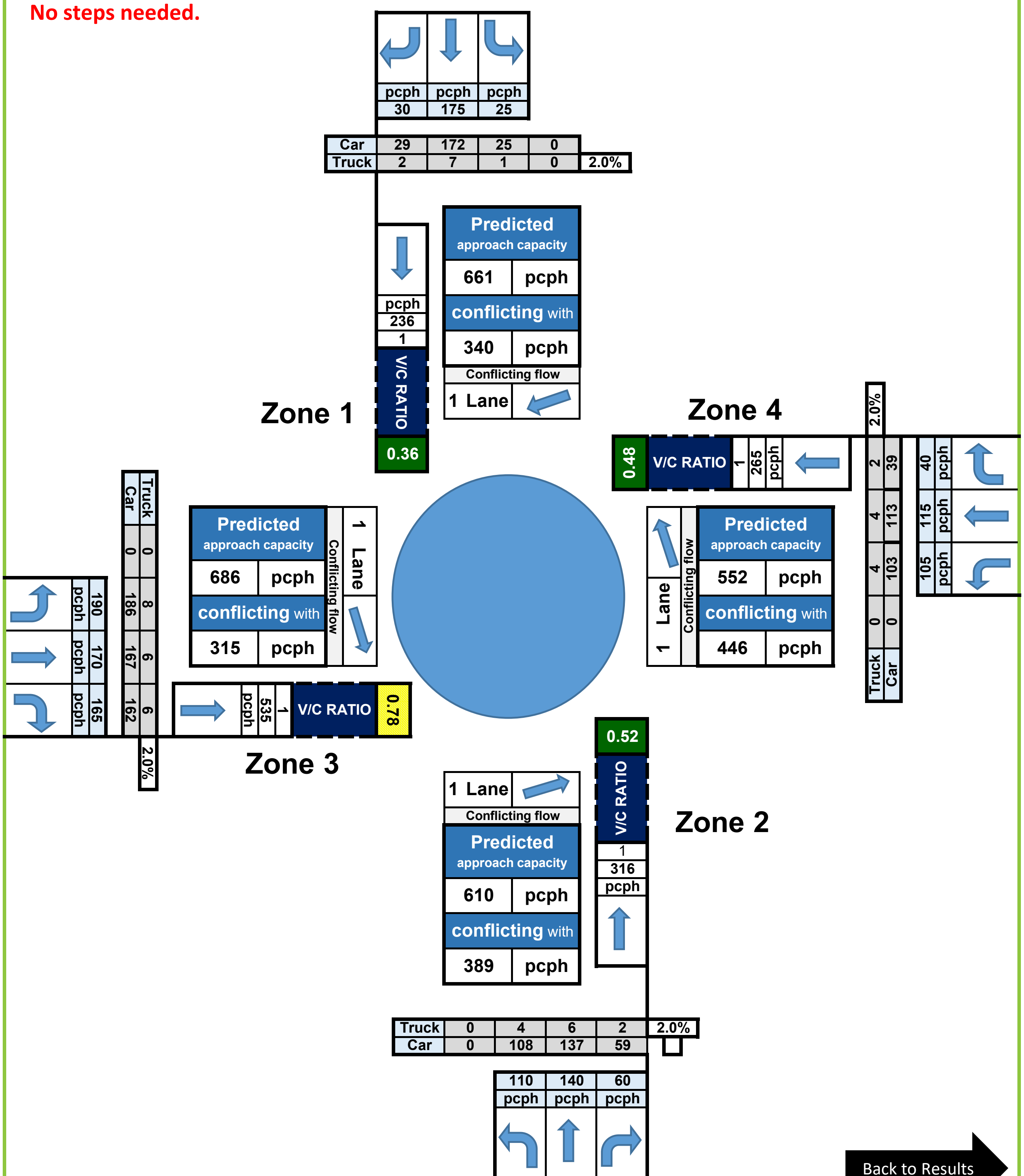
Assu

● This worksheet does not u
calculations are based on the
Roundabout Capacity in the
Journal of Transportation En

50' ICD Mini-Roundabout

DATA INPUT AND CONFIGURATION

No steps needed.



Back to Results

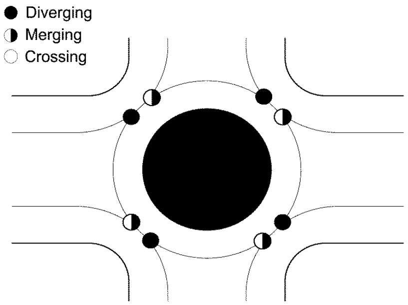
mptions

se the CLV methodology. The e article *Determination of Mini-* *United States* , published in the *gineering* .

Planning Level Cost $ $ $ $ $ 1

- Cost Category 1
- Assumes conversion from two-way stop control or all-way stop control.

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

Assumptions

● This worksheet does not use the CLV methodology. The calculations are based on the article *Determination of Mini-Roundabout Capacity in the United States* , published in the *Journal of Transportation Engineering* .

Planning Level Cost $ $ $ $ $ 1

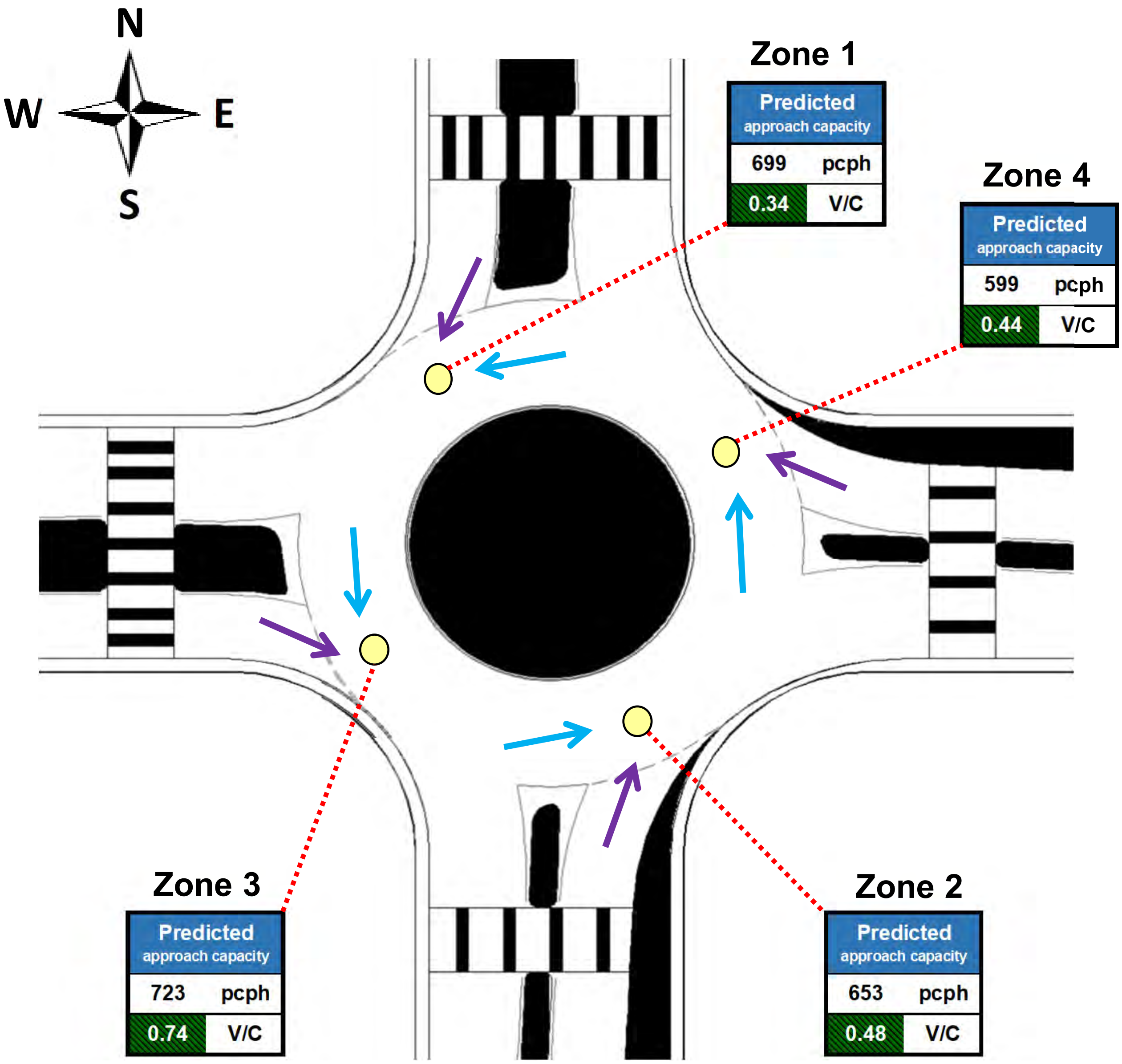
● Cost Category 1

● Assumes conversion from two-way stop control or all-way stop control.

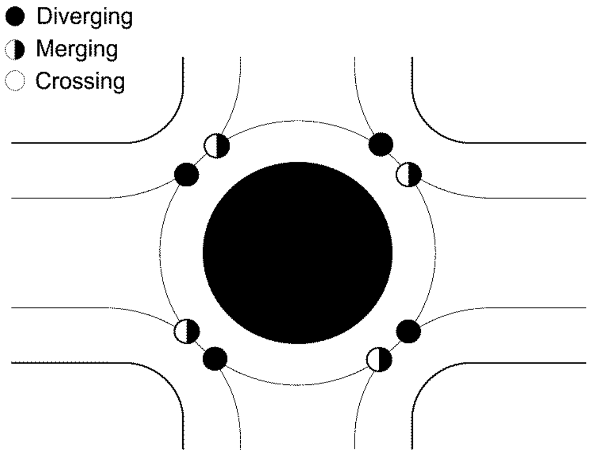
75' ICD Mini-Roundabout

DESIGN AND RESULTS

		Critical Lane Volume Sum			
Project Name:	*Marina Way Extension*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
EW Facility:	*Marina Way*	VOLUME / CAPACITY RATIO:	0.74		
NS Facility:	*Annapolis Way*				
Date:	*November 4, 2023*				



Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

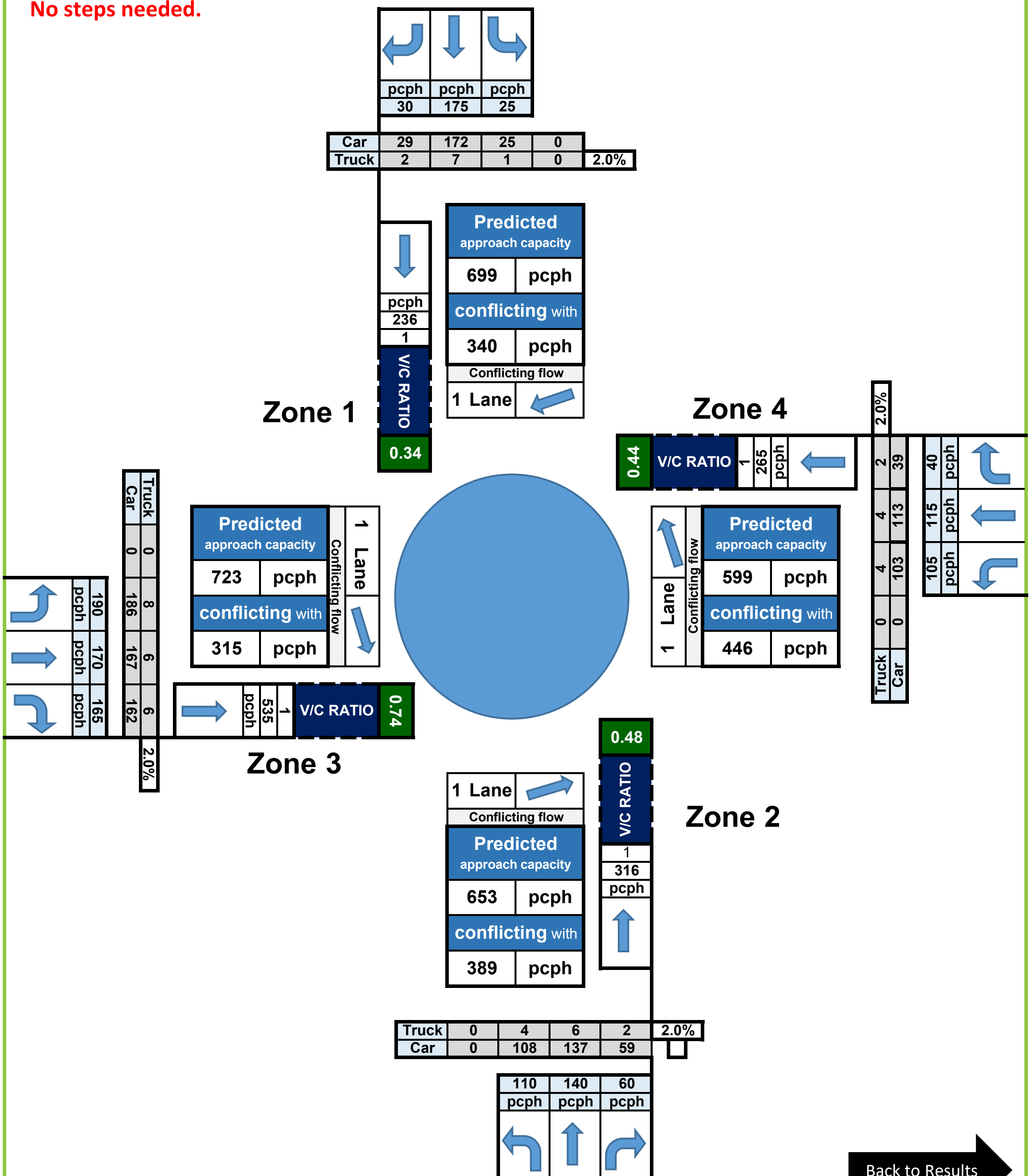
Assu

- This worksheet does not u
calculations are based on the
Roundabout Capacity in the
Journal of Transportation En

75' ICD Mini-Roundabout

DATA INPUT AND CONFIGURATION

No steps needed.



Back to Results

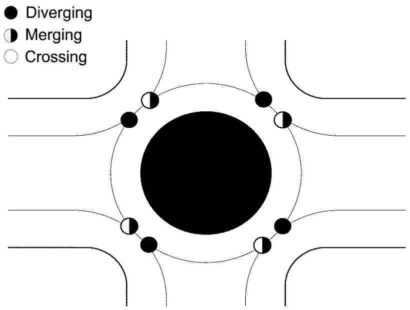
mptions

se the CLV methodology. The
e article *Determination of Mini-*
United States , published in the
gineering .

Planning Level Cost $ $ $ $ $ 1

- Cost Category 1
- Assumes conversion from two-way stop control or all-way stop control.

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

Assumptions

● This worksheet does not use the CLV methodology. The calculations are based on the article *Determination of Mini-Roundabout Capacity in the United States*, published in the *Journal of Transportation Engineering*.

Planning Level Cost $ $ $ $ $ 1

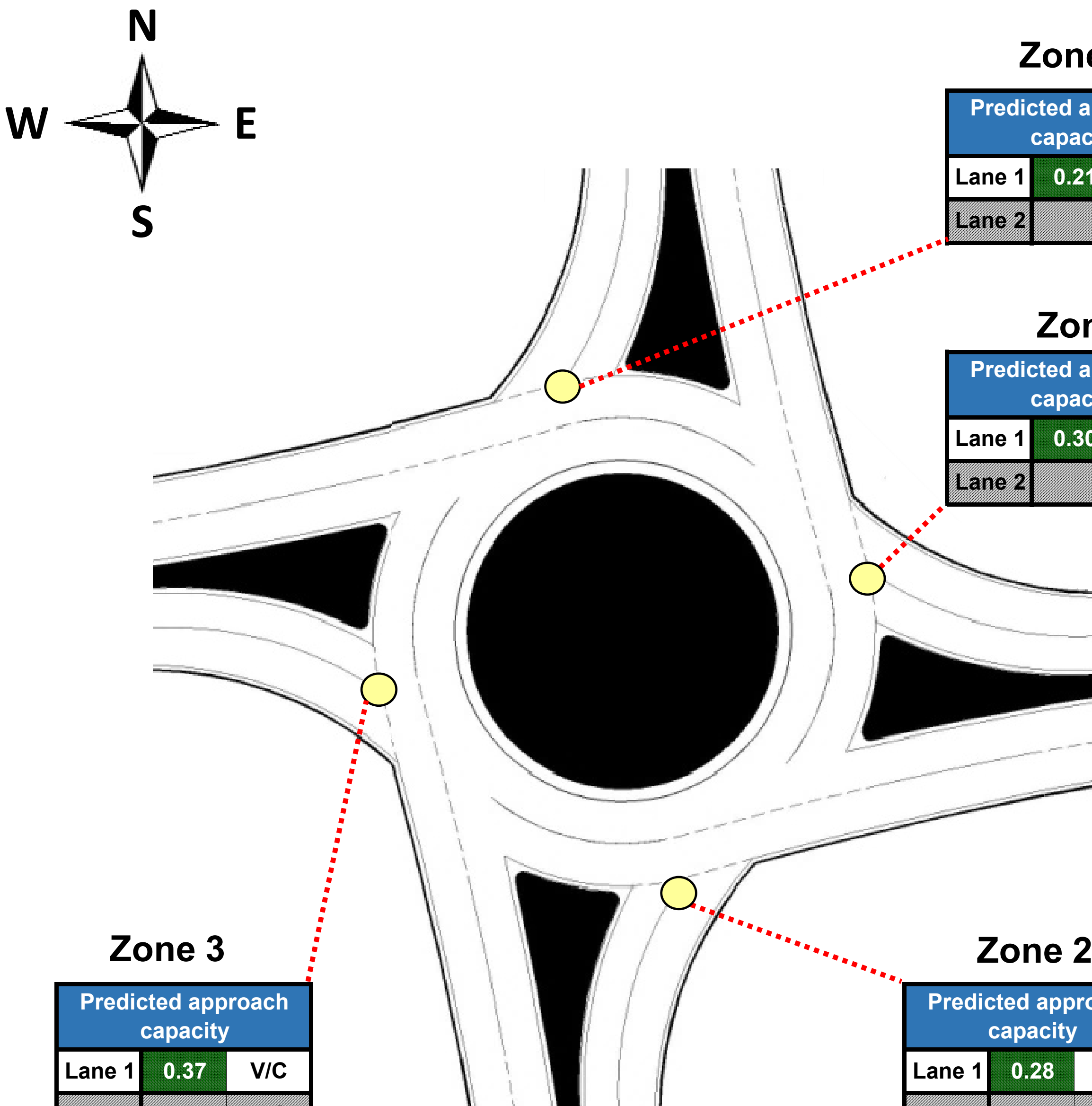
● Cost Category 1

● Assumes conversion from two-way stop control or all-way stop control.

Roundabout

DESIGN AND RESULTS

Project Name:	*Marina Way Extension*	*Critical Lane Volume Sum*			
EW Facility:	*Marina Way*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
NS Facility:	*Annapolis Way*	VOLUME / CAPACITY RATIO:	0.37		
Date:	*November 4, 2023*				



Zone 1

Predicted approach capacity		
Lane 1	0.21	V/C
Lane 2		V/C

Zone 4

Predicted approach capacity		
Lane 1	0.30	V/C
Lane 2		V/C

Zone 3

Predicted approach capacity		
Lane 1	0.37	V/C
Lane 2		V/C

Zone 2

Predicted approach capacity		
Lane 1	0.28	V/C
Lane 2		V/C

Roundabout

DATA INPUT AND CONFIGURATION

Enter the lane configurations in the yellow cells.

pcph	pcph	pcph
31	179	26

41	117	107
pcph	pcph	pcph

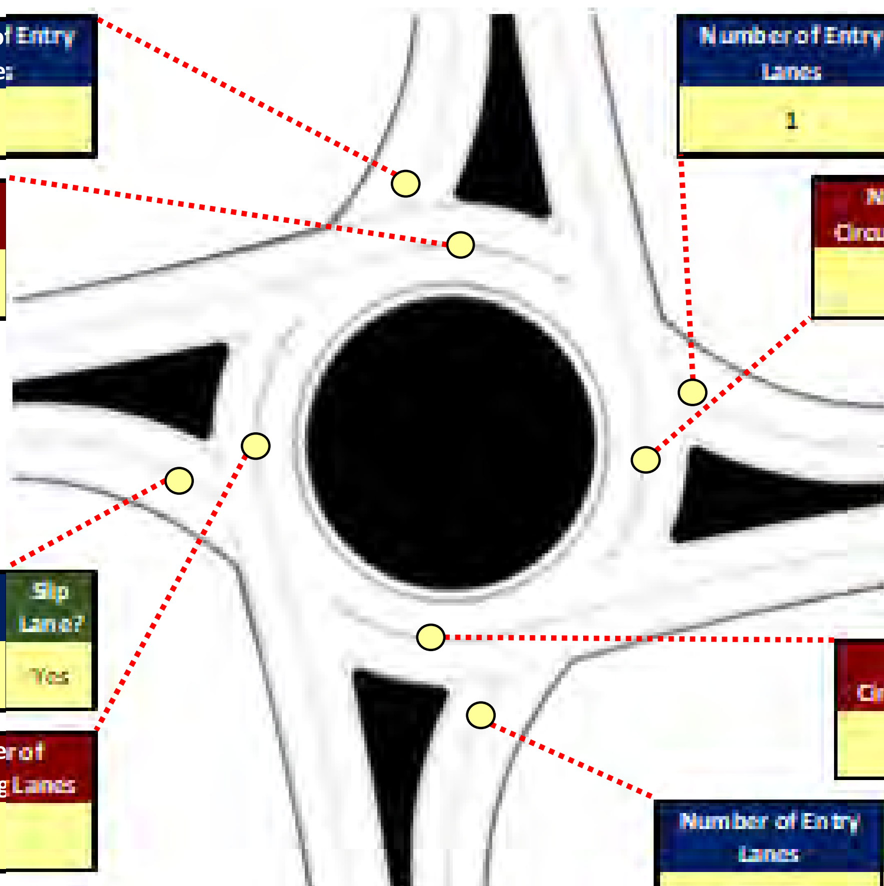
SB

Slip Lane?	Number of Entry Lanes
Yes	1

Number of Circulating Lanes
1

Number of Entry Lanes	Slip Lane?
1	No

Number of Circulating Lanes
1



EB

WB

Number of Entry Lanes	Slip Lane?
1	Yes

Number of Circulating Lanes
1

Number of Circulating Lanes
1

Number of Entry Lanes	Slip Lane?
1	Yes

NB

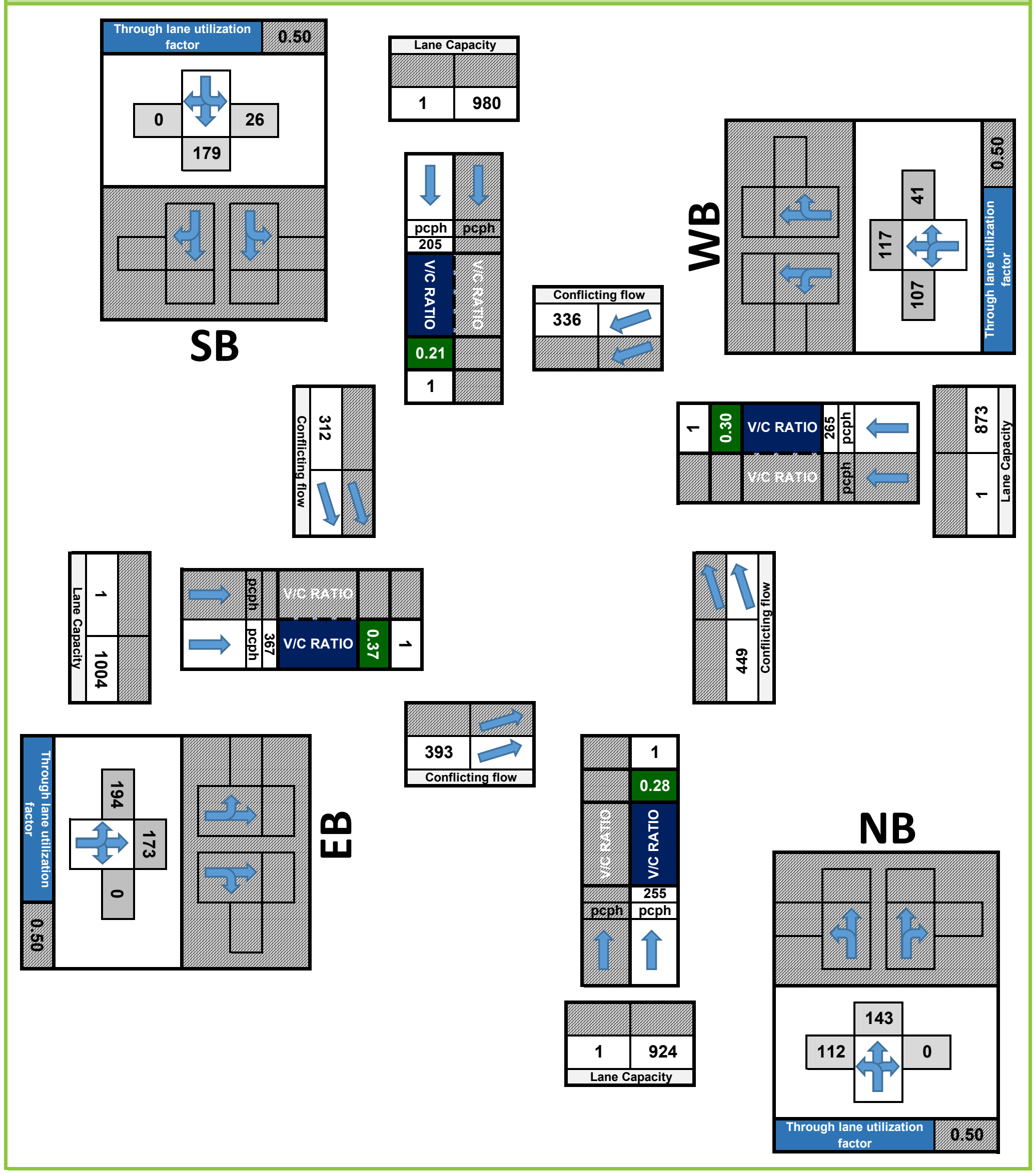
pcph	pcph	pcph
194	173	168

112	143	61
pcph	pcph	pcph

Back to Results

Roundabout

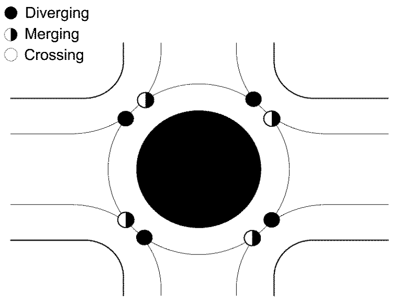
CAPACITY CALCULATIONS



EQUATION: A x exp(-B x Q)

Number of Entry Lanes	Number of Circulating Lanes	Lane	A	B
1	1	-	1380	0.00102
1	2	-	1420	0.00085
2	1	Left	1420	0.00091
2	1	Right	1420	0.00091
2	2	Left	1350	0.00092
2	2	Right	1420	0.00085

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

Assumptions

- The number of circulating lanes in one quadrant is assumed to be equal to the number of exiting lanes in the next quadrant.
- The roundabout is limited to a maximum of two entry lanes and two circulating lanes.
- All left-turning vehicles are assumed to stay in the innermost lane until exiting the roundabout.
- This worksheet does not use the CLV methodology. The calculations are based on the *HCM 6th Edition* .

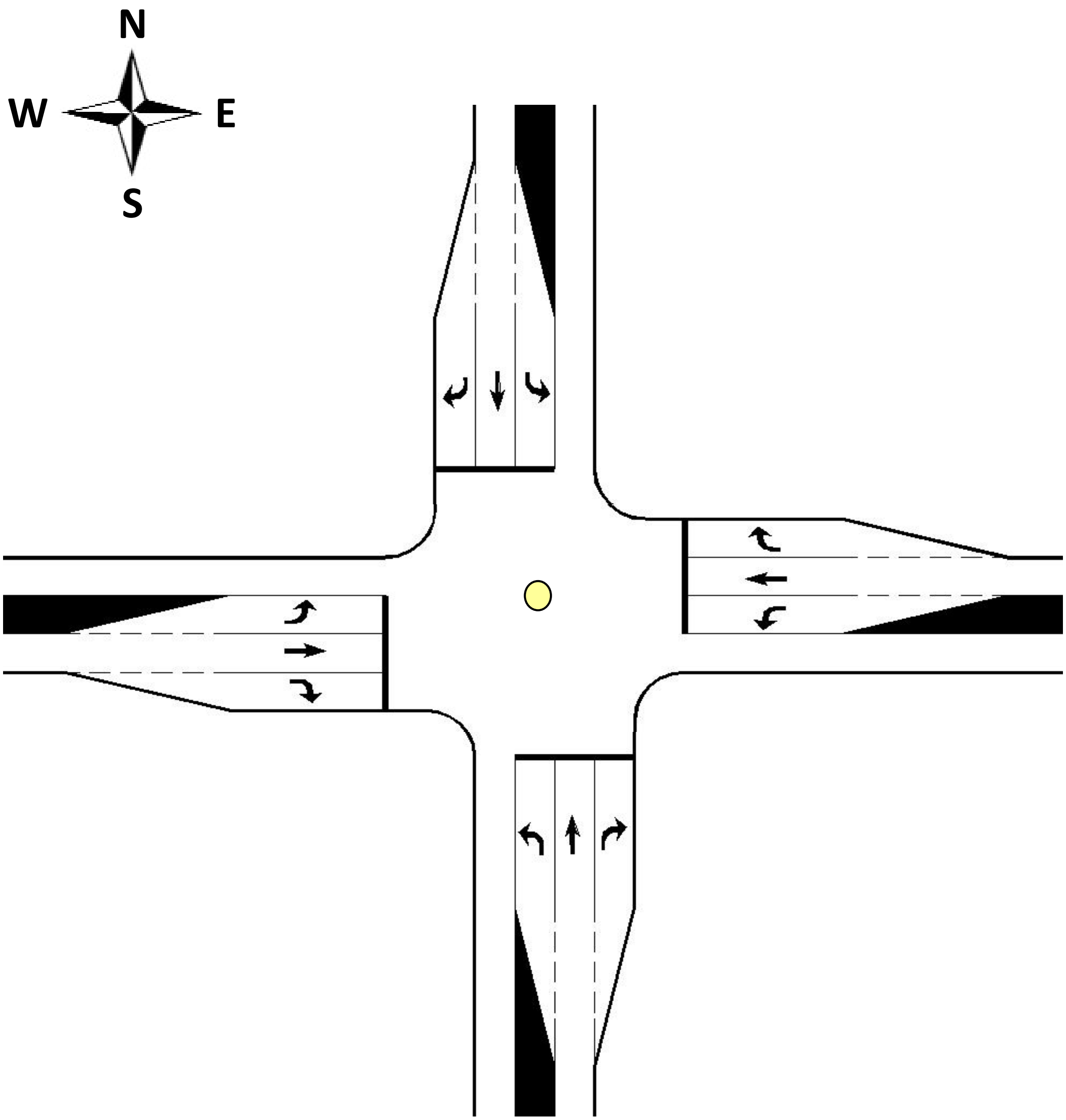
Planning Level Cost $ $ $ $ $ 2

- Cost Category 2
- Assumes conversion from two-way stop control or all-way stop control.

Two-Way Stop Control (TWSC)

DESIGN AND RESULTS

Project Name:	*Marina Way Extension*	***Critical Lane Volume Sum***			
EW Facility:	*Marina Way*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
NS Facility:	*Annapolis Way*	**VOLUME / CAPACITY RATIO:**		**0.96**	
Date:	*November 4, 2023*				



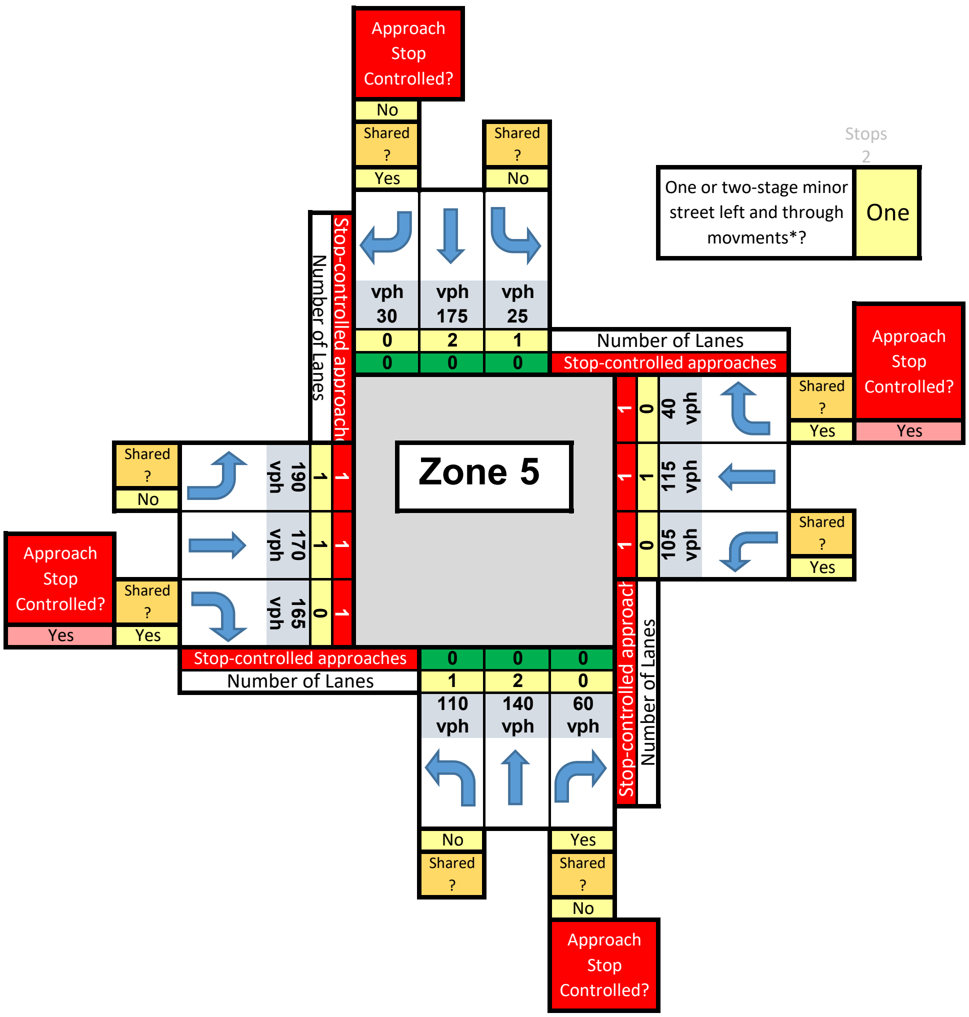
Note: This diagram does not reflect the actual lane configuration of the intersection

Two-Way Stop Control (TWSC)

DATA INPUT AND CONFIGURATION

Step 1: Identify which approaches are stop-controlled by selecting "Yes" from the drop-down box.

Step 2: Enter the lane configurations in the yellow cells.



Back to Results

Two-Way Stop Control (TWSC)

HCM 6 CALCULATIONS

Priority	MVMT	Rank
7	EBL	4
8	EBT	3
9	EBR	2
10	WBL	4
11	WBT	3
12	WBR	2
4	NBL	2
5	NBT	1
6	NBR	1
1	SBL	2
2	SBT	1
3	SBR	1

MAJOR	MINOR
NB	EB
SB	WB

Major street lanes	4
M1 Shared?	FALSE
M4 Shared?	FALSE

Priority	Rank	Flow Rates	Lanes	Shared?	Stop controlled?	Truck %
1	2	25	1	No		0.02
4	2	110	1	No		0.02
7	4	190	1	No	Yes	0.02
8	3	170	1		Yes	0.02
9	2	165	0	Yes	Yes	0.02
10	4	105	0	Yes	Yes	0.02
11	3	115	1		Yes	0.02
12	2	40	0	Yes	Yes	0.02
2	1	175	2			0.02
3	1	30	0	Yes	No	0.02
5	1	140	2			0.02
6	1	60	0	Yes	No	0.02

Conflicting Flows	
$v_{c,1}$	200.00
$v_{c,4}$	205.00
$v_{c,7}$	587.50
$v_{c,8}$	660.00
$v_{c,9}$	102.50
$v_{c,10}$	612.50
$v_{c,11}$	645.00
$v_{c,12}$	100.00

$v_{c,I,7}$	240.00
$v_{c,II,7}$	347.50
$v_{c,I,8}$	240.00
$v_{c,II,8}$	420.00
$v_{c,I,10}$	390.00
$v_{c,II,10}$	222.50
$v_{c,I,11}$	390.00
$v_{c,II,11}$	255.00

Critical Headways	
$t_{c,1}$	4.14
$t_{c,4}$	4.14
$t_{c,7}$	7.54
$t_{c,8}$	6.54
$t_{c,9}$	6.94
$t_{c,10}$	7.54
$t_{c,11}$	6.54
$t_{c,12}$	6.94

$t_{c,I,7}$	6.54
$t_{c,II,7}$	6.54
$t_{c,I,8}$	5.54
$t_{c,II,8}$	5.54
$t_{c,I,10}$	6.54
$t_{c,II,10}$	6.54
$t_{c,I,11}$	5.54
$t_{c,II,11}$	5.54

α	0.91

*Assumption:	One storage space in median (n_m = 1) for two-stage turns

Saturation Flow Rates	
Through	1800
Right	1500

Follow-Up Headways	
$t_{f,1}$	2.22
$t_{f,4}$	2.22
$t_{f,7}$	3.52
$t_{f,8}$	4.02
$t_{f,9}$	3.32
$t_{f,10}$	3.52
$t_{f,11}$	4.02
$t_{f,12}$	3.32

Potential Capacities	
$c_{p,1}$	1369.52
$c_{p,4}$	1363.72
$c_{p,7}$	392.78
$c_{p,8}$	381.60
$c_{p,9}$	932.64
$c_{p,10}$	376.88
$c_{p,11}$	389.26
$c_{p,12}$	936.08

Two-Stage Potential Capacities	
$c_{p,I,7}$	741.94
$c_{p,II,7}$	641.63
$c_{p,I,8}$	705.62
$c_{p,II,8}$	587.82
$c_{p,I,10}$	605.67
$c_{p,II,10}$	759.63
$c_{p,I,11}$	606.13
$c_{p,II,11}$	695.05

y_7	2.88
y_8	2.04
y_{10}	2.16
$y11$	0.93

Movement Capacities	
$c_{m,1}$	1369.52
$c_{m,4}$	1363.72
$c_{m,7}$	260.88
$c_{m,8}$	344.42
$c_{m,9}$	932.64
$c_{m,10}$	176.98
$c_{m,11}$	351.33
$c_{m,12}$	936.08

Two-Stage Movement Capacities	
$c_{m,I,7}$	728.40
$c_{m,II,7}$	448.14
$c_{m,I,8}$	692.74
$c_{m,II,8}$	540.41
$c_{m,I,10}$	556.82
$c_{m,II,10}$	463.19
$c_{m,I,11}$	557.24
$c_{m,II,11}$	682.37

$c_{T,7}$	348.08
$c_{T,8}$	419.07
$c_{T,10}$	271.42
$c_{T,11}$	418.00

Mvmt 1, excl left		$p_{0,1}$	0.98
Mvmt 4, excl left		$p_{0,4}$	0.92

Mvmt 1, shared left		$p^*_{0,1}$	0.98
Mvmt 4, shared left		$p^*_{0,4}$	0.91

Mvmt 7, 4-leg		p''_7	0.607
Mvmt 10, 4-leg		p''_{10}	0.457

$x_{1i,1+2}$	0.12
$x_{4i,1+2}$	0.12

One Stage	f_8	0.90
	f_{11}	0.90
	f_7	0.00
	f_{10}	0.00

Two Stage	$f_{I,8}$	0.98
	$f_{I,11}$	0.92
	$f_{I,7}$	0.98
	$f_{I.10}$	0.92

Shared Movement Capacities	
0	499.62
1	
1	
1	269.89
1	
1	

Single-Stage Movement Capacities	
$c_{m,7}$	260.88
$c_{m,8}$	344.42
$c_{m,10}$	176.98
$c_{m,11}$	351.33

$p_{0,8}$	0.51
$p_{0,11}$	0.67

p'_7	0.69
p'_{10}	0.57

$f_{II,8}$	0.92
$f_{II,11}$	0.98
$f_{II,7}$	0.70
$f_{II.10}$	0.61

Movement Capacities	
1	1369.52
2	3600.00
3	1500.00
4	1363.72
5	3600.00
6	1500.00
7	260.88
8-9	499.62
--	--
--	--
10-11-12	269.89
--	--

$p_{0,9}$	0.82
$p_{0,12}$	0.96

$f_{p,7}$	0.66
$f_{p,10}$	0.47

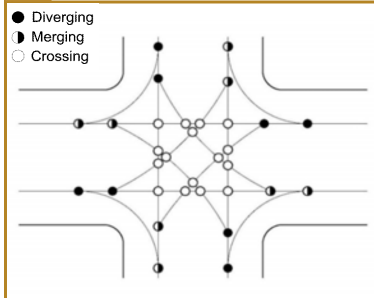
$p_{0,I,8}$	0.75
$p_{0,I,11}$	0.79

Movement V/C	
1	0.02
2	0.05
3	0.02
4	0.08
5	0.04
6	0.04
7	0.73
8-9	0.67
--	--
--	--
10-11-12	0.96
--	--

Intersection V/C
0.96

V/C Not Reported for Any Movements?
No

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

48

Assumptions

- This worksheet does not use the CLV methodology. The calculations are based on the *HCM, 6th Edition* . The calculations are based on vehicles per hour.

Planning Level Cost $ $ $ $ $ 1

- Cost Category 1
- Assumes no intersection, but cost of new road is not included

Appendix D

PM VJuST Worksheets

VDOT Junction Screening Tool

Input Worksheet

Project Title:	*Marina Way Extension*
E-W Facility:	*Marina Way*
N-S Facility:	*Annapolis Way*
Date:	*November 4, 2023*

Traffic Volume Demand

Direction	Volume (veh/hr)				Truck Percent (%)
	U-Turn / Left		Through	Right	
Eastbound	180		120	90	2.00%
Westbound	95		115	25	2.00%
Northbound	375		190	145	2.00%
Southbound	30		185	190	2.00%
Adjustment Factor	0.80	0.95		0.85	
Suggested	**U - 0.8**	**L - 0.95**		**0.85**	
Truck to PCE Factor			**Suggested = 2.00**		2.00
Critical Lane Volume			1600		

Equivalent Passenger Car Volume

	Volume (pc/hr)			
	U-Turn / Left	Through	Right	Approach
Eastbound	184	122	92	398
Westbound	97	117	26	240
Northbound	383	194	148	725
Southbound	31	189	194	414

Notes:

Left-turn Adjustment Factor	*Conversion of left-turning vehicles to equivalent through vehicles*
Right-turn Adjustment Factor	*Conversion of right-turning vehicles to equivalent through vehicles*
U-turn Adjustment Factor	*Conversion of U-turning vehicles to equivalent through vehicles*
Truck to PCE Factor	*1 truck = X Passenger Car Equivalents*
Critical Lane Volume Sum Limit	*Saturation value for critical lane volume sum at an intersection*

VDOT Junction Screening Tool

Possible Configurations

Indicate with a "Y" or "N" if each intersection or interchange configuration should or should not be considered. Use the information links for guidance. Then, click the "Show/Hide Configurations button" to hide the worksheets for the configurations that will not be considered.

#	Intersections	Information	Consider?	Justification
	Signalized Intersections			
1	Conventional	-	Y	
2	Bowtie	Link	N	Insufficient intersection spacing
3	Center Turn Overpass	Link	N	Not feasible for roadway facility type
4	Continuous Green-T	Link	N	Not feasible for roadway facility type
5	Echelon	Link	N	Not feasible for roadway facility type
6	Full Displaced Left Turn	Link	N	Not feasible for roadway facility type
7	Median U-Turn	Link	N	Unable to accommodate traffic patterns
8	Partial Displaced Left Turn	Link	N	Not feasible for roadway facility type
9	Partial Median U-Turn	Link	N	Unable to accommodate traffic patterns
10	Quadrant Roadway N-E	Link	N	Right-of-way restrictions identified
11	Quadrant Roadway N-W	Link	N	Right-of-way restrictions identified
12	Quadrant Roadway S-E	Link	N	Right-of-way restrictions identified
13	Quadrant Roadway S-W	Link	N	Right-of-way restrictions identified
14	Restricted Crossing U-Turn	Link	N	Unable to accommodate traffic patterns
15	Single Loop	Link	N	Right-of-way restrictions identified
16	Split Intersection	Link	N	Right-of-way restrictions identified
17	Thru-Cut	Link	N	Unable to accommodate traffic patterns
	Unsignalized Intersections			
18	50 Mini Roundabout	Link	Y	
19	75 Mini Roundabout	Link	Y	
20	Roundabout	Link	Y	
21	Two-Way Stop Control	-	Y	
#	**Interchanges**	**Information**	**Consider?**	**Justification**
22	Traditional Diamond	Link	N	Not feasible for roadway facility type
23	Contraflow Left	Link	N	Not feasible for roadway facility type
24	Displaced Left Turn	Link	N	Not feasible for roadway facility type
25	Diverging Diamond	Link	N	Not feasible for roadway facility type
26	Double Roundabout	Link	N	Not feasible for roadway facility type
27	Michigan Urban Diamond	Link	N	Not feasible for roadway facility type
28	Partial Cloverleaf	Link	N	Not feasible for roadway facility type
29	Single Point	Link	N	Not feasible for roadway facility type
30	Single Roundabout	Link	N	Not feasible for roadway facility type

VDOT Junction Screening Tool

Directional Questions and Base Lane Configurations

Before entering a base number of through lanes for each direction, answer all applicable directional question for each intersection or interchange configuration selected for consideration. Navigate to the lane configuration worksheet for example diagrams, if provided.

Intersections	Question	Direction
Bowtie	N/A	N/A
Continuous Green-T	N/A	N/A
Echelon	N/A	N/A
Median U-Turn	N/A	N/A
Partial Displaced Left Turn	N/A	N/A
Partial Median U-Turn	N/A	N/A
Restricted Crossing U-Turn	N/A	N/A
Single Loop	N/A	N/A
Split Intersection	N/A	N/A
Thru-Cut	N/A	N/A
Interchanges	**Question**	**Direction**
All	N/A	N/A

Base Number of Through Lanes

Enter a base number of through lanes for each direction. The number of through lanes entered will populate on each non-roundabout lane configuration worksheet. This tool also allows the user to enter the number of through lanes on the lane configuration worksheets directly. This base number may be overwritten on individual lane configuration worksheets. Turn lanes, shared lanes, and channelized lanes must still be entered in each lane configuration worksheet.

Eastbound	1
Westbound	1
Northbound	2
Southbound	2

VDOT Junction Screening Tool

Results Worksheet

VJuST
VDOT Junction Screening Tool

General Information	
Project Title:	Marina Way Extension
EW Facility:	Marina Way
NS Facility:	Annapolis Way
Date:	November 4, 2023

Volumes (veh/hr)	U-Turn / Left	Through		Right
Eastbound	180	120	180	90
Westbound	95	115	180	25
Northbound	375	190	180	145
Southbound	30	185	180	190

General Instructions: All intersection and interchange configurations have a default assumption of one exclusive lane per movement. No results shall be interpreted until the user has verified the lane configurations on each worksheet.

Intersection Results

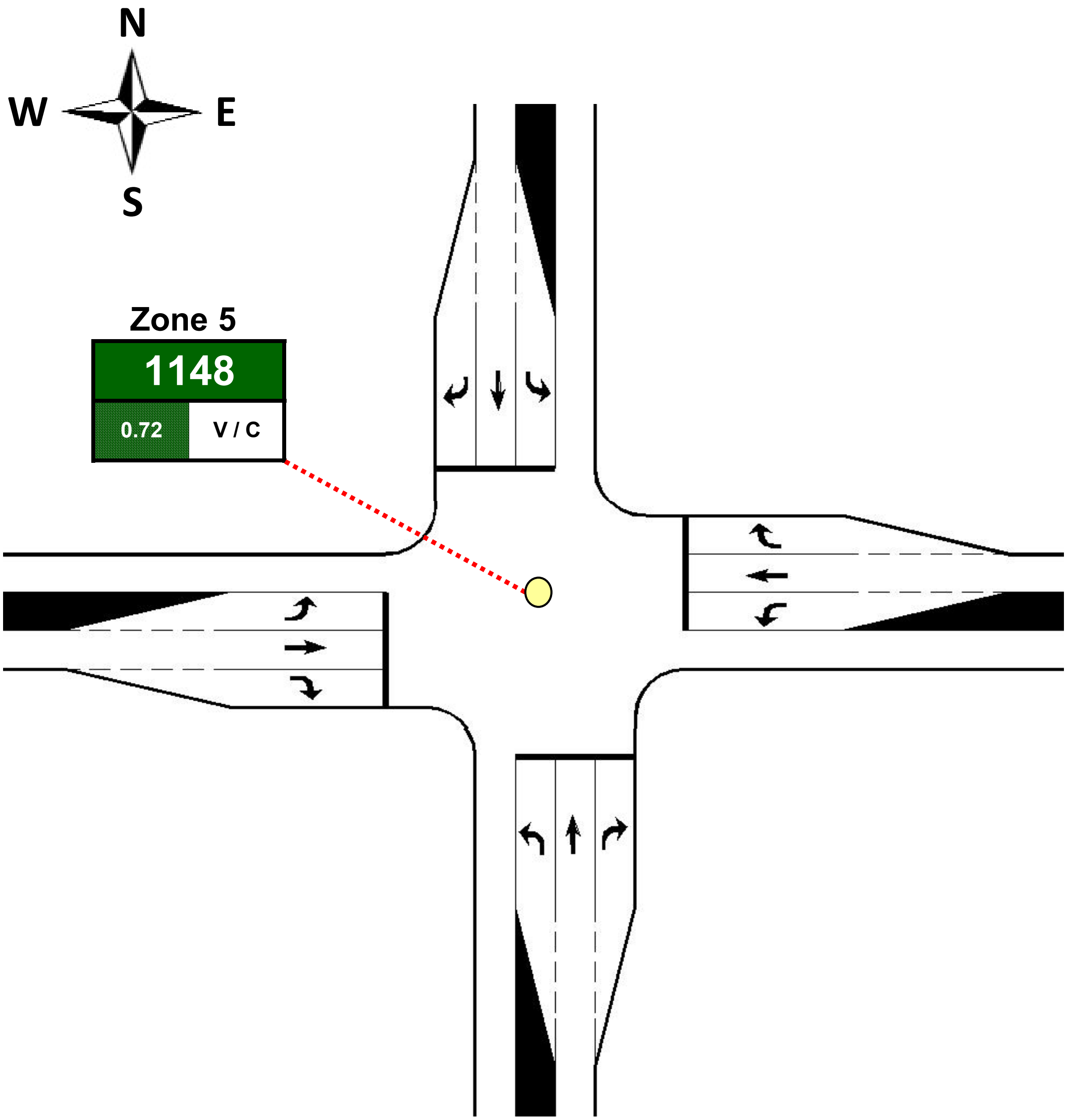
		Congestion	Pedestrian	Safety	Planning Level Costs	Notes
Type	**Dir**	**Maximum V/C**	**Accommodation Compared to Conventional**	**Weighted Total Conflict Points**	**Planning Level Cost Category**	
Conventional	-	0.72		48	$	
50 Mini Roundabout	-	1.09		8	$	
75 Mini Roundabout	-	1.03		8	$	
Roundabout	-	0.59		8	$$	
Two-Way Stop Control	-	N/A*		48	$	

*The continuous green-T is the only three-legged innovative intersection in this tool. To compare the continuous green-T to other innovative intersections, conflicts corresponding with the fourth leg must be removed. This has been done for the conventional intersection. Conflict point diagrams for three-legged and four-legged conventional intersections have been provided on the conventional intersection worksheet for reference.

Conventional

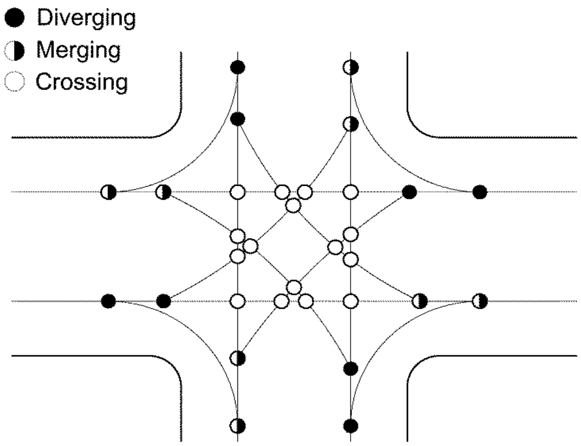
DESIGN AND RESULTS

		Critical Lane Volume Sum			
Project Name:	*Marina Way Extension*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
EW Facility:	*Marina Way*	VOLUME / CAPACITY RATIO:		0.72	
NS Facility:	*Annapolis Way*				
Date:	*November 4, 2023*				



Note: This diagram does not reflect the actual lane configuration of the intersection

Safety - Conflict Point Diagram



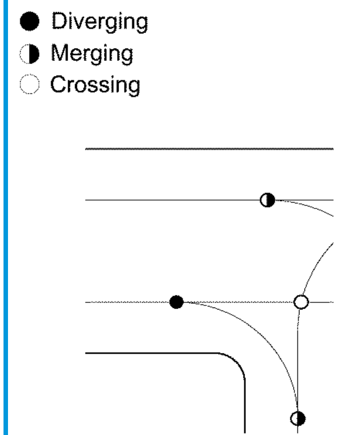
Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

48

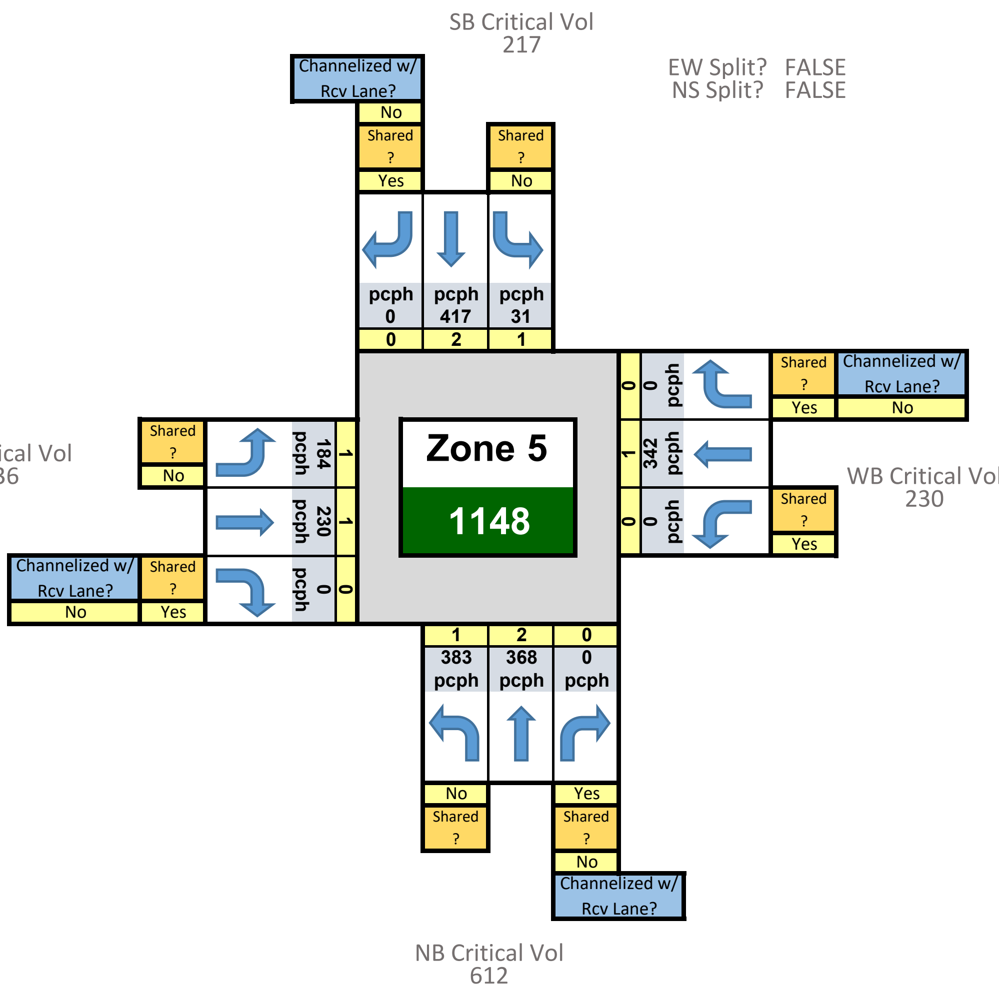
Safety - Cor



Conventional

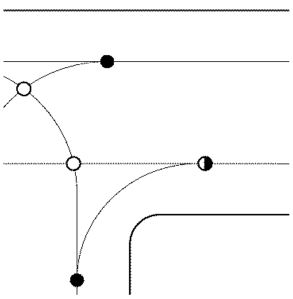
DATA INPUT AND CONFIGURATION

Enter the lane configurations in the yellow cells.



Back to Results

nflict Point Diagram (Three Legs)



Conflict Type	Count
Crossing	3
Merging	3
Diverging	3
Total	**9**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

12

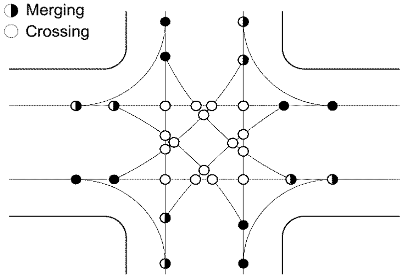
Planning Level Cost

$ $ $ $ $ **1**

- Are new lanes and/or pavement needed? **No**
- Cost category 1 if no new pavement needed, else cost cateogry 2.
- Assumes existing two-way stop contol or all-way stop control

Safety - Conflict Point Diagram

- ● Diverging
- ◑ Merging
- ○ Crossing



Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

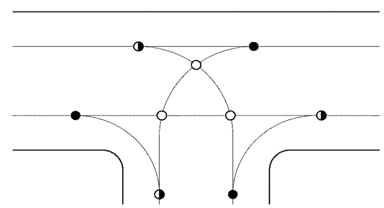
Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

48

Safety - Conflict Point Diagram (Three Legs)

- ● Diverging
- ◑ Merging
- ○ Crossing



Conflict Type	Count
Crossing	3
Merging	3
Diverging	3
Total	**9**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

12

Planning Level Cost

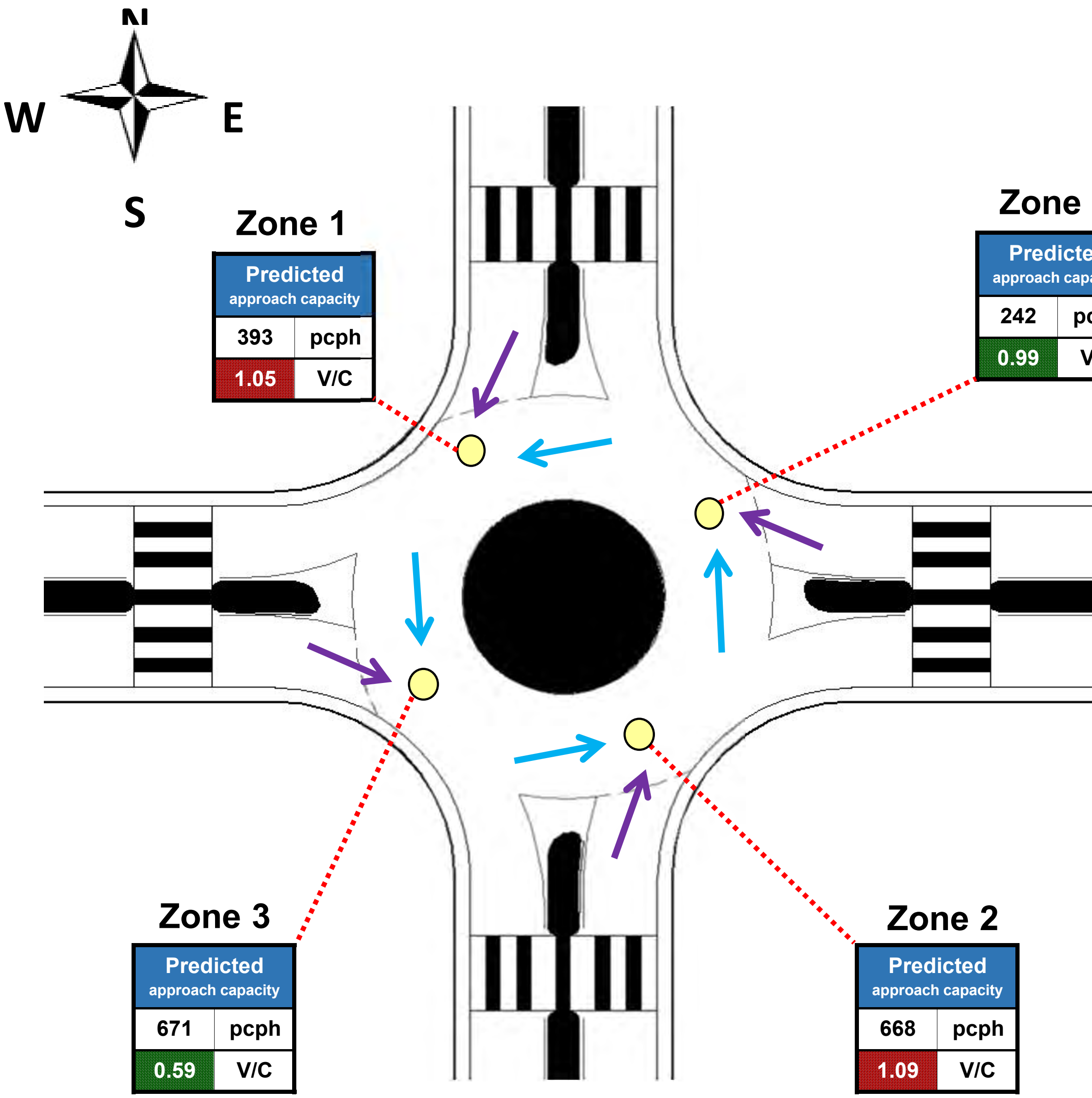
$ $ $ $ $ **1**

- Are new lanes and/or pavement needed? **No**
- Cost category 1 if no new pavement needed, else cost cateogry 2.
- Assumes existing two-way stop contol or all-way stop control

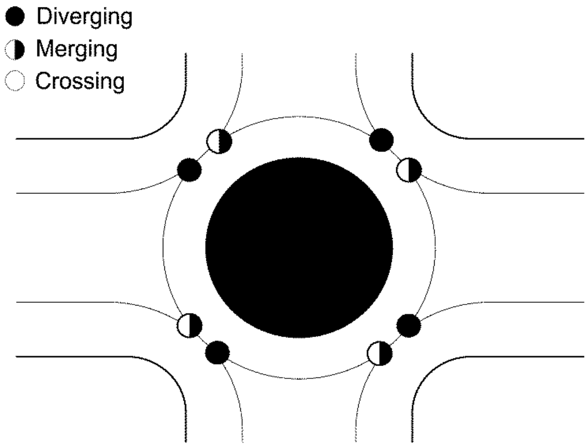
50' ICD Mini-Roundabout

DESIGN AND RESULTS

		Critical Lane Volume Sum			
Project Name:	*Marina Way Extension*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
EW Facility:	*Marina Way*	VOLUME / CAPACITY RATIO:	1.09		
NS Facility:	*Annapolis Way*				
Date:	*November 4, 2023*				



Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

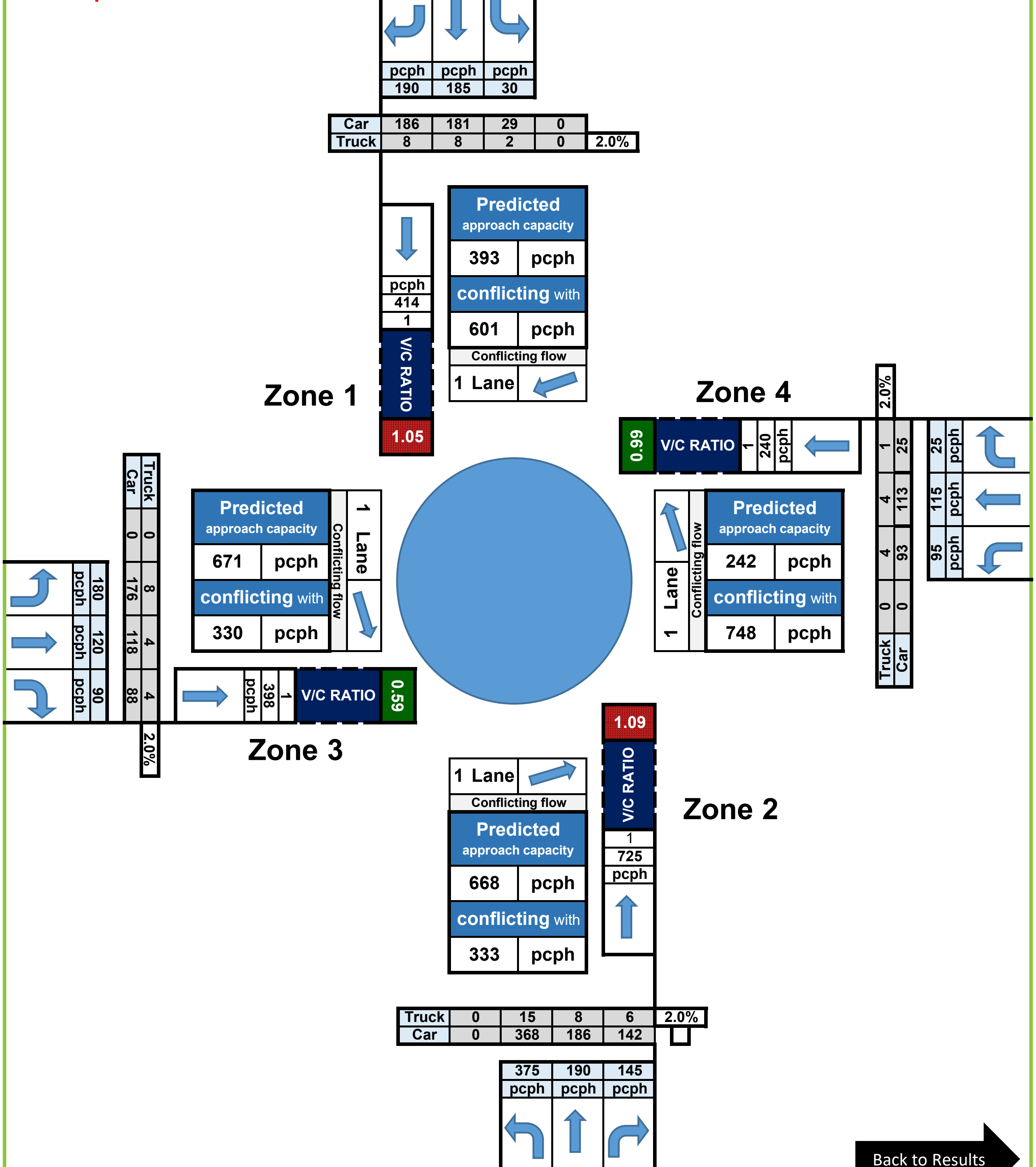
Assu

- This worksheet does not u calculations are based on the *Roundabout Capacity in the Journal of Transportation En*

50' ICD Mini-Roundabout

DATA INPUT AND CONFIGURATION

No steps needed.



Back to Results

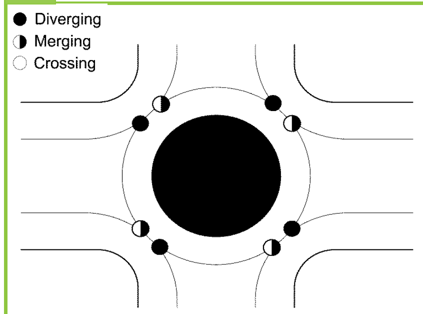
mptions

se the CLV methodology. The e article *Determination of Mini- United States* , published in the *gineering* .

Planning Level Cost $ $ $ $ $ 1

- Cost Category 1
- Assumes conversion from two-way stop control or all-way stop control.

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

Assumptions

● This worksheet does not use the CLV methodology. The calculations are based on the article *Determination of Mini-Roundabout Capacity in the United States* , published in the *Journal of Transportation Engineering* .

Planning Level Cost $ $ $ $ $ 1

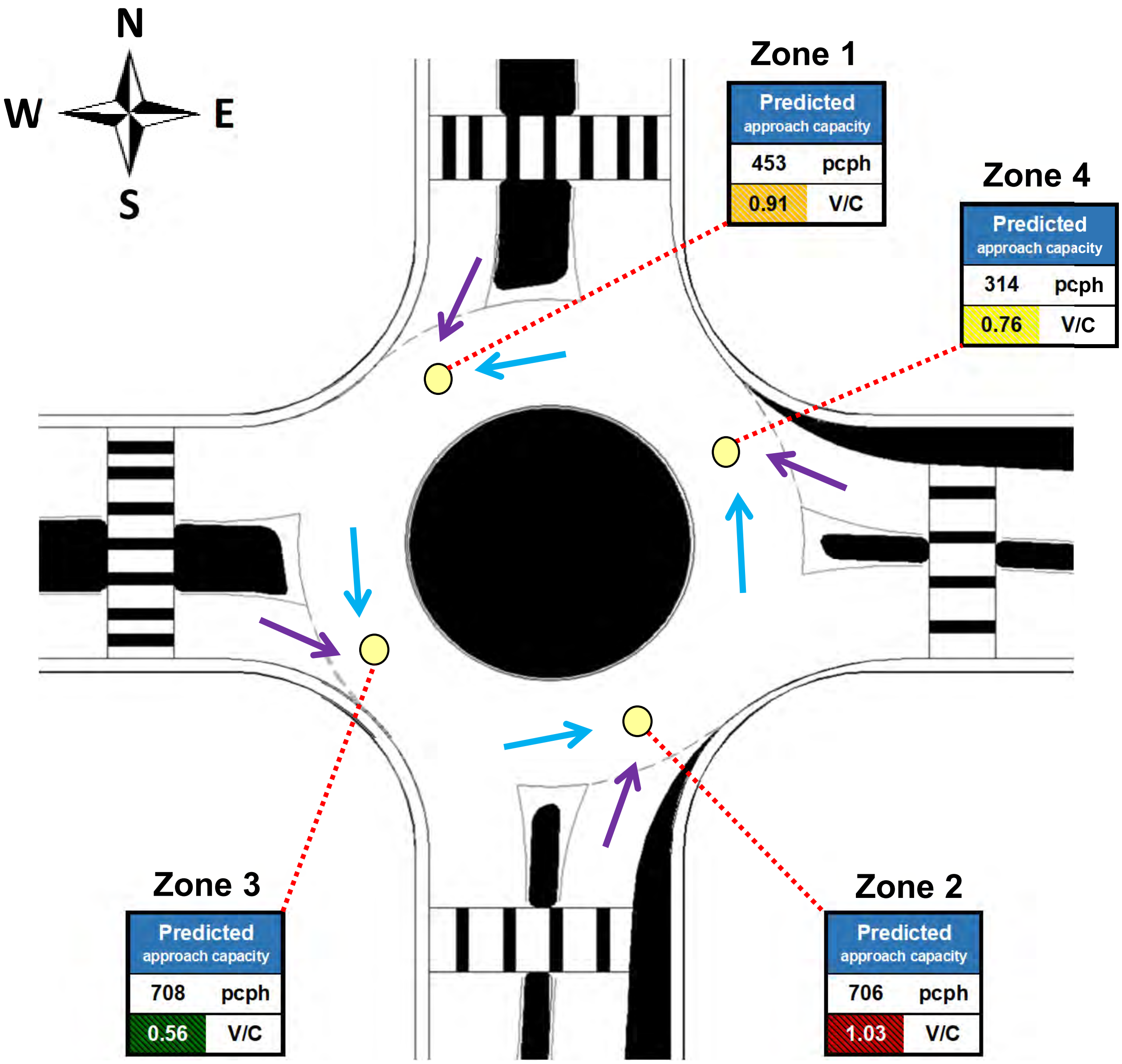
● Cost Category 1

● Assumes conversion from two-way stop control or all-way stop control.

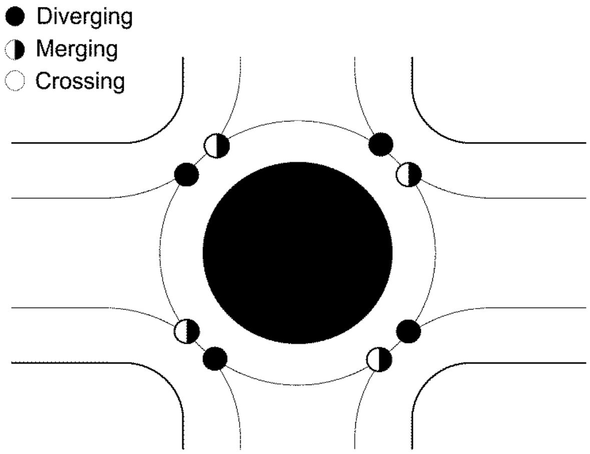
75' ICD Mini-Roundabout

DESIGN AND RESULTS

		Critical Lane Volume Sum			
Project Name:	*Marina Way Extension*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
EW Facility:	*Marina Way*	VOLUME / CAPACITY RATIO:	1.03		
NS Facility:	*Annapolis Way*				
Date:	*November 4, 2023*				



Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

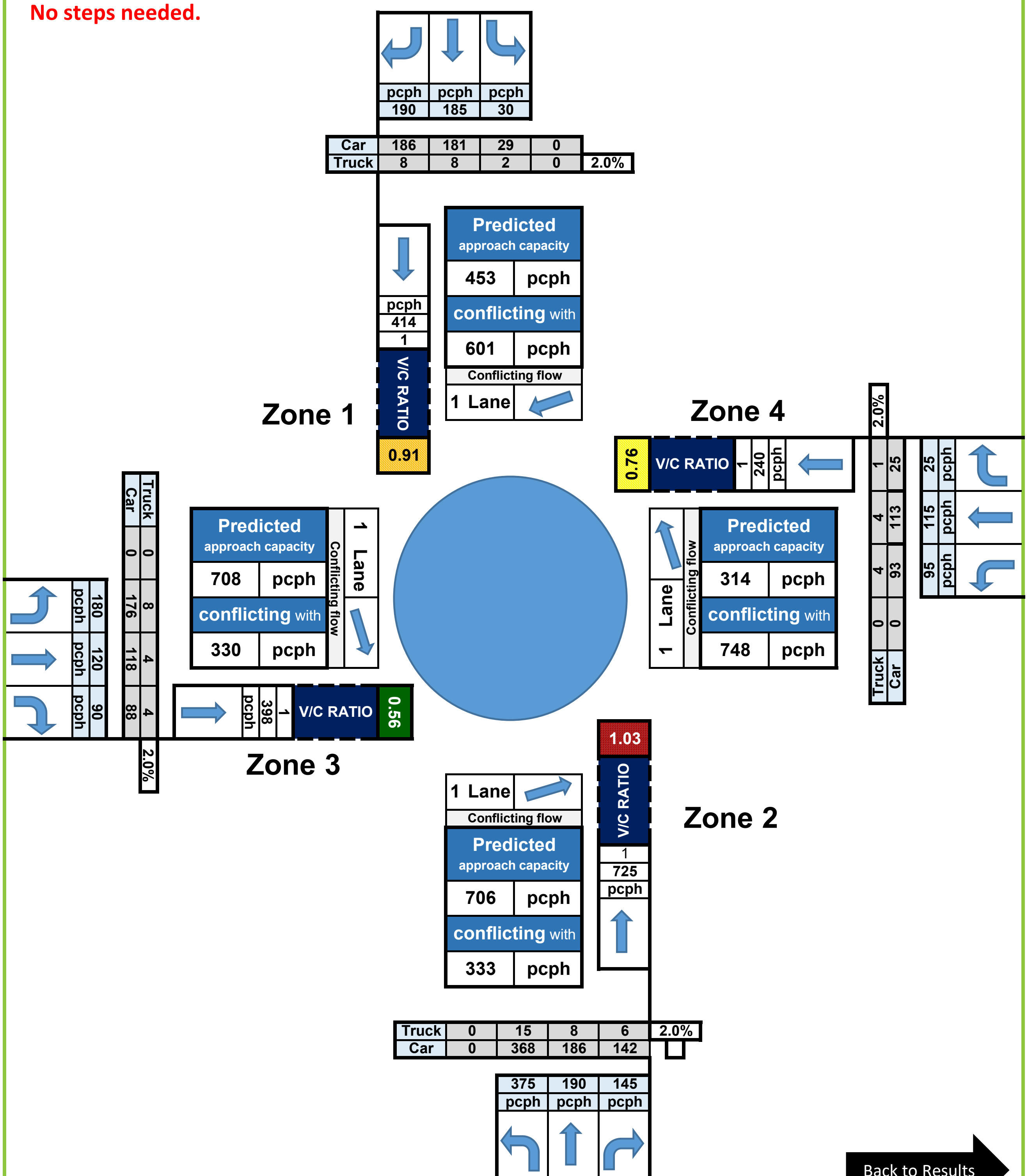
Assu

● This worksheet does not u
calculations are based on the
Roundabout Capacity in the
Journal of Transportation En

75' ICD Mini-Roundabout

DATA INPUT AND CONFIGURATION

No steps needed.



Back to Results

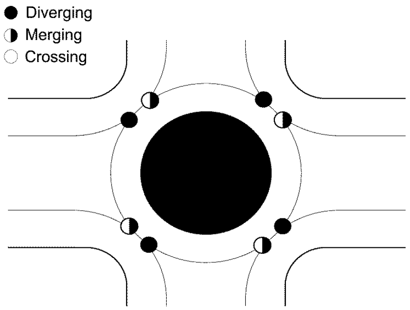
mptions

se the CLV methodology. The
e article *Determination of Mini-*
United States , published in the
gineering .

Planning Level Cost $ $ $ $ $ 1

- Cost Category 1
- Assumes conversion from two-way stop control or all-way stop control.

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

Assumptions

● This worksheet does not use the CLV methodology. The calculations are based on the article *Determination of Mini-Roundabout Capacity in the United States* , published in the *Journal of Transportation Engineering* .

Planning Level Cost $ $ $ $ $ 1

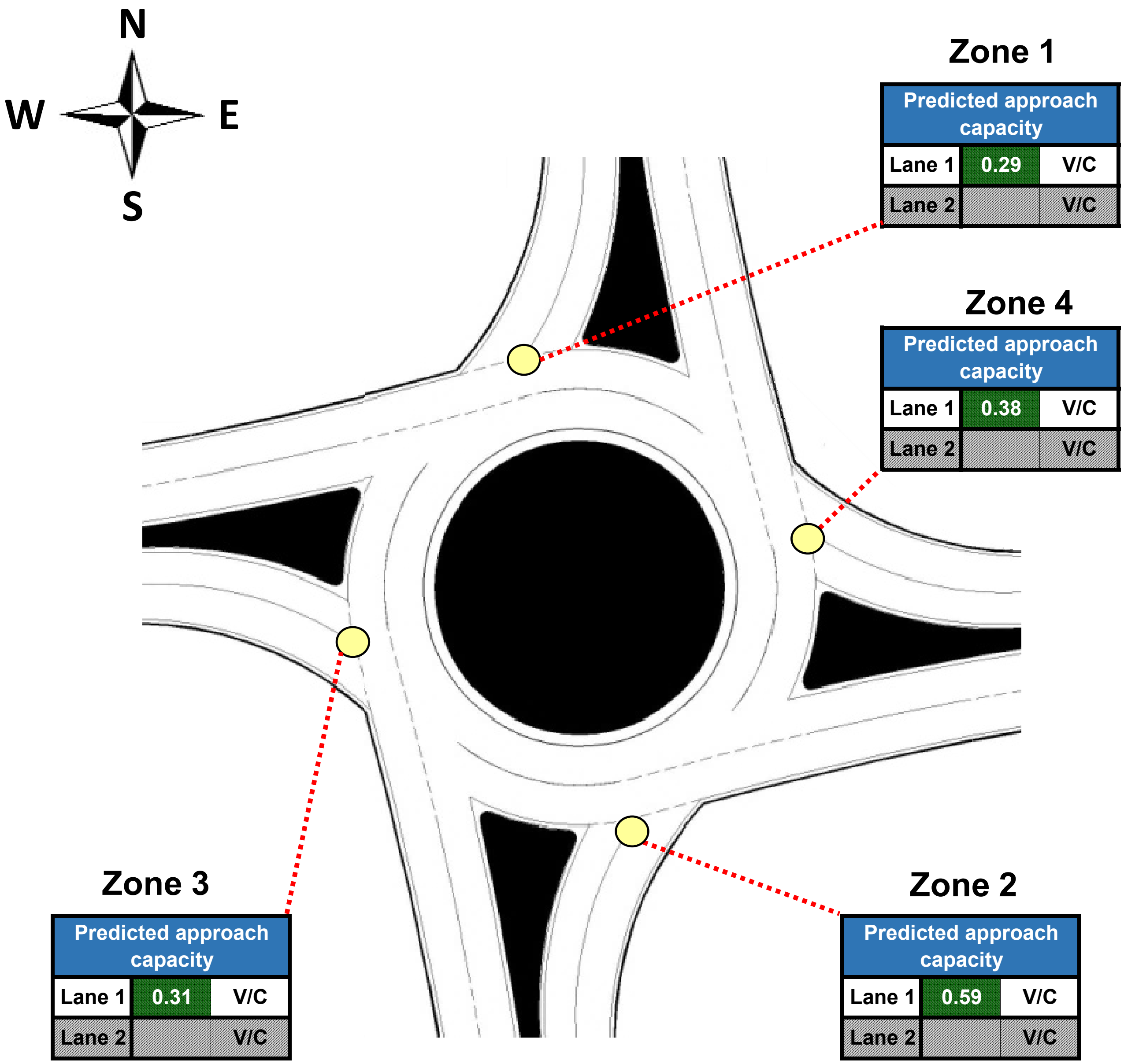
● Cost Category 1

● Assumes conversion from two-way stop control or all-way stop control.

Roundabout

DESIGN AND RESULTS

Project Name:	*Marina Way Extension*	*Critical Lane Volume Sum*			
EW Facility:	*Marina Way*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
NS Facility:	*Annapolis Way*	VOLUME / CAPACITY RATIO:	0.59		
Date:	*November 4, 2023*				



Roundabout

DATA INPUT AND CONFIGURATION

Enter the lane configurations in the yellow cells.

pcph	pcph	pcph
194	189	31

26 pcph	117 pcph	97 pcph

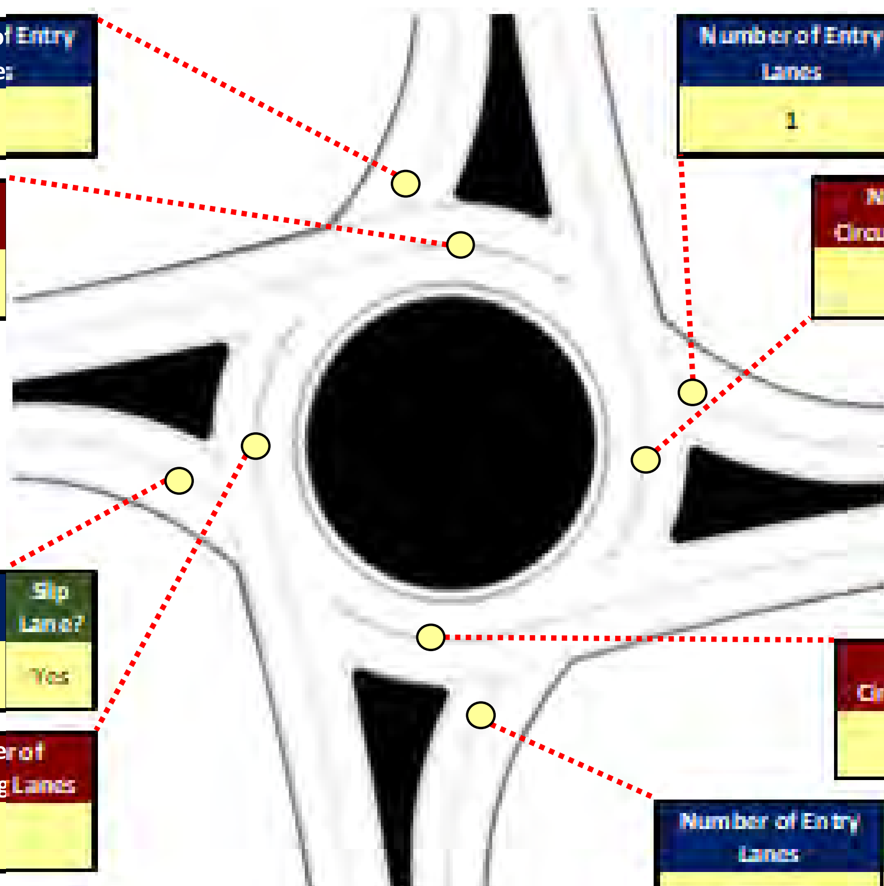
SB

Slip Lane?	Number of Entry Lanes
Yes	1

Number of Entry Lanes	Slip Lane?
1	No

Number of Circulating Lanes
1

Number of Circulating Lanes
1



EB

WB

Number of Entry Lanes	Slip Lane?
1	Yes

Number of Circulating Lanes
1

Number of Circulating Lanes
1

Number of Entry Lanes	Slip Lane?
1	Yes

184 pcph	122 pcph	92 pcph

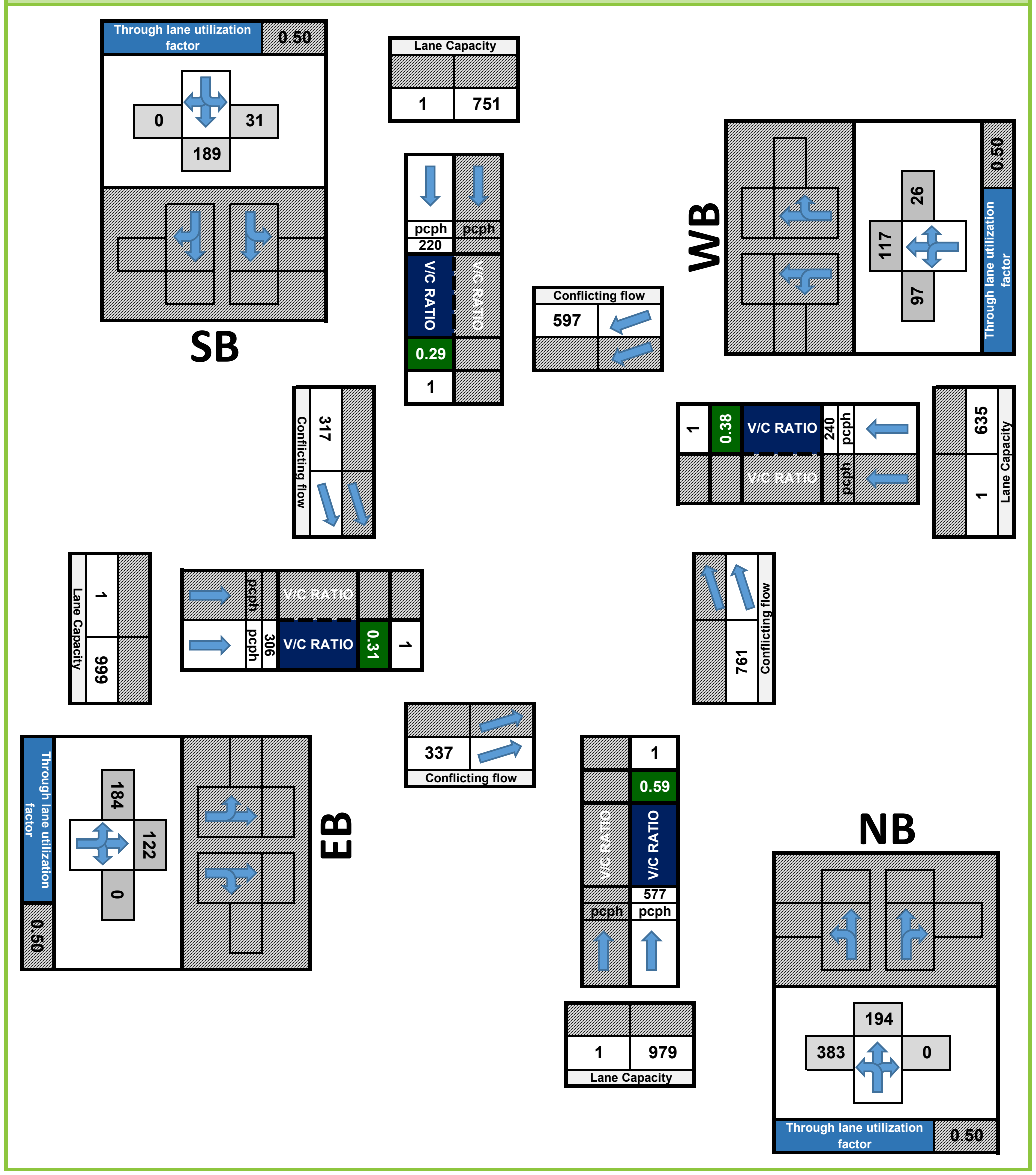
NB

383	194	148
pcph	pcph	pcph

Back to Results

Roundabout

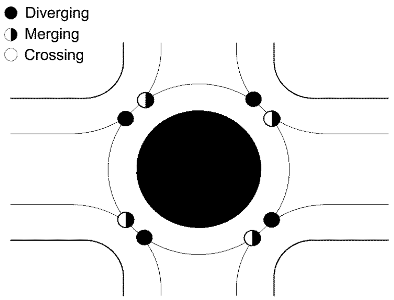
CAPACITY CALCULATIONS



EQUATION: A x exp(-B x Q)

Number of Entry Lanes	Number of Circulating Lanes	Lane	A	B
1	1	-	1380	0.00102
1	2	-	1420	0.00085
2	1	Left	1420	0.00091
2	1	Right	1420	0.00091
2	2	Left	1350	0.00092
2	2	Right	1420	0.00085

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total	**8**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

8

Assumptions

● The number of circulating lanes in one quadrant is assumed to be equal to the number of exiting lanes in the next quadrant.

● The roundabout is limited to a maximum of two entry lanes and two circulating lanes.

● All left-turning vehicles are assumed to stay in the innermost lane until exiting the roundabout.

● This worksheet does not use the CLV methodology. The calculations are based on the *HCM 6th Edition* .

Planning Level Cost $ $ $ $ $ 2

● Cost Category 2

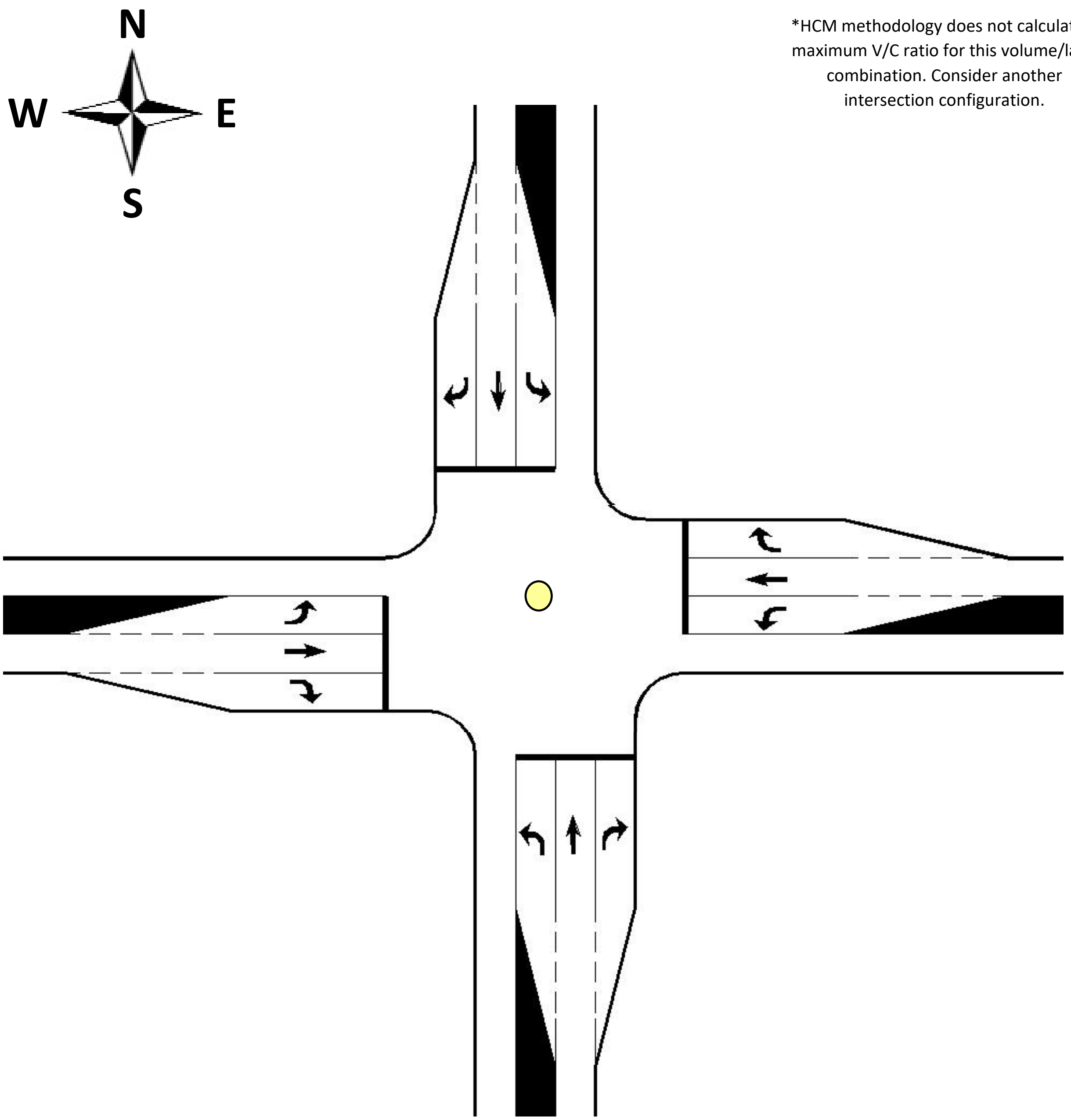
● Assumes conversion from two-way stop control or all-way stop control.

Two-Way Stop Control (TWSC)

DESIGN AND RESULTS

Project Name:	*Marina Way Extension*	***Critical Lane Volume Sum***			
EW Facility:	*Marina Way*	< 1200	1200 - 1399	1400 - 1599	≥ 1600
NS Facility:	*Annapolis Way*	VOLUME / CAPACITY RATIO:		N/A*	
Date:	*November 4, 2023*				

*HCM methodology does not calculate a maximum V/C ratio for this volume/lane combination. Consider another intersection configuration.



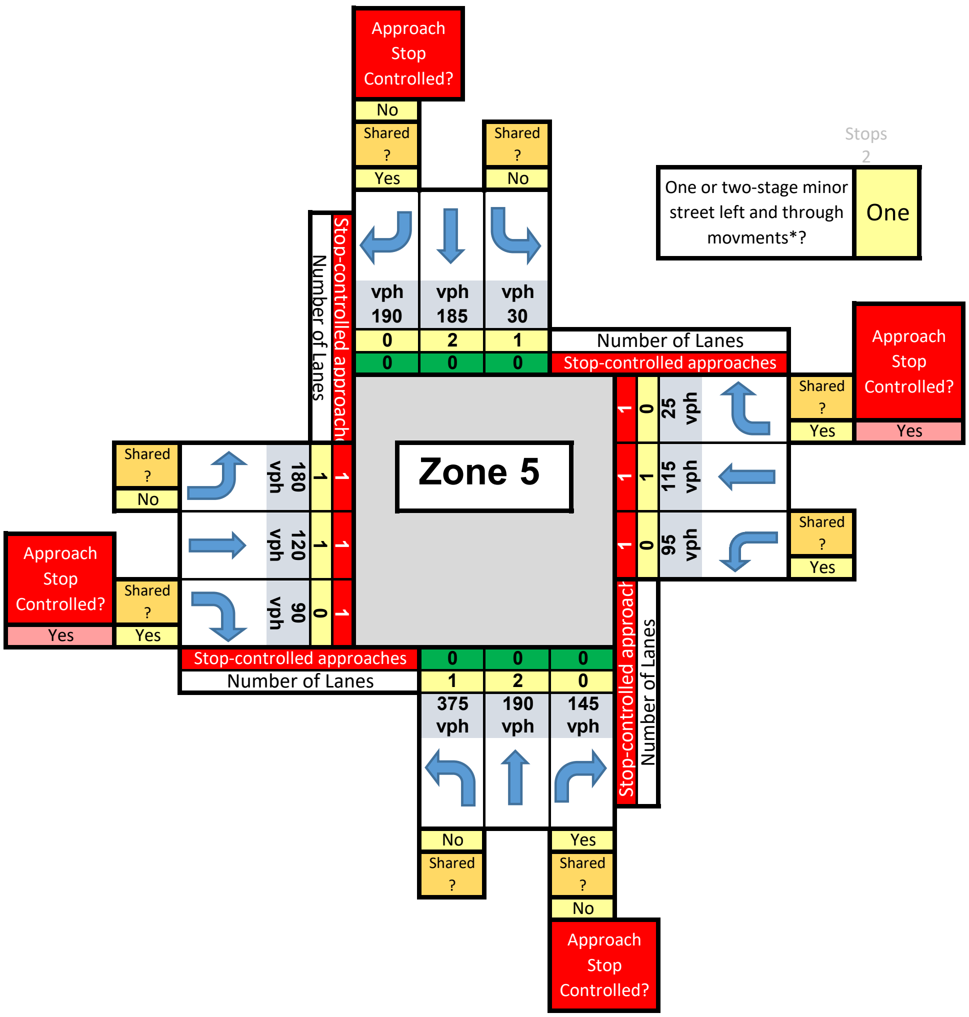
Note: This diagram does not reflect the actual lane configuration of the intersection

Two-Way Stop Control (TWSC)

DATA INPUT AND CONFIGURATION

Step 1: Identify which approaches are stop-controlled by selecting "Yes" from the drop-down box.

Step 2: Enter the lane configurations in the yellow cells.



Back to Results

Two-Way Stop Control (TWSC)

HCM 6 CALCULATIONS

Priority	MVMT	Rank
7	EBL	4
8	EBT	3
9	EBR	2
10	WBL	4
11	WBT	3
12	WBR	2
4	NBL	2
5	NBT	1
6	NBR	1
1	SBL	2
2	SBT	1
3	SBR	1

MAJOR	MINOR
NB	EB
SB	WB

Major street lanes	4
M1 Shared?	FALSE
M4 Shared?	FALSE

Priority	Rank	Flow Rates	Lanes	Shared?	Stop controlled?	Truck %
1	2	30	1	No		0.02
4	2	375	1	No		0.02
7	4	180	1	No	Yes	0.02
8	3	120	1		Yes	0.02
9	2	90	0	Yes	Yes	0.02
10	4	95	0	Yes	Yes	0.02
11	3	115	1		Yes	0.02
12	2	25	0	Yes	Yes	0.02
2	1	185	2			0.02
3	1	190	0	Yes	No	0.02
5	1	190	2			0.02
6	1	145	0	Yes	No	0.02

Conflicting Flows	
$v_{c,1}$	335.00
$v_{c,4}$	375.00
$v_{c,7}$	1242.50
$v_{c,8}$	1425.00
$v_{c,9}$	187.50
$v_{c,10}$	1225.00
$v_{c,11}$	1447.50
$v_{c,12}$	167.50

$v_{c,I,7}$	340.00
$v_{c,II,7}$	902.50
$v_{c,I,8}$	340.00
$v_{c,II,8}$	1085.00
$v_{c,I,10}$	1012.50
$v_{c,II,10}$	212.50
$v_{c,I,11}$	1012.50
$v_{c,II,11}$	435.00

Critical Headways	
$t_{c,1}$	4.14
$t_{c,4}$	4.14
$t_{c,7}$	7.54
$t_{c,8}$	6.54
$t_{c,9}$	6.94
$t_{c,10}$	7.54
$t_{c,11}$	6.54
$t_{c,12}$	6.94

$t_{c,I,7}$	6.54
$t_{c,II,7}$	6.54
$t_{c,I,8}$	5.54
$t_{c,II,8}$	5.54
$t_{c,I,10}$	6.54
$t_{c,II,10}$	6.54
$t_{c,I,11}$	5.54
$t_{c,II,11}$	5.54

a	0.91

***Assumption:**	One storage space in median (n_m = 1) for two-stage turns

Saturation Flow Rates	
Through	1800
Right	1500

Follow-Up Headways	
$t_{f,1}$	2.22
$t_{f,4}$	2.22
$t_{f,7}$	3.52
$t_{f,8}$	4.02
$t_{f,9}$	3.32
$t_{f,10}$	3.52
$t_{f,11}$	4.02
$t_{f,12}$	3.32

Potential Capacities	
$c_{p,1}$	1221.03
$c_{p,4}$	1180.07
$c_{p,7}$	130.92
$c_{p,8}$	134.41
$c_{p,9}$	822.61
$c_{p,10}$	134.87
$c_{p,11}$	130.24
$c_{p,12}$	847.31

Two-Stage Potential Capacities	
$c_{p,I,7}$	648.19
$c_{p,II,7}$	298.77
$c_{p,I,8}$	637.80
$c_{p,II,8}$	290.93
$c_{p,I,10}$	256.04
$c_{p,II,10}$	769.91
$c_{p,I,11}$	314.78
$c_{p,II,11}$	578.86

y_7	10.22
y_8	6.74
y_{10}	1.06
$y11$	1.24

Movement Capacities	
$c_{m,1}$	1221.03
$c_{m,4}$	1180.07
$c_{m,7}$	0.00
$c_{m,8}$	89.45
$c_{m,9}$	822.61
$c_{m,10}$	0.00
$c_{m,11}$	86.67
$c_{m,12}$	847.31

Two-Stage Movement Capacities	
$c_{m,I,7}$	632.26
$c_{m,II,7}$	91.88
$c_{m,I,8}$	622.13
$c_{m,II,8}$	198.48
$c_{m,I,10}$	174.68
$c_{m,II,10}$	539.82
$c_{m,I,11}$	214.75
$c_{m,II,11}$	564.63

$c_{T,7}$	51.45
$c_{T,8}$	144.46
$c_{T,10}$	77.41
$c_{T,11}$	131.21

Mvmt 1, excl left	$p_{0,1}$	0.98
Mvmt 4, excl left	$p_{0,4}$	0.68

Mvmt 1, shared left	$p^*_{0,1}$	0.97
Mvmt 4, shared left	$p^*_{0,4}$	0.60

Mvmt 7, 4-leg	p''_7	0.000
Mvmt 10, 4-leg	p''_{10}	0.000

$x_{1i,1+2}$	0.23
$x_{4i,1+2}$	0.20

One Stage	f_8	0.67
	f_{11}	0.67
	f_7	0.00
	f_{10}	0.00

Two Stage	$f_{I,8}$	0.98
	$f_{I,11}$	0.68
	$f_{I,7}$	0.98
	$f_{I.10}$	0.68

Shared Movement Capacities	
0	144.73
1	
1	
1	0.00
1	
1	

Single-Stage Movement Capacities	
$c_{m,7}$	0.00
$c_{m,8}$	89.45
$c_{m,10}$	0.00
$c_{m,11}$	86.67

$p_{0,8}$	0.00
$p_{0,11}$	0.00

p'_7	0.00
p'_{10}	0.00

$f_{II,8}$	0.68
$f_{II,11}$	0.98
$f_{II,7}$	0.31
$f_{II.10}$	0.70

Movement Capacities	
1	1221.03
2	3600.00
3	1500.00
4	1180.07
5	3600.00
6	1500.00
7	0.00
8-9	144.73
--	--
--	--
10-11-12	0.00
--	--

$p_{0,9}$	0.89
$p_{0,12}$	0.97

$f_{p,7}$	0.00
$f_{p,10}$	0.00

$p_{0,I,8}$	0.81
$p_{0,I,11}$	0.46

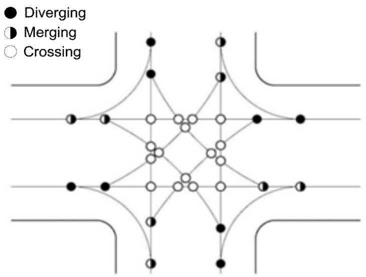
Movement V/C	
1	0.02
2	0.05
3	0.13
4	0.32
5	0.05
6	0.10
7	0.00
8-9	1.45
--	--
--	--
10-11-12	0.00
--	--

Intersection V/C
N/A*

V/C Not Reported for Any Movements?
Yes

*HCM methodology does not calculate a maximum V/C ratio for this volume/lane combination. Consider another intersection configuration.

Safety - Conflict Point Diagram



Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Weighted Total Conflict Points

48

Assumptions

- This worksheet does not use the CLV methodology. The calculations are based on the *HCM, 6th Edition* . The calculations are based on vehicles per hour.

Planning Level Cost $ $ $ $ $ 1

- Cost Category 1
- Assumes no intersection, but cost of new road is not included

Appendix E

Signalized Intersection Synchro/SimTraffic Outputs

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	190	170	165	105	115	40	110	140	60	25	175	30
Future Volume (veh/h)	190	170	165	105	115	40	110	140	60	25	175	30
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	207	185	179	114	125	43	120	152	65	27	190	33
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	494	324	313	196	172	51	607	996	408	587	1109	189
Arrive On Green	0.07	0.37	0.37	0.24	0.24	0.24	0.06	0.41	0.41	0.02	0.37	0.37
Sat Flow, veh/h	1781	873	845	470	724	215	1781	2459	1007	1781	3036	518
Grp Volume(v), veh/h	207	0	364	282	0	0	120	108	109	27	110	113
Grp Sat Flow(s),veh/h/ln	1781	0	1718	1409	0	0	1781	1777	1689	1781	1777	1777
Q Serve(g_s), s	4.0	0.0	10.1	9.2	0.0	0.0	2.4	2.3	2.5	0.6	2.5	2.6
Cycle Q Clear(g_c), s	4.0	0.0	10.1	11.3	0.0	0.0	2.4	2.3	2.5	0.6	2.5	2.6
Prop In Lane	1.00		0.49	0.40		0.15	1.00		0.60	1.00		0.29
Lane Grp Cap(c), veh/h	494	0	637	419	0	0	607	720	684	587	649	649
V/C Ratio(X)	0.42	0.00	0.57	0.67	0.00	0.00	0.20	0.15	0.16	0.05	0.17	0.17
Avail Cap(c_a), veh/h	494	0	773	527	0	0	612	720	684	663	649	649
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	15.0	0.0	15.1	21.6	0.0	0.0	10.3	11.3	11.3	11.4	12.9	12.9
Incr Delay (d2), s/veh	0.6	0.0	0.8	2.4	0.0	0.0	0.2	0.4	0.5	0.0	0.6	0.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.0	0.0	3.8	3.8	0.0	0.0	0.9	0.9	0.9	0.2	1.0	1.1
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	15.6	0.0	15.9	24.0	0.0	0.0	10.5	11.7	11.8	11.4	13.4	13.5
LnGrp LOS	B	A	B	C	A	A	B	B	B	B	B	B
Approach Vol, veh/h		571			282			337			250	
Approach Delay, s/veh		15.8			24.0			11.3			13.2	
Approach LOS		B			C			B			B	
Timer - Assigned Phs	1	2		4	5	6	7	8				
Phs Duration (G+Y+Rc), s	5.4	28.3		26.2	7.8	25.9	8.0	18.2				
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0	4.0	4.0				
Max Green Setting (Gmax), s	4.0	17.0		27.0	4.0	17.0	4.0	19.0				
Max Q Clear Time (g_c+I1), s	2.6	4.5		12.1	4.4	4.6	6.0	13.3				
Green Ext Time (p_c), s	0.0	1.0		2.1	0.0	1.0	0.0	0.9				
Intersection Summary												
HCM 6th Ctrl Delay			15.9									
HCM 6th LOS			B									

Intersection: 4: Annapolis Way & Marina Way Ext/Marina Way

Movement	EB	EB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	TR	LTR	L	T	TR	L	T	TR
Maximum Queue (ft)	164	211	224	105	93	88	41	100	56
Average Queue (ft)	78	107	119	40	39	30	10	38	10
95th Queue (ft)	132	180	196	82	80	66	31	78	32
Link Distance (ft)	763	763	547		489	489		544	544
Upstream Blk Time (%)									
Queuing Penalty (veh)									
Storage Bay Dist (ft)				225			250		
Storage Blk Time (%)									
Queuing Penalty (veh)									

Network Summary

Network wide Queuing Penalty: 0

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↱			✥		↰	↑↱		↰	↑↱	
Traffic Volume (veh/h)	180	120	90	95	115	25	375	190	145	30	185	190
Future Volume (veh/h)	180	120	90	95	115	25	375	190	145	30	185	190
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	196	130	98	103	125	27	408	207	158	33	201	207
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	472	332	251	188	171	33	583	856	622	507	588	524
Arrive On Green	0.07	0.34	0.34	0.20	0.20	0.20	0.13	0.44	0.44	0.03	0.33	0.33
Sat Flow, veh/h	1781	990	746	515	845	161	1781	1964	1426	1781	1777	1585
Grp Volume(v), veh/h	196	0	228	255	0	0	408	186	179	33	201	207
Grp Sat Flow(s),veh/h/ln	1781	0	1736	1521	0	0	1781	1777	1614	1781	1777	1585
Q Serve(g_s), s	4.0	0.0	6.0	7.9	0.0	0.0	8.0	4.0	4.2	0.7	5.1	6.0
Cycle Q Clear(g_c), s	4.0	0.0	6.0	9.5	0.0	0.0	8.0	4.0	4.2	0.7	5.1	6.0
Prop In Lane	1.00		0.43	0.40		0.11	1.00		0.88	1.00		1.00
Lane Grp Cap(c), veh/h	472	0	583	392	0	0	583	775	704	507	588	524
V/C Ratio(X)	0.42	0.00	0.39	0.65	0.00	0.00	0.70	0.24	0.25	0.07	0.34	0.39
Avail Cap(c_a), veh/h	472	0	694	487	0	0	583	775	704	575	588	524
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	16.5	0.0	15.2	22.7	0.0	0.0	11.5	10.7	10.7	12.6	15.1	15.4
Incr Delay (d2), s/veh	0.6	0.0	0.4	2.1	0.0	0.0	3.7	0.7	0.9	0.1	1.6	2.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.0	0.0	2.3	3.5	0.0	0.0	3.6	1.6	1.5	0.3	2.2	2.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	17.1	0.0	15.7	24.9	0.0	0.0	15.2	11.4	11.6	12.6	16.7	17.7
LnGrp LOS	B	A	B	C	A	A	B	B	B	B	B	B
Approach Vol, veh/h		424			255			773			441	
Approach Delay, s/veh		16.3			24.9			13.5			16.9	
Approach LOS		B			C			B			B	

Timer - Assigned Phs	1	2		4	5	6	7	8
Phs Duration (G+Y+Rc), s	5.7	30.2		24.1	12.0	23.9	8.0	16.1
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	4.0	20.0		24.0	8.0	16.0	4.0	16.0
Max Q Clear Time (g_c+I1), s	2.7	6.2		8.0	10.0	8.0	6.0	11.5
Green Ext Time (p_c), s	0.0	1.9		1.2	0.0	1.6	0.0	0.6

Intersection Summary	
HCM 6th Ctrl Delay	16.4
HCM 6th LOS	B

Intersection: 4: Annapolis Way & Marina Way Ext/Marina Way

Movement	EB	EB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	TR	LTR	L	T	TR	L	T	TR
Maximum Queue (ft)	168	143	214	209	139	132	43	109	118
Average Queue (ft)	81	70	107	114	38	55	13	49	39
95th Queue (ft)	137	119	178	192	97	101	34	92	86
Link Distance (ft)	763	763	547		489	489		544	544
Upstream Blk Time (%)									
Queuing Penalty (veh)									
Storage Bay Dist (ft)				225			250		
Storage Blk Time (%)				0	0				
Queuing Penalty (veh)				0	0				

Network Summary

Network wide Queuing Penalty: 0

Appendix F

Roundabout SIDRA Output

MOVEMENT SUMMARY

Site: 101 [AM (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

New Site
Site Category: Proposed Design 1
Roundabout
Sensitivity Analysis (Critical Gap & Follow-up Headway): Results for Parameter Scale = 120.0 %

Vehicle Movement Performance

Mov ID	Turn	Mov Class	Demand Flows [Total	HV]	Arrival Flows [Total	HV]	Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue [Veh.	Dist]	Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			veh/h	%	veh/h	%	v/c	sec		veh	ft				mph
South: Annapolis Way															
3	L2	All MCs	120	2.0	120	2.0	0.377	9.8	LOS A	1.7	43.9	0.58	0.49	0.62	17.6
8	T1	All MCs	152	2.0	152	2.0	0.377	9.8	LOS A	1.7	43.9	0.58	0.49	0.62	17.9
18	R2	All MCs	65	2.0	65	2.0	0.041	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	24.3
Approach			337	2.0	337	2.0	0.377	7.9	LOS A	1.7	43.9	0.47	0.40	0.50	18.7
East: Marina Way															
1	L2	All MCs	114	2.0	114	2.0	0.454	12.7	LOS B	2.6	67.1	0.67	0.69	0.89	16.7
6	T1	All MCs	125	2.0	125	2.0	0.454	12.7	LOS B	2.6	67.1	0.67	0.69	0.89	17.2
16	R2	All MCs	43	2.0	43	2.0	0.454	12.7	LOS B	2.6	67.1	0.67	0.69	0.89	17.2
Approach			283	2.0	283	2.0	0.454	12.7	LOS B	2.6	67.1	0.67	0.69	0.89	17.0
North: Annapolis Way															
7	L2	All MCs	27	2.0	27	2.0	0.287	11.0	LOS B	1.2	30.5	0.52	0.40	0.52	19.4
4	T1	All MCs	190	2.0	190	2.0	0.287	8.0	LOS A	1.2	30.5	0.52	0.40	0.52	19.4
14	R2	All MCs	33	2.0	33	2.0	0.020	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	24.3
Approach			250	2.0	250	2.0	0.287	7.3	LOS A	1.2	30.5	0.45	0.34	0.45	19.9
West: Proposed Marina Way															
5	L2	All MCs	207	2.0	207	2.0	0.497	11.3	LOS B	3.3	83.5	0.60	0.55	0.78	17.2
2	T1	All MCs	185	2.0	185	2.0	0.497	14.3	LOS B	3.3	83.5	0.60	0.55	0.78	17.6
12	R2	All MCs	179	2.0	179	2.0	0.109	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	24.3
Approach			571	2.0	571	2.0	0.497	8.8	LOS A	3.3	83.5	0.41	0.38	0.53	18.8
All Vehicles			1440	2.0	1440	2.0	0.497	9.1	LOS A	3.3	83.5	0.48	0.44	0.58	18.6

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Options tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Stopline Delay: Geometric Delay is not included).
Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.
Gap-Acceptance Capacity Formula: Siegloch M1 implied by US HCM 6 Roundabout Capacity Model.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.
Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

Site: 101 [PM (Site Folder: General)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

New Site
Site Category: Proposed Design 1
Roundabout
Sensitivity Analysis (Critical Gap & Follow-up Headway): Results for Parameter Scale = 120.0 %

Vehicle Movement Performance

Mov ID	Turn	Mov Class	Demand Flows [Total veh/h	HV] %	Arrival Flows [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% Back Of Queue [Veh. veh	Dist] ft	Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed mph
South: Annapolis Way															
3	L2	All MCs	408	2.0	408	2.0	0.810	24.9	LOS C	13.8	349.8	0.92	1.29	1.94	12.9
8	T1	All MCs	207	2.0	207	2.0	0.810	24.9	LOS C	13.8	349.8	0.92	1.29	1.94	13.2
18	R2	All MCs	158	2.0	158	2.0	0.100	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	24.3
Approach			772	2.0	772	2.0	0.810	19.8	LOS C	13.8	349.8	0.73	1.03	1.54	14.3
East: Marina Way															
1	L2	All MCs	103	2.0	103	2.0	0.602	25.1	LOS D	3.5	88.4	0.82	1.02	1.29	13.3
6	T1	All MCs	125	2.0	125	2.0	0.602	25.1	LOS D	3.5	88.4	0.82	1.02	1.29	13.7
16	R2	All MCs	5	2.0	5	2.0	0.602	25.1	LOS D	3.5	88.4	0.82	1.02	1.29	13.8
Approach			234	2.0	234	2.0	0.602	25.1	LOS D	3.5	88.4	0.82	1.02	1.29	13.5
North: Annapolis															
7	L2	All MCs	33	2.0	33	2.0	0.434	16.8	LOS C	2.2	56.4	0.70	0.76	0.93	17.1
4	T1	All MCs	201	2.0	201	2.0	0.434	13.8	LOS B	2.2	56.4	0.70	0.76	0.93	16.9
14	R2	All MCs	207	2.0	207	2.0	0.126	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	24.3
Approach			440	2.0	440	2.0	0.434	7.6	LOS A	2.2	56.4	0.37	0.40	0.49	19.6
West: Marina Way															
5	L2	All MCs	196	2.0	196	2.0	0.423	10.1	LOS B	2.2	56.1	0.58	0.46	0.63	17.5
2	T1	All MCs	130	2.0	130	2.0	0.423	13.1	LOS B	2.2	56.1	0.58	0.46	0.63	17.9
12	R2	All MCs	98	2.0	98	2.0	0.060	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	24.3
Approach			424	2.0	424	2.0	0.423	8.7	LOS A	2.2	56.1	0.44	0.36	0.48	18.7
All Vehicles			1870	2.0	1870	2.0	0.810	15.1	LOS C	13.8	349.8	0.59	0.73	1.02	16.0

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Options tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Stopline Delay: Geometric Delay is not included).
Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.
Gap-Acceptance Capacity Formula: Siegloch M1 implied by US HCM 6 Roundabout Capacity Model.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.
Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

Site: 101 [AM -2 (Site Folder: Dual Lane)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

New Site
Site Category: Proposed Design 1
Roundabout
Sensitivity Analysis (Critical Gap & Follow-up Headway): Results for Parameter Scale = 120.0 %

Vehicle Movement Performance

Mov ID	Turn	Mov Class	Demand Flows [Total veh/h	HV] %	Arrival Flows [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% Back Of Queue [Veh. veh	Dist] ft	Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed mph
South: Annapolis Way															
3	L2	All MCs	120	2.0	120	2.0	0.233	7.6	LOS A	0.9	22.6	0.51	0.41	0.51	16.3
8	T1	All MCs	152	2.0	152	2.0	0.233	7.6	LOS A	0.9	22.6	0.51	0.41	0.51	20.1
18	R2	All MCs	65	2.0	65	2.0	0.233	7.6	LOS A	0.9	22.6	0.51	0.41	0.51	20.4
Approach			337	2.0	337	2.0	0.233	7.6	LOS A	0.9	22.6	0.51	0.41	0.51	18.5
East: Marina Way															
1	L2	All MCs	114	2.0	114	2.0	0.401	10.5	LOS B	1.9	48.2	0.58	0.56	0.71	20.2
6	T1	All MCs	125	2.0	125	2.0	0.401	10.5	LOS B	1.9	48.2	0.58	0.56	0.71	19.2
16	R2	All MCs	43	2.0	43	2.0	0.401	10.5	LOS B	1.9	48.2	0.58	0.56	0.71	19.2
Approach			283	2.0	283	2.0	0.401	10.5	LOS B	1.9	48.2	0.58	0.56	0.71	19.6
North: Annapolis Way															
7	L2	All MCs	27	2.0	27	2.0	0.164	6.4	LOS A	0.6	15.5	0.46	0.35	0.46	17.9
4	T1	All MCs	190	2.0	190	2.0	0.164	6.4	LOS A	0.6	15.5	0.46	0.35	0.46	20.9
14	R2	All MCs	33	2.0	33	2.0	0.164	6.4	LOS A	0.6	15.5	0.46	0.35	0.46	21.1
Approach			250	2.0	250	2.0	0.164	6.4	LOS A	0.6	15.5	0.46	0.35	0.46	20.5
West: Proposed Marina Way															
5	L2	All MCs	207	2.0	207	2.0	0.483	10.8	LOS B	2.9	74.4	0.56	0.51	0.71	15.5
2	T1	All MCs	185	2.0	185	2.0	0.483	10.8	LOS B	2.9	74.4	0.56	0.51	0.71	19.0
12	R2	All MCs	179	2.0	179	2.0	0.238	7.4	LOS A	0.9	22.9	0.46	0.35	0.46	19.9
Approach			571	2.0	571	2.0	0.483	9.8	LOS A	2.9	74.4	0.53	0.46	0.63	17.7
All Vehicles			1440	2.0	1440	2.0	0.483	8.8	LOS A	2.9	74.4	0.52	0.45	0.59	18.7

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Options tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Stopline Delay: Geometric Delay is not included).
Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.
Gap-Acceptance Capacity Formula: Siegloch M1 implied by US HCM 6 Roundabout Capacity Model.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.
Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

MOVEMENT SUMMARY

Site: 101 [PM - 2 (Site Folder: Dual Lane)]

Output produced by SIDRA INTERSECTION Version: 9.1.3.210

New Site
Site Category: Proposed Design 1
Roundabout
Sensitivity Analysis (Critical Gap & Follow-up Headway): Results for Parameter Scale = 120.0 %

Vehicle Movement Performance

Mov ID	Turn	Mov Class	Demand Flows [Total	HV]	Arrival Flows [Total	HV]	Deg. Satn	Aver. Delay	Level of Service	95% Back Of Queue [Veh.	Dist]	Prop. Que	Eff. Stop Rate	Aver. No. of Cycles	Aver. Speed
			veh/h	%	veh/h	%	v/c	sec		veh	ft				mph
South: Annapolis Way															
3	L2	All MCs	408	2.0	408	2.0	0.535	12.5	LOS B	4.0	100.7	0.65	0.65	0.91	19.2
8	T1	All MCs	207	2.0	207	2.0	0.478	11.2	LOS B	3.0	75.7	0.61	0.56	0.78	18.6
18	R2	All MCs	158	2.0	158	2.0	0.478	11.2	LOS B	3.0	75.7	0.61	0.56	0.78	18.7
Approach			772	2.0	772	2.0	0.535	11.9	LOS B	4.0	100.7	0.63	0.61	0.85	18.9
East: Marina Way															
1	L2	All MCs	103	2.0	103	2.0	0.480	16.3	LOS C	2.3	59.2	0.71	0.86	1.05	18.0
6	T1	All MCs	125	2.0	125	2.0	0.480	16.3	LOS C	2.3	59.2	0.71	0.86	1.05	17.2
16	R2	All MCs	5	2.0	5	2.0	0.480	16.3	LOS C	2.3	59.2	0.71	0.86	1.05	17.3
Approach			234	2.0	234	2.0	0.480	16.3	LOS C	2.3	59.2	0.71	0.86	1.05	17.5
North: Annapolis															
7	L2	All MCs	33	2.0	33	2.0	0.396	12.6	LOS B	1.9	47.9	0.67	0.71	0.85	16.1
4	T1	All MCs	201	2.0	201	2.0	0.396	12.6	LOS B	1.9	47.9	0.67	0.71	0.85	18.2
14	R2	All MCs	207	2.0	207	2.0	0.396	12.6	LOS B	1.9	47.9	0.67	0.71	0.85	17.8
Approach			440	2.0	440	2.0	0.396	12.6	LOS B	1.9	47.9	0.67	0.71	0.85	17.8
West: Marina Way															
5	L2	All MCs	196	2.0	196	2.0	0.410	9.6	LOS A	1.9	49.1	0.54	0.42	0.56	15.8
2	T1	All MCs	130	2.0	130	2.0	0.410	9.6	LOS A	1.9	49.1	0.54	0.42	0.56	19.5
12	R2	All MCs	98	2.0	98	2.0	0.133	6.3	LOS A	0.5	12.1	0.44	0.34	0.44	20.6
Approach			424	2.0	424	2.0	0.410	8.9	LOS A	1.9	49.1	0.51	0.40	0.53	17.7
All Vehicles			1870	2.0	1870	2.0	0.535	11.9	LOS B	4.0	100.7	0.62	0.62	0.80	18.2

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Options tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Stopline Delay: Geometric Delay is not included).
Queue Model: SIDRA queue estimation methods are used for Back of Queue and Queue at Start of Gap.
Gap-Acceptance Capacity Formula: Siegloch M1 implied by US HCM 6 Roundabout Capacity Model.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.
Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

Appendix G

All-Way Stop Control Intersection Synchro Output – Opening Year

Intersection	
Intersection Delay, s/veh	12.3
Intersection LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	135	120	115	75	80	30	75	100	40	20	125	20
Future Vol, veh/h	135	120	115	75	80	30	75	100	40	20	125	20
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	147	130	125	82	87	33	82	109	43	22	136	22
Number of Lanes	1	1	0	0	1	0	1	1	0	0	1	1

Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	2	2	2
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	2	2	2	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	2	2	1	2
HCM Control Delay	12.4	13.2	11.5	12
HCM LOS	B	B	B	B

Lane	NBLn1	NBLn2	EBLn1	EBLn2	WBLn1	SBLn1	SBLn2
Vol Left, %	100%	0%	100%	0%	41%	14%	0%
Vol Thru, %	0%	71%	0%	51%	43%	86%	0%
Vol Right, %	0%	29%	0%	49%	16%	0%	100%
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	75	140	135	235	185	145	20
LT Vol	75	0	135	0	75	20	0
Through Vol	0	100	0	120	80	125	0
RT Vol	0	40	0	115	30	0	20
Lane Flow Rate	82	152	147	255	201	158	22
Geometry Grp	7	7	7	7	6	7	7
Degree of Util (X)	0.162	0.271	0.273	0.414	0.362	0.297	0.036
Departure Headway (Hd)	7.135	6.421	6.691	5.838	6.476	6.79	6.005
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cap	501	557	536	613	553	526	593
Service Time	4.905	4.191	4.452	3.597	4.544	4.565	3.779
HCM Lane V/C Ratio	0.164	0.273	0.274	0.416	0.363	0.3	0.037
HCM Control Delay	11.3	11.6	12	12.7	13.2	12.4	9
HCM Lane LOS	B	B	B	B	B	B	A
HCM 95th-tile Q	0.6	1.1	1.1	2	1.6	1.2	0.1

Intersection	
Intersection Delay, s/veh	15.3
Intersection LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	125	80	60	65	80	20	265	135	100	20	130	135
Future Vol, veh/h	125	80	60	65	80	20	265	135	100	20	130	135
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	136	87	65	71	87	22	288	147	109	22	141	147
Number of Lanes	1	1	0	0	1	0	1	1	0	0	1	1

Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	2	2	2
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	2	2	2	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	2	2	1	2
HCM Control Delay	13.5	15.4	17.6	12.7
HCM LOS	B	C	C	B

Lane	NBLn1	NBLn2	EBLn1	EBLn2	WBLn1	SBLn1	SBLn2
Vol Left, %	100%	0%	100%	0%	39%	13%	0%
Vol Thru, %	0%	57%	0%	57%	48%	87%	0%
Vol Right, %	0%	43%	0%	43%	12%	0%	100%
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	265	235	125	140	165	150	135
LT Vol	265	0	125	0	65	20	0
Through Vol	0	135	0	80	80	130	0
RT Vol	0	100	0	60	20	0	135
Lane Flow Rate	288	255	136	152	179	163	147
Geometry Grp	7	7	7	7	6	7	7
Degree of Util (X)	0.587	0.463	0.301	0.302	0.381	0.331	0.266
Departure Headway (Hd)	7.336	6.52	7.966	7.147	7.652	7.309	6.522
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cap	493	552	451	504	470	492	550
Service Time	5.075	4.259	5.708	4.888	5.698	5.053	4.265
HCM Lane V/C Ratio	0.584	0.462	0.302	0.302	0.381	0.331	0.267
HCM Control Delay	20	14.8	14.1	13	15.4	13.6	11.6
HCM Lane LOS	C	B	B	B	C	B	B
HCM 95th-tile Q	3.7	2.4	1.3	1.3	1.8	1.4	1.1

Appendix H

All-Way Stop Control Intersection Synchro Output – Design Year

Intersection	
Intersection Delay, s/veh	20.4
Intersection LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	190	170	165	105	115	40	110	140	60	25	175	30
Future Vol, veh/h	190	170	165	105	115	40	110	140	60	25	175	30
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	207	185	179	114	125	43	120	152	65	27	190	33
Number of Lanes	1	1	0	0	1	0	1	1	0	0	1	1

Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	2	2	2
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	2	2	2	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	2	2	1	2
HCM Control Delay	22.6	22.9	16.3	17.8
HCM LOS	C	C	C	C

Lane	NBLn1	NBLn2	EBLn1	EBLn2	WBLn1	SBLn1	SBLn2
Vol Left, %	100%	0%	100%	0%	40%	12%	0%
Vol Thru, %	0%	70%	0%	51%	44%	88%	0%
Vol Right, %	0%	30%	0%	49%	15%	0%	100%
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	110	200	190	335	260	200	30
LT Vol	110	0	190	0	105	25	0
Through Vol	0	140	0	170	115	175	0
RT Vol	0	60	0	165	40	0	30
Lane Flow Rate	120	217	207	364	283	217	33
Geometry Grp	7	7	7	7	6	7	7
Degree of Util (X)	0.282	0.469	0.455	0.714	0.617	0.496	0.067
Departure Headway (Hd)	8.494	7.759	7.923	7.056	7.863	8.216	7.425
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cap	422	463	452	510	458	437	480
Service Time	6.274	5.539	5.698	4.831	5.945	5.999	5.208
HCM Lane V/C Ratio	0.284	0.469	0.458	0.714	0.618	0.497	0.069
HCM Control Delay	14.6	17.3	17.2	25.7	22.9	18.9	10.7
HCM Lane LOS	B	C	C	D	C	C	B
HCM 95th-tile Q	1.1	2.5	2.3	5.7	4.1	2.7	0.2

Intersection	
Intersection Delay, s/veh	37.4
Intersection LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	180	120	90	95	115	25	375	190	145	30	185	190
Future Vol, veh/h	180	120	90	95	115	25	375	190	145	30	185	190
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	196	130	98	103	125	27	408	207	158	33	201	207
Number of Lanes	1	1	0	0	1	0	1	1	0	0	1	1

Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	2	2	2
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	2	2	2	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	2	2	1	2
HCM Control Delay	21.5	28.1	58.6	20.9
HCM LOS	C	D	F	C

Lane	NBLn1	NBLn2	EBLn1	EBLn2	WBLn1	SBLn1	SBLn2
Vol Left, %	100%	0%	100%	0%	40%	14%	0%
Vol Thru, %	0%	57%	0%	57%	49%	86%	0%
Vol Right, %	0%	43%	0%	43%	11%	0%	100%
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	375	335	180	210	235	215	190
LT Vol	375	0	180	0	95	30	0
Through Vol	0	190	0	120	115	185	0
RT Vol	0	145	0	90	25	0	190
Lane Flow Rate	408	364	196	228	255	234	207
Geometry Grp	7	7	7	7	6	7	7
Degree of Util (X)	1.007	0.816	0.509	0.543	0.649	0.576	0.47
Departure Headway (Hd)	8.898	8.064	9.557	8.725	9.346	9.054	8.188
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cap	408	448	380	415	388	402	440
Service Time	6.656	5.822	7.257	6.425	7.346	6.754	5.95
HCM Lane V/C Ratio	1	0.813	0.516	0.549	0.657	0.582	0.47
HCM Control Delay	77	38	21.8	21.3	28.1	23.3	18.1
HCM Lane LOS	F	E	C	C	D	C	C
HCM 95th-tile Q	12.5	7.6	2.8	3.1	4.4	3.5	2.5