

ROUNABOUT JUSTIFICATION REPORT

For

State Aid Project Numbers:
S.A.P. 062-593-004
Spine Road at Rice Creek Commons
in Ramsey County, Minnesota

Proposed Letting Date: Fiscal Year 2019

I hereby certify that this report was prepared by me or under my supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

_____	52721	10/10/2018
Douglas M. Arnold	Reg. No.	Date

REVIEWED:

_____	_____
County Engineer	Date

APPROVED:

_____	_____
Metro District State Aid Engineer	Date

PROJECT DESCRIPTION

Rice Creek Commons is a proposed multi-use development located generally north of CSAH 96 and east of US Highway 10 in the City of Arden Hills, Ramsey County, Minnesota. As part of the proposed development, a four-lane divided *A Minor Arterial* roadway is planned to be constructed to serve as the main roadway through the development. The roadway would be constructed from the current roundabout intersection located at the east interchange terminal at I-35W & CR H and would extend southeast to CSAH 96.

This Roundabout Justification Report (RJR) has been prepared to evaluate three proposed intersections along the Spine Road that will serve the “downtown” area of Rice Creek Commons that is generally located in the northern third of the development. Through the master planning of the Rice Creek Commons development, there is a desire to provide full movement roundabouts at the three northern intersections that are near the “downtown” area of the development.

Exhibit 1, provided in the **Appendix**, provides the general location of the Rice Creek Commons development and the three study intersections.

TRAFFIC ANALYSIS

Since this area is currently undeveloped, the traffic analysis was performed for build-out conditions (assumed to be 2040) of the proposed Rice Creek Commons development. Using information from previous traffic studies and data provided in the Institute of Transportation Engineers (ITE) *Trip Generation* 10th Edition, AM and PM peak hour traffic volumes were developed for the three intersections. The traffic analysis was performed to evaluate multiple intersection control alternatives, including side-street stop control, all-way stop control, traffic signal, and roundabout. The following section provides a summary of the traffic analysis.

VOLUME DEVELOPMENT

Forecasted traffic volumes at the three intersections were developed by a combination of proposed Rice Creek Commons development traffic and background (non-project) traffic that is anticipated to use the Spine Road. Following provides a summary of the volume development.

Development Traffic

Development traffic was generated based on the proposed development plan for the entire Rice Creek Commons project. Land uses and intensities were provided by the development team for each of the five (5) areas that the development is broken down into, with a total of 25 development areas. The overall development includes the following land uses:

- Residential: 580 single-family dwelling units, 580 multi-family dwelling units, 300 senior adult housing units
- Hotel: 200 hotel rooms
- Industrial: 234,400 SF of industrial park space
- Office: 472,400 SF of general office, 46,400 SF of medial office, 740,000 SF corporate campus
- Retail: 292,900 SF of general retail and 42,000 SF of movie theater

Trip generation for the development was calculated for daily, AM peak hour, and PM peak hour conditions using the Institute of Transportation Engineers (ITE) *Trip Generation* 10th Edition. Additionally, trip generation was calculated for the off-peak hours using *Trip Generation* for volume forecasting for the warrant analysis. A 10% reduction was considered to account for internal capture trips and trips generated by the development that would be served by alternative modes of transportation (i.e. transit, walking, and bicycle). Based on the calculation, the development is anticipated to generate +/- 34,700 daily trips, +/- 2,200 trips during the AM peak hour, and +/- 3,300 trips during the PM peak hour. A detailed trip generation table, broken up by development areas, is provided in the **Appendix**.

Based on the anticipated travel patterns of development traffic, it was assumed that 60% of the development traffic would travel to/from the north (I-35W, CR H, and Thumb Road) and 40% of the development traffic would travel to/from the south (CSAH 96) along the Spine Road. Anticipated development traffic for each of the 25 areas was assigned to the Spine Road assuming the 60%/40% split in traffic arrivals/destinations. **Exhibit 2**, provided in the **Appendix**, provides the forecasted AM and PM peak hour turning movement volumes for development traffic at the three study intersections.

Pedestrian activity is anticipated to be significant given the compatible land uses and density in the “down-town” area. The following forecast pedestrian volumes were provided by the developer team for the three intersections being analyzed:

- Northern Intersection – 30 (AM) to 60 (PM) pedestrians crossing Spine Road in the peak hour
- Central Intersection – 60 (AM) to 120 (PM) pedestrians crossing Spine Road in the peak hour
- Southern Intersection – 30 (AM) to 60 (PM) pedestrians crossing Spine Road in the peak hour

Background Traffic

In addition to development traffic, some background traffic is anticipated along the Spine Road. Based on the 2014 Traffic Forecast Memorandum for the I-35W/CR H Interchange Reconstruction Study, it was estimated that +/- 4,700 daily background trips would utilize the Spine Road. The daily traffic volume was broken down into AM and PM peak hour directional volumes using a K-factor of 0.09 for the AM peak hour and 0.10 for the PM peak hour, and a D-factor of 0.50 for the AM and PM peak hours. The background growth is higher during the AM and PM peak periods as the majority of the traffic is anticipated to be regional traffic that is diverting to avoid congestion on I-35W. For the warrant analysis, it was assumed that the background traffic would be +/- 15% lower one hour before/after the peak hour and +/- 45% lower other hours outside of the peak hours.

Total Forecasted Traffic

Exhibit 3, provided in the **Appendix A**, provides the total 2040 forecasted AM and PM peak hour turning movement volumes at the three intersections that includes both development traffic and background traffic.

INTERSECTION CONTROL WARRANT ANALYSIS

In order to determine if alternative intersection traffic control is justified, a warrant analysis was performed using the 2040 forecasted traffic volumes for all three intersections. All-way stop and traffic signal warrants are documented in the Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD). For the purposes of the warrant analysis and based on traffic patterns, the Spine Road is assumed to be the major street.

- All-Way Stop Warrant** – Section 2B.7 of the MnMUTCD provides guidance on when an all-way stop is warranted. This warrant is satisfied when the vehicle volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour (vph) for any eight hours of an average day and the combined vehicle, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 vph for the same eight-hour period of the major street.
- Traffic Signal Warrant** – Section 4 of the MnMUTCD provides guidance on when a traffic signal is a warranted. Typically, signal warrants are reviewed for the 8-hour (Warrant 1) requirements and under certain circumstances, the 4-hour (Warrant 2) and peak hour (Warrant 3).

Table 1 provides a summary of the all-way stop and traffic signal warrants for the three intersections based on the forecasted traffic volumes. It was assumed that the Spine Road (major street) approaches would include two through lanes and dedicated left and right turn lanes while the minor street approaches include a dedicated left-turn lane and shared through-right lane. For the warrant analysis, all volumes were included for the major street and left-turn volumes were included for the minor street.

Based on the analysis, all three intersections meet the warrants for all-way stop control. If the all-way stop warrant is satisfied, it is acceptable to consider roundabout control in addition to all-way stop control. The northern and southern intersections do not meet traffic signal warrants for Warrant 1. Although the Central intersection meets the Eight-Hour traffic signal warrant, a signal would not meet Ramsey County signal spacing requirements. All three intersections meet traffic signal warrants for Warrant 2 and Warrant 3. The warrant spreadsheets are provided in **Appendix B**.

Table 1 –Warrant Analysis Results

Warrant	Northern Intersection	Central Intersection	Southern Intersection
All-Way Stop Warrant (Stop Control)	0	0	0
Warrant 1A – Eight Hour (Signal)	X (0 of 8 Hours)	X (0 of 8 Hours)	X (4 of 8 Hours)
Warrant 1B – Eight Hour (Signal)	X (5 of 8 Hours)	0 (8 of 8 Hours)	X (5 of 8 Hours)
Warrant 2 – Four Hour (Signal)	0 (5 of 4 Hours)	0 (7 of 4 Hours)	0 (5 of 4 Hours)
Warrant 3 – Peak Hour (Signal)	0 (2 of 1 Hour)	0 (2 of 1 Hour)	0 (4 of 1 Hour)

INTERSECTION CAPACITY ANALYSIS

An intersection capacity analysis was performed using Synchro/SimTraffic in order to evaluate side-street stop, all-way stop, and signal intersection scenarios. RODEL was used to evaluate the roundabout condition. The SimTraffic analysis output is included in **Appendix C** and the RODEL analysis output is included in **Appendix D**.

For the stop control and signal analysis, it was assumed that the northbound and southbound approaches (major street) would include two through lanes and dedicated left and right turn lanes, and the eastbound and westbound approaches (minor street) would one shared left-through-right lane. For the roundabout analysis, it was assumed that the northbound and southbound approaches (major street) would be two lanes (two circulating lanes) and the eastbound and westbound approaches (minor street) would be one lane (one circulating lane). The following section provides a summary of intersection delay and LOS for each of the three intersections.

Northern Intersection

Table 2 provides a summary of the intersection analysis for the northern intersection. The analysis shows that the intersection is not anticipated to operate at an acceptable LOS with side-street stop control during the PM peak hour; therefore, a change in intersection control is necessary. Following provides a summary of the capacity analysis for all-way stop control, traffic signal, and roundabout:

- **All-Way Stop Control** – The overall intersection is anticipated to operate at LOS B during the AM and PM peak hours. During the PM peak hour, the northbound approach is anticipated to experience +/- 17 seconds of delay per vehicle and the southbound approach is anticipated to experience +/- 16 seconds of delay per vehicle.
- **Traffic Signal Control** – The overall intersection is anticipated to operate at LOS A during the AM and PM peak hours. During the PM peak hour, the eastbound approach is anticipated to experience +/- 33 seconds of delay per vehicle and the westbound approach is anticipated to experience +/- 18 seconds of delay per vehicle.
- **Roundabout Control** – The overall intersection is anticipated to operate at LOS A during the AM and PM peak hours. During the AM and PM peak hours, all approaches are anticipated to experience less than 10 seconds of delay per vehicle.

Based on the capacity analysis, a roundabout provides the best LOS at the northern intersection from an overall intersection and approach LOS perspective.

Table 2 –Intersection Operations Analysis Results (North Intersection)

CONTROL	APPROACH	AM PEAK HOUR		PM PEAK HOUR	
		Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
SIDE-STREET STOP CONTROL (EB/WB STOP)	EB	20.2	C	100+	F
	WB	13.1	B	87.8	F
	NB	0.8	A	1.4	A
	SB	1.0	A	1.7	A
	Overall	2.4	A	37.7	E
ALL-WAY STOP CONTROL	EB	4.4	A	7.5	A
	WB	4.9	A	7.1	A
	NB	12.5	B	17.0	C
	SB	9.9	A	15.6	C
	Overall	10.5	B	15.0	B
TRAFFIC SIGNAL	EB	22.6	C	33.3	C
	WB	16.2	B	17.9	B
	NB	2.6	A	4.9	A
	SB	2.2	A	5.0	A
	Overall	4.1	A	8.0	A
ROUNDAABOUT	EB	4.3	A	6.2	A
	WB	4.8	A	5.8	A
	NB	2.2	A	3.0	A
	SB	2.5	A	3.3	A
	Overall	2.6	A	3.5	A

Central Intersection

Table 3 provides a summary of the intersection analysis for the central intersection. The analysis shows that the intersection is not anticipated to operate at acceptable LOS with side-street stop control during the PM peak hour; therefore, a change in intersection control is necessary. Following provides a summary of the capacity analysis for all-way stop control, traffic signal, and roundabout:

- **All-Way Stop Control** – The overall intersection is anticipated to operate at LOS B during the AM and PM peak hours. During the PM peak hour, the northbound approach is anticipated to experience +/- 15 seconds of delay per vehicle and the southbound approach is anticipated to experience +/- 16 seconds of delay per vehicle.
- **Traffic Signal Control** – The overall intersection is anticipated to operate at LOS A during the AM and PM peak hours. During the PM peak hour, the eastbound approach is anticipated to experience +/- 23 seconds of delay per vehicle and the westbound approach is anticipated to experience +/- 28 seconds of delay per vehicle.
- **Roundabout Control** – The overall intersection is anticipated to operate at LOS A during the AM and PM peak hours. During the AM and PM peak hours, all approaches are anticipated to experience less than 10 seconds of delay per vehicle.

Based on the capacity analysis, a roundabout provides the best LOS at the central intersection from an overall intersection and approach LOS perspective.

Table 3 –Intersection Operations Analysis Results (Central Intersection)

CONTROL	APPROACH	AM PEAK HOUR		PM PEAK HOUR	
		Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
SIDE-STREET STOP CONTROL (EB/WB STOP)	EB	12.0	B	90.7	F
	WB	36.5	E	100+	F
	NB	0.7	A	1.6	A
	SB	0.9	A	1.7	A
	Overall	4.2	A	42.5	E
ALL-WAY STOP CONTROL	EB	3.9	A	7.0	A
	WB	5.3	A	7.8	A
	NB	12.0	B	15.4	C
	SB	12.2	B	15.9	C
	Overall	11.4	B	14.5	B
TRAFFIC SIGNAL	EB	19.7	B	22.5	C
	WB	31.6	C	27.8	C
	NB	2.8	A	4.8	A
	SB	2.9	A	4.9	A
	Overall	5.5	A	8.0	A
ROUNDAABOUT	EB	4.2	A	5.7	A
	WB	4.7	A	6.0	A
	NB	2.5	A	3.2	A
	SB	2.5	A	3.4	A
	Overall	2.7	A	3.7	A

Southern Intersection

Table 4 provides a summary of the intersection analysis for the southern intersection. The analysis shows that the intersection is not anticipated to operate at acceptable LOS with side-street stop control during the PM peak hour; therefore, a change in intersection control is necessary. Following provides a summary of the capacity analysis for all-way stop control, traffic signal, and roundabout:

- **All-Way Stop Control** – The overall intersection is anticipated to operate at LOS B during the AM and PM peak hours. During the PM peak hour, the northbound approach is anticipated to experience +/- 15 seconds of delay per vehicle and the southbound approach is anticipated to experience +/- 16 seconds of delay per vehicle.
- **Traffic Signal Control** – The overall intersection is anticipated to operate at LOS A during the AM and PM peak hours. During the PM peak hour, the eastbound approach is anticipated to experience +/- 36 seconds of delay per vehicle and the westbound approach is anticipated to experience +/- 23 seconds of delay per vehicle.
- **Roundabout Control** – The overall intersection is anticipated to operate at LOS A during the AM and PM peak hours. During the AM and PM peak hours, all approaches are anticipated to experience less than 10 seconds of delay per vehicle.

Based on the capacity analysis, a roundabout provides the best LOS at the southern intersection from an overall intersection and approach LOS perspective.

Table 4 –Intersection Operations Analysis Results (Southern Intersection)

CONTROL	APPROACH	AM PEAK HOUR		PM PEAK HOUR	
		Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
SIDE-STREET STOP CONTROL (EB/WB STOP)	EB	17.3	C	100+	F
	WB	16.0	C	66.2	F
	NB	1.0	A	1.0	A
	SB	0.9	A	1.5	A
	Overall	2.4	A	53.8	F
ALL-WAY STOP CONTROL	EB	5.0	A	8.4	B
	WB	4.9	A	6.3	A
	NB	10.4	B	15.3	C
	SB	11.6	B	16.3	C
	Overall	10.4	B	14.5	B
TRAFFIC SIGNAL	EB	27.4	C	36.3	D
	WB	20.6	C	22.7	C
	NB	2.3	A	5.1	A
	SB	2.6	A	4.8	A
	Overall	4.3	A	9.4	A
ROUNDAABOUT	EB	4.2	A	6.9	A
	WB	4.7	A	5.2	A
	NB	2.5	A	3.3	A
	SB	2.7	A	3.0	A
	Overall	2.8	A	3.7	A

CORRIDOR DELAY

An analysis was performed to determine the total average delay a vehicle would experience travelling through the three study intersections for all-way stop control, traffic signal control, and roundabout control. This was calculated by adding the approach delay in each direction for the three intersections based on information provided in Tables 2-4.

Table 5 provides a summary of the analysis, that includes the approach delay in each direction at the three study intersections. Based on this analysis, roundabout control is anticipated to provide the least amount of delay experienced through the three study intersections for the major street through movements.

Table 5 –Corridor Delay

CONTROL	DIRECTION OF TRAVEL	AM PEAK HOUR (SEC/VEH)	PM PEAK HOUR (SEC/VEH)
ALL-WAY STOP CONTROL	NB	34.9	47.7
	SB	33.7	47.8
TRAFFIC SIGNAL	NB	7.7	14.8
	SB	7.7	14.7
ROUNDAABOUT	NB	7.2	9.5
	SB	7.7	9.7

DESIGN DATA

The roundabout design meets MnDOT and FHWA guidelines for speed control and speed differential, and the layout is provided in **Exhibit 4**. The roundabouts have been designed to provide two approach lanes and two circulating lanes in the northbound and southbound directions, and one approach lane and one circulating lane in the eastbound and westbound directions.

The circulating lanes in the northbound and southbound directions have been designed with a width of 30 feet, while the circulating lane in the eastbound and westbound directions have been designed with a width of 22 feet. A 13-foot wide mountable truck apron with a D-style curb adjacent to the inside of the circulatory roadway has been proposed to accommodate the tracking of large vehicles, and protect future landscaping in the center island. The typical section of the roundabout (E/W and N/S circulating lanes) is provided in **Exhibit 5**.

Exhibit 6 provides the vehicle turning paths through the roundabout (assuming a WB-62 design vehicle). The fastest path results for each leg, as described in the FHWA [Roundabouts: An Informational Guide](#), is provided in **Exhibit 7**.

HORIZONTAL AND VERTICAL SIGHT DISTANCE

A horizontal sight distance analysis was completed to make sure that a vehicle entering or traveling through the roundabouts would have enough sight distance to see another potentially conflicting vehicle from far enough away to make a decision. The areas of the central island and median in which tall plantings would negatively impact driver sight triangles will be limited to low ground cover. **Exhibit 8** shows the assumed sight distance triangles for the typical roundabout.

AESTHETICS

The proposed project will introduce native landscape plantings in the central island. All plantings will have a caliper width of 4 inches or less at full maturity and will not obstruct views of the signs or impede sight distance.

SAFETY

At a roundabout, drivers must be aware of vehicles circulating through the roundabout to their left only, while at a typical intersection, drivers must be aware of vehicles on all approaches. With a traditional intersection, there are 32 conflict points. This number is reduced to 14 with a 2x1 roundabout.

There are reductions to crash rates with the introduction of a roundabout. Based on MnDOT's *A Study of the Traffic Safety at Roundabouts in Minnesota* (October 2017), there is a 78% reduction in serious injury crashes and an 18% decrease in all injury type crashes at intersections where unbalanced (2x1) roundabouts have been installed. Additionally, right-angle crashes, which are typically the deadliest type of crashes in Minnesota, are reduced by approximately 25%. Left-turn crashes are reduced by 83% for unbalanced (2x1) roundabouts.

Roundabouts have proven to improve safety is their ability to reduce operating speeds through the intersection. The geometry of the approaches to the roundabout and the circulating roadway limit driver speeds thus reducing the speed differential between vehicles, shallowing out conflict angles, and reducing the severity of crashes at the intersection.

PEDESTRIAN AND BICYCLIST IMPACTS

Due to the nature of the Main Street concept of the Rice Creek Commons development near the three study intersections, there is an anticipated to be a significant number of pedestrians crossing these intersections. Based on information provided by the project team, there are anticipated to be 30 to 60 pedestrians per hour crossing the Spine Road at the northern and southern intersections, and 60 to 120 per hour pedestrians crossing the Spine Road at the central intersection.

A 10-foot multi-use path is proposed along the east and west sides of the Spine Road.

There are no bike lanes proposed along the Spine Road or the side streets; therefore, bicyclists may ride through the roundabout with vehicular traffic or utilize the multi-use trail. Traffic circulating the roundabout will be traveling slowly enough for bicyclist to safely navigate the intersection, as long as they obey the rules of the roundabout, such as yielding to circulating traffic prior to entry.

COST

The largest cost typically required for construction of a roundabout is the cost to acquire the right-of-way to accommodate a roundabout. This cost is often greater than the right-of-way cost for a traditional intersection, because roundabouts generally take up more land area. However, since this is a proposed development, sufficient right-of-way can be set aside to accommodate roundabouts.

Construction of a roundabout compared to a traditional signalized intersection eliminates the large up-front cost of a traffic signal system. Operating and maintenance costs are similar between a roundabout and a traffic signal, as a roundabout has more cost in street lighting that is comparable to the cost to operate a traffic signal.

JUSTIFICATION

Roundabouts are justified at the three study intersections along the Spine Road for the following reasons:

- Minimum volume thresholds for all-way stop control are satisfied under future conditions, and a roundabout may be considered as an alternative to all-way stop control.
- Given that the Spine Road is classified as an *A Minor Arterial*, multi-way stop control is not desirable along this corridor given the delay introduced to through traffic on the major roadway.
- Traffic signals are not warranted for the Eight-Hour warrant (Warrant 1) at the Northern and Southern intersections. A traffic at the Central intersection does not meet Ramsey County signal spacing requirements.
- The analysis shows that all-way stop control and traffic signals introduces more delay than roundabout control. Roundabouts typically result in lower vehicle delay especially during off-peak periods than all-way stop control.
- The proposed roundabout is anticipated to provide adequate capacity and operate with very little delay on all approaches under future conditions.
- Pedestrian safety is anticipated to be improved with the installation of a roundabout as the splitter islands provide a two-stage crossing.
- Roundabouts fit the context of the area where significant public and private investment is planned near the roundabouts ultimately resulting in an increase in non-motorized trips along and across the Spine Road.
- Roundabouts are generally safer intersections. At unbalanced roundabouts (2x1), there is a significant decrease in serious injury crashes (83%) and all injury crashes (18%). Additionally, right-angle crashes, which are typically the deadliest type of crashes in Minnesota, are reduced by approximately 25%.

EXHIBITS

Exhibit 1: Project Site Location

Exhibit 2: Design (2040) Peak Hour Project Traffic Volumes

Exhibit 3: Design (2040) Peak Hour Total Traffic Volumes

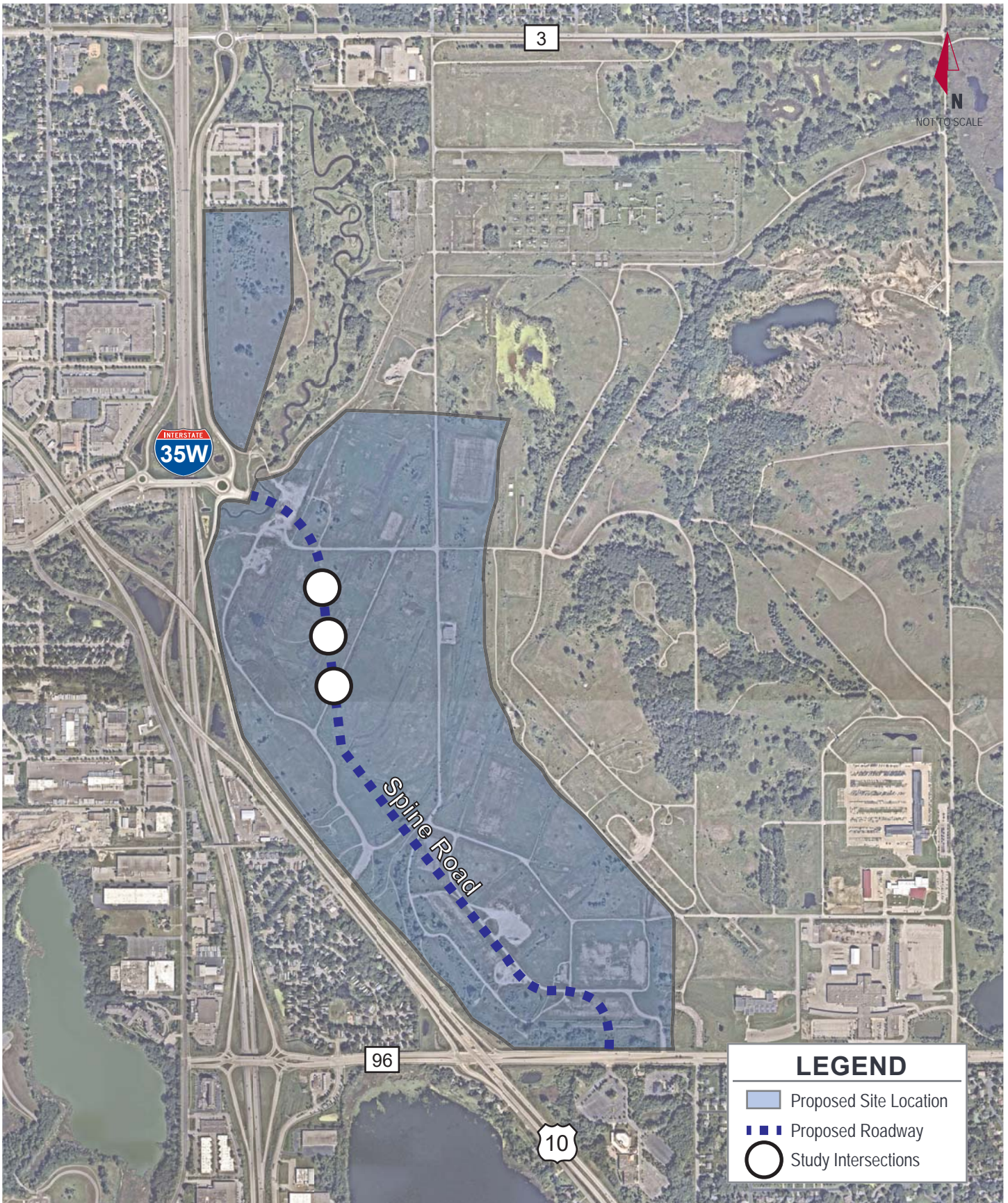
Exhibit 4: Roundabout Layout

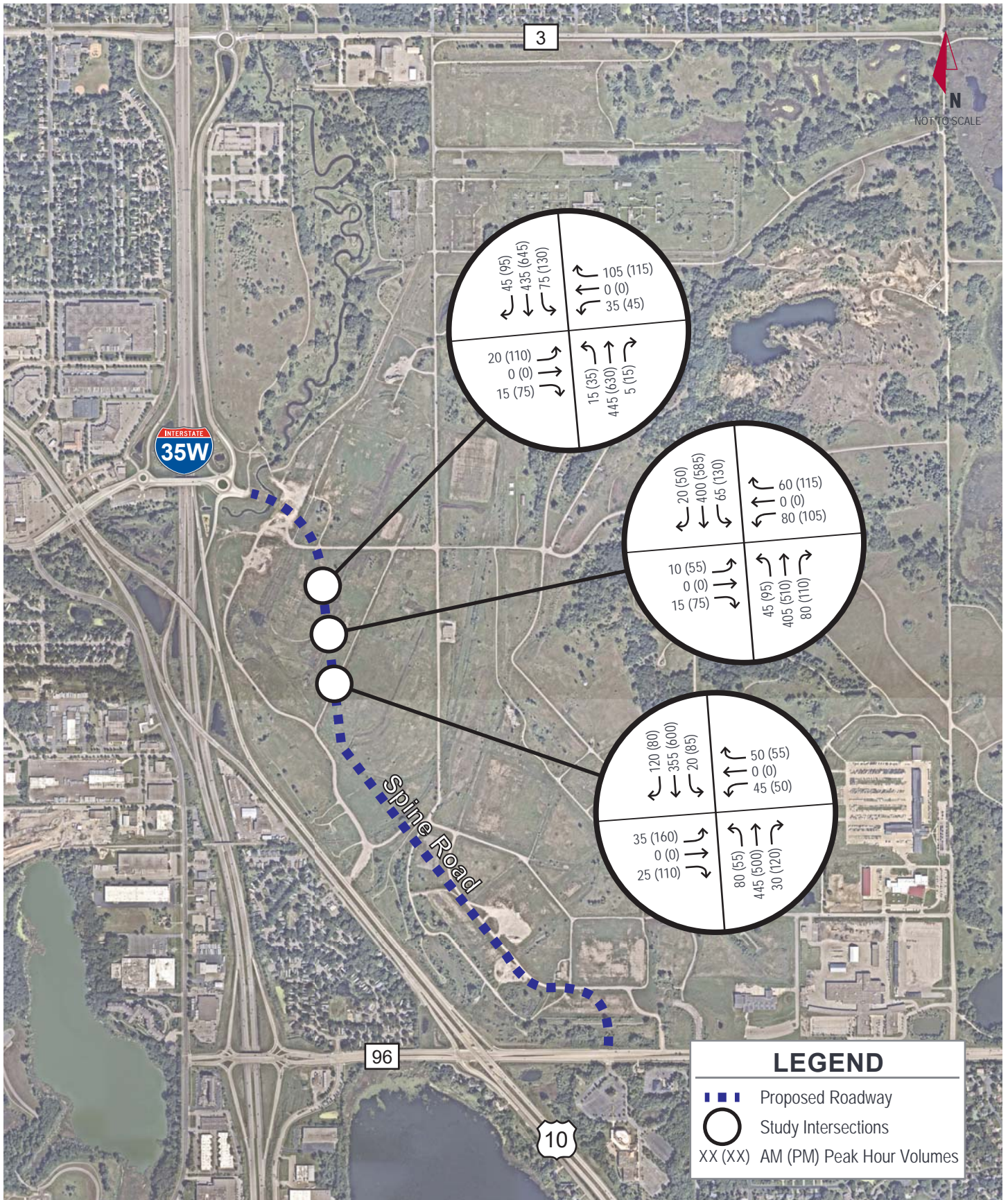
Exhibit 5: Typical Sections

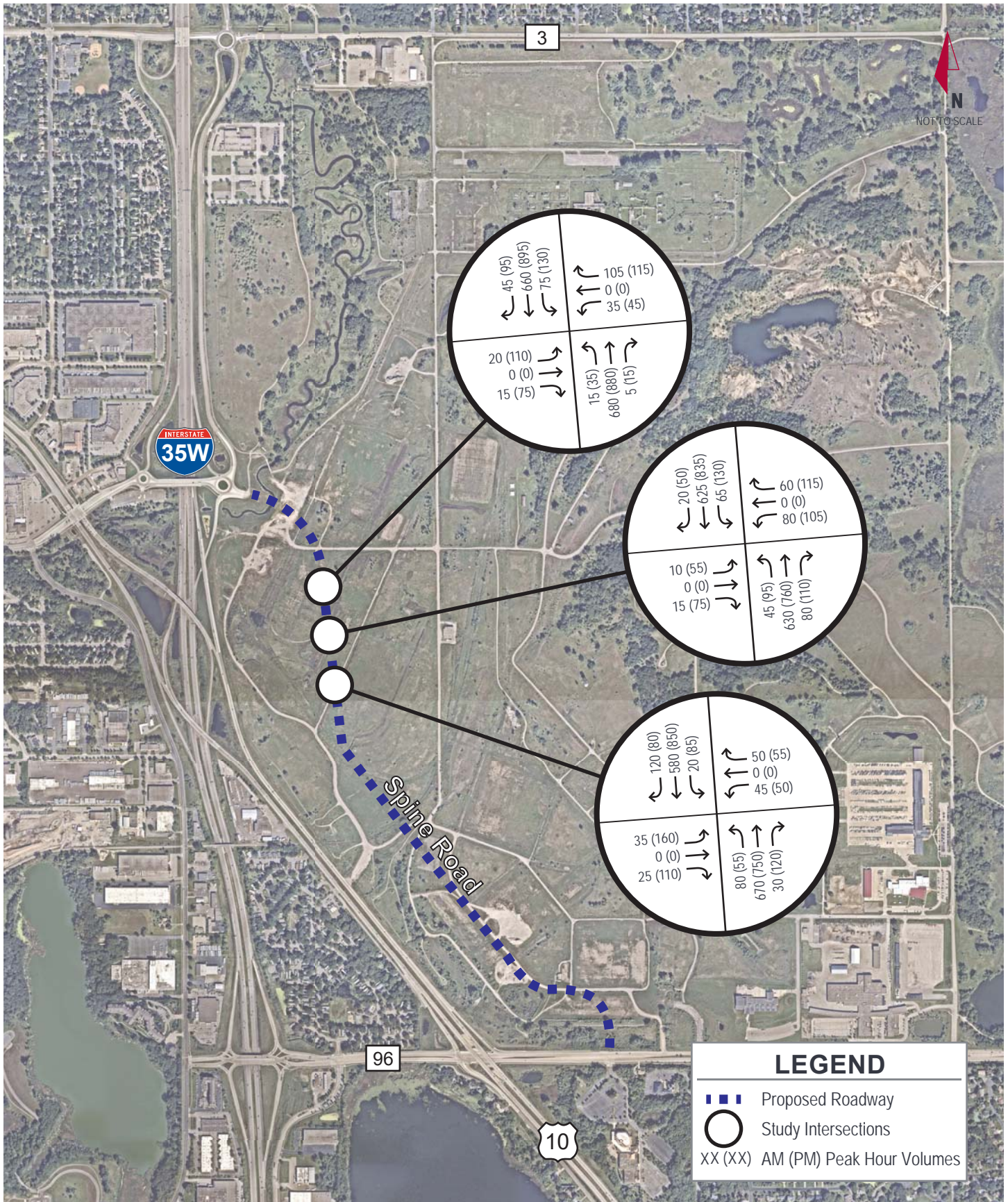
Exhibit 6: Vehicle Turning Paths

Exhibit 7: Fastest Path

Exhibit 8: Sight Distance Triangles







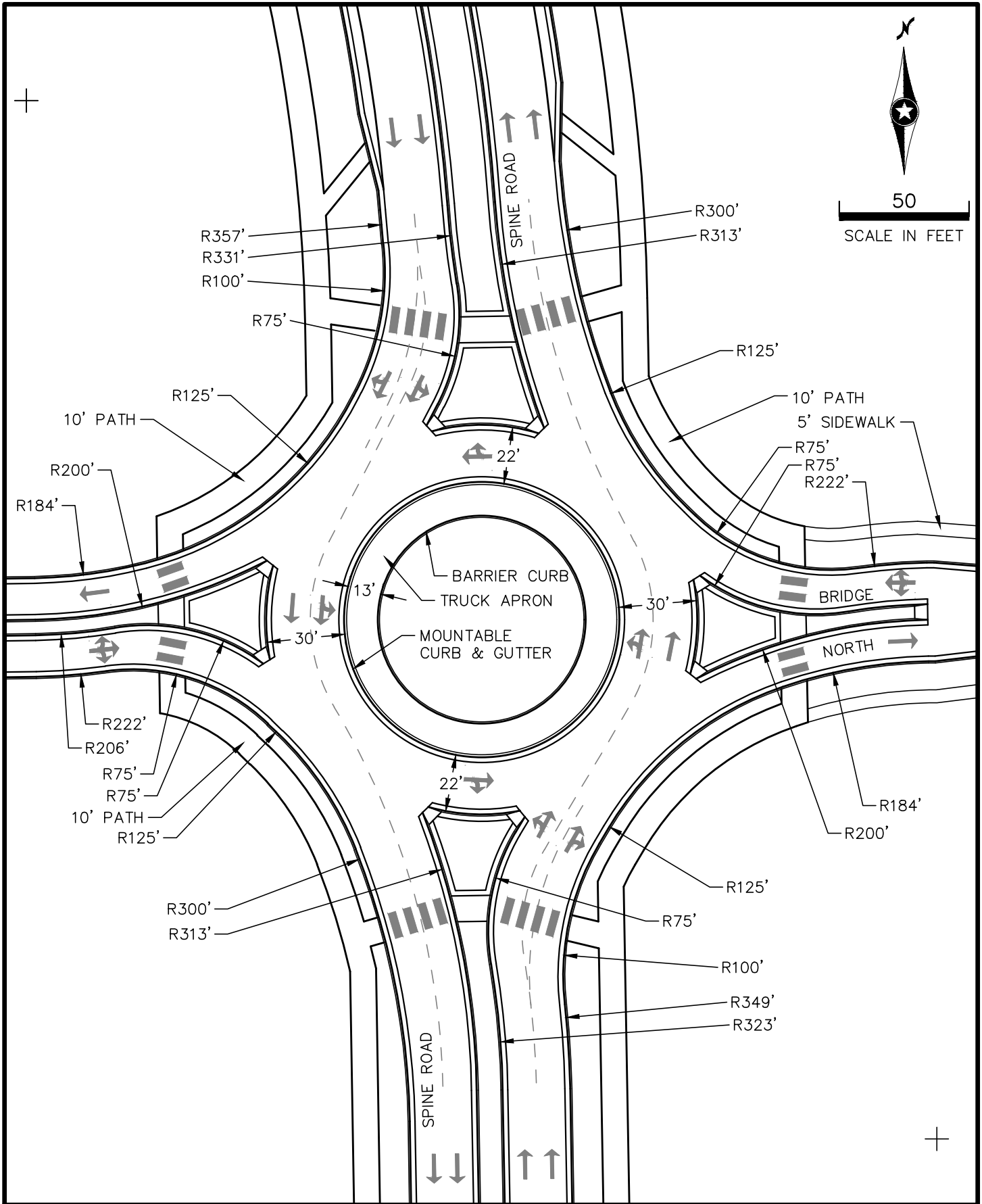
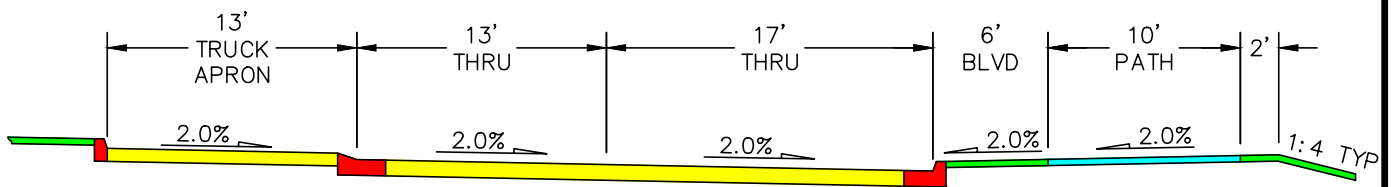
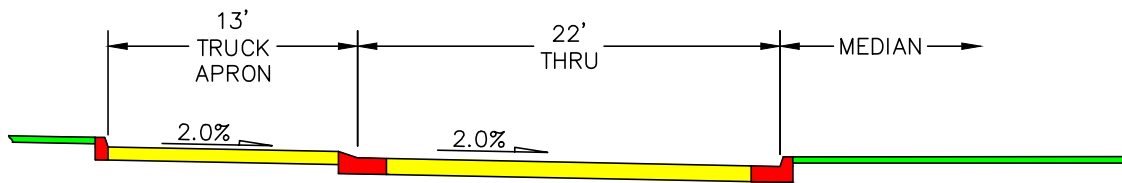


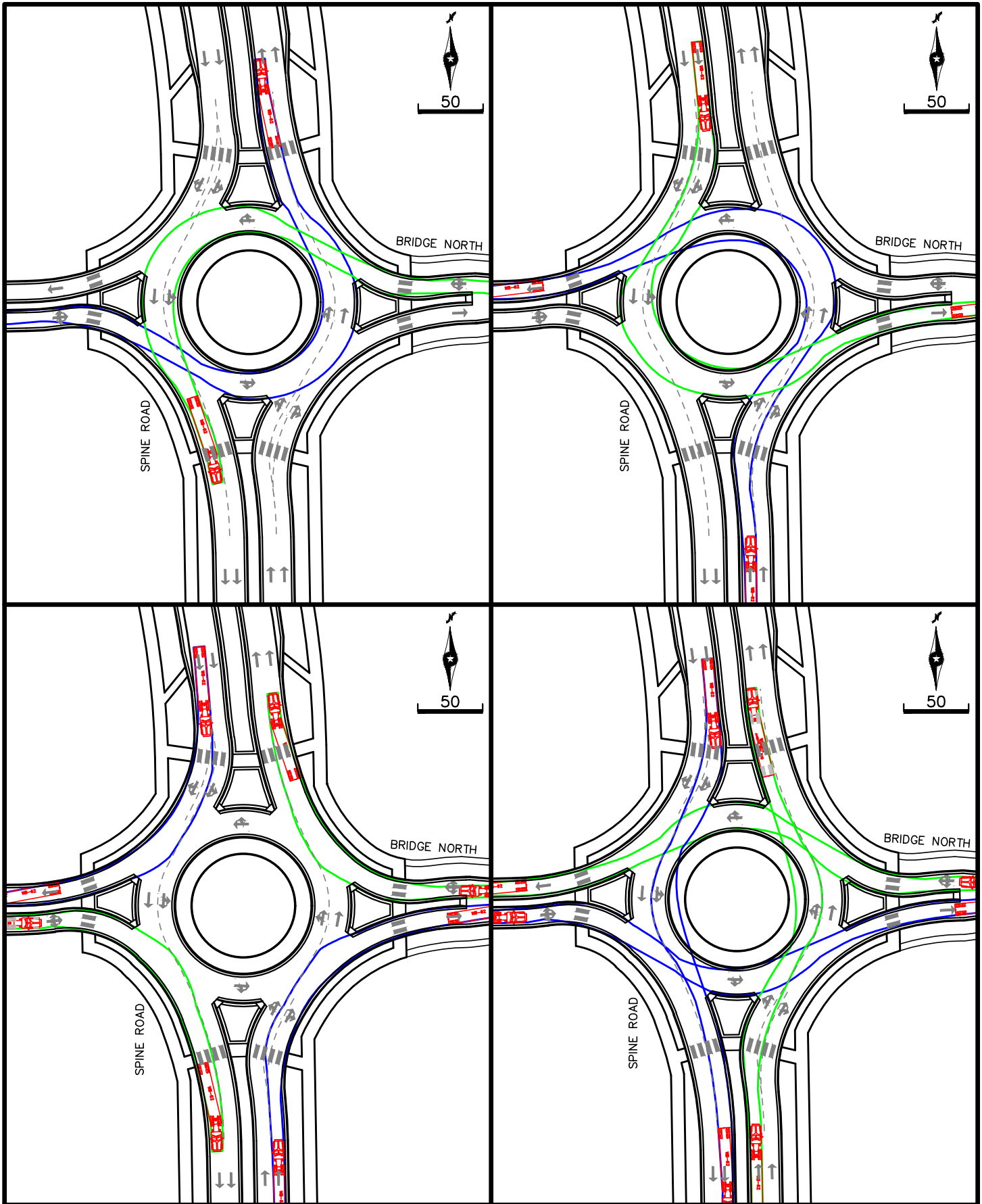
EXHIBIT 4

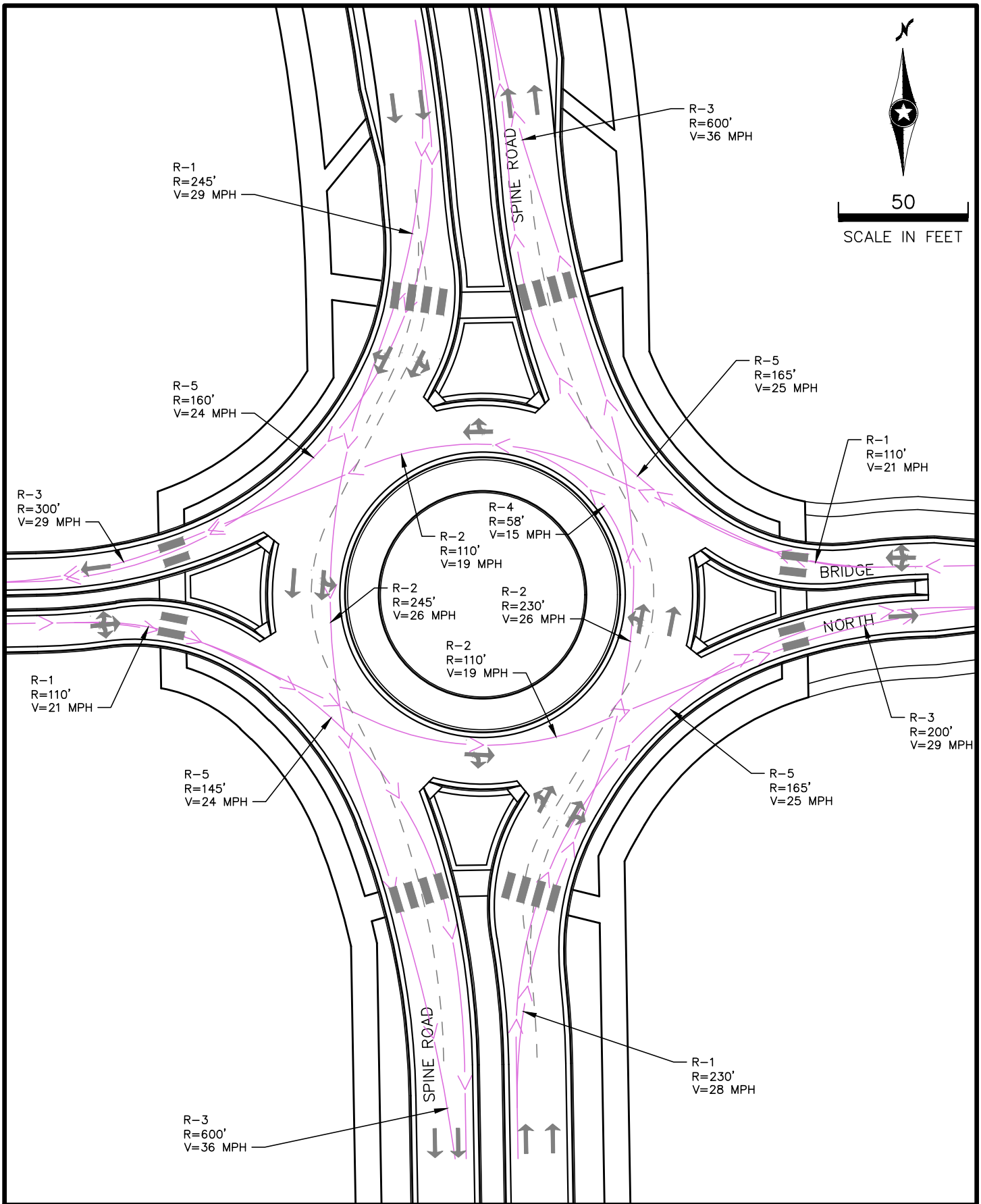


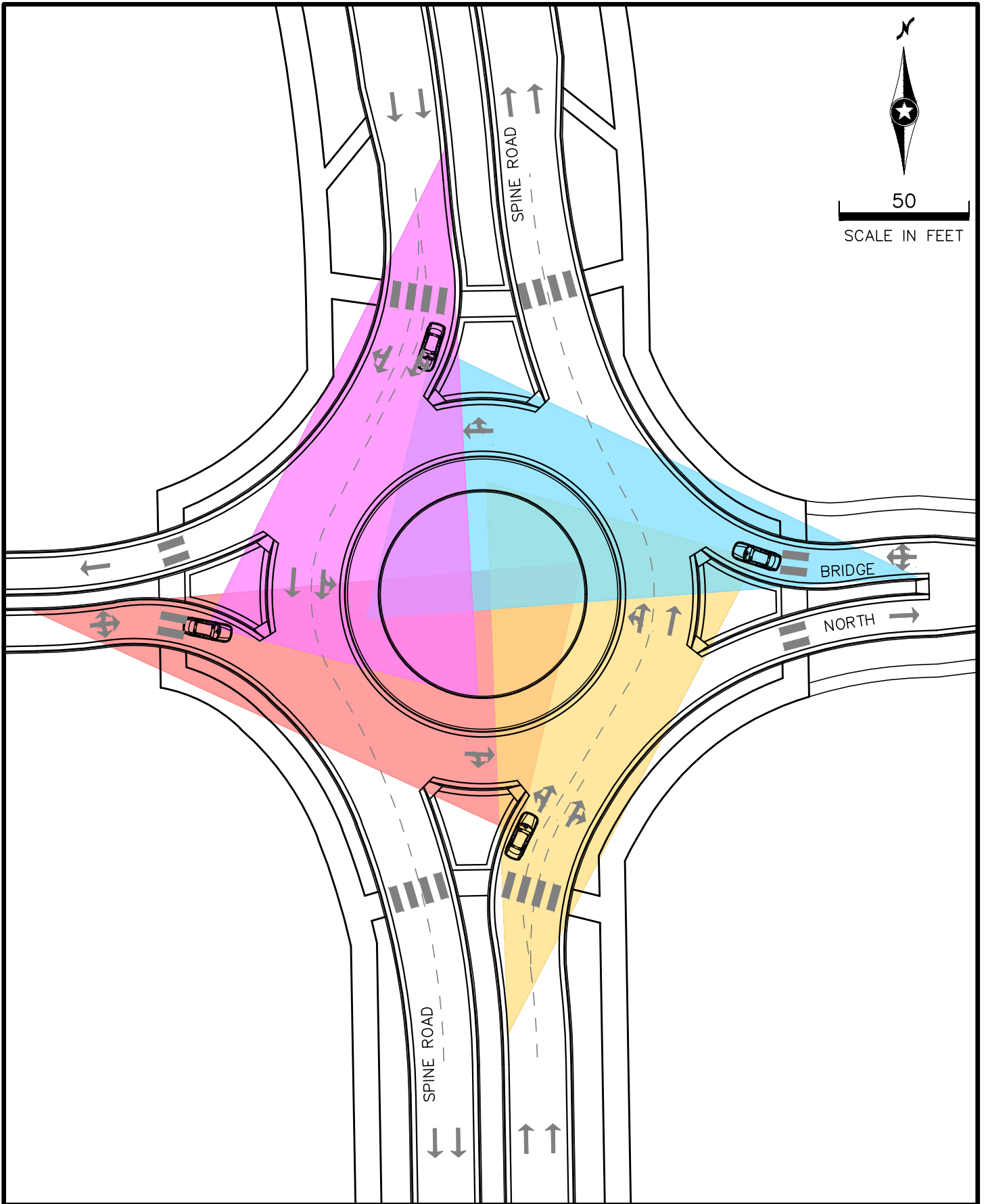
NORTH/SOUTH CIRCULATING LANE



EAST/WEST CIRCULATING LANE







APPENDIX

Appendix A: Trip Generation Summary

Appendix B: Design Year (2040) All-Way Stop & Signal Warrant Analysis

Appendix C: Design Year (2040) SimTraffic Analysis Outputs

Appendix D: Design Year (2040) RODEL Analysis Outputs

Appendix A: Trip Generation Summary

Rice Creek Commons - Trip Generation Analysis

Parcel	Land Use Description		ITE	Description	Intensity / Units	Daily	AM Peak Hour			PM Peak Hour			
	Tranche	ITE Land Uses					Parcel Name	In	Out	Total	In	Out	Total
1	5	ITE 714	714	Corporate Headquarters Building	740 1,000 Sq Ft	5,295	455	25	480	12	388	400	
2A			820	Shopping Center	166 1,000 Sq Ft	5,640	87	53	140	273	296	569	
2B	1	ITE 820/710	710	General Office Building	45 1,000 Sq Ft	394	41	6	47	7	40	47	
2C			820	Shopping Center	17 1,000 Sq Ft	578	9	5	14	28	31	59	
				Total		6,612	137	64	201	308	367	675	
3A			710	General Office Building	93 1,000 Sq Ft	815	84	13	97	15	81	96	
3B	4	ITE 710/720/820	720	Medical-Dental Office Building	46 1,000 Sq Ft	1,456	91	25	116	41	104	145	
3C			820	Shopping Center	46 1,000 Sq Ft	1,580	24	16	40	77	82	159	
				Total		3,851	199	54	253	133	267	400	
4			710	General Office Building	234 1,000 Sq Ft	2,055	211	34	245	39	204	243	
5	4	ITE 710/130	130	Industrial Park	234 1,000 Sq Ft	711	68	17	85	18	67	85	
				Total		2,766	279	51	330	57	271	328	
6	2	ITE 820	820	Shopping Center	21 1,000 Sq Ft	714	11	7	18	34	38	72	
7,8,9	1	ITE 210	210	Single-Family Detached	170 Dwelling Unit(s)	1,445	29	84	113	95	56	151	
10,11,12	3	ITE 210	210	Single-Family Detached	138 Dwelling Unit(s)	1,173	23	69	92	77	46	123	
13,14	3	ITE 210	210	Single-Family Detached	122 Dwelling Unit(s)	1,037	21	60	81	68	41	109	
15,16,17	3	ITE 210	210	Single-Family Detached	62 Dwelling Unit(s)	527	11	30	41	34	21	55	
18,19	2	ITE 210	210	Single-Family Detached	88 Dwelling Unit(s)	748	14	45	59	50	28	78	
20A			220	Multifamily (low-rise)	60 Dwelling Unit(s)	395	5	20	25	19	12	31	
20B			220	Multifamily (low-rise)	60 Dwelling Unit(s)	395	5	20	25	19	12	31	
20C	2	ITE 220/820	820	Shopping Center	9 1,000 Sq Ft	289	5	2	7	14	15	29	
				Total		1,079	15	42	57	52	39	91	
21A			220	Multifamily (low-rise)	210 Dwelling Unit(s)	1,383	20	67	87	67	39	106	
21B	2	ITE 220/820	820	Shopping Center	9 1,000 Sq Ft	289	5	2	7	14	15	29	
				Total		1,672	25	69	94	81	54	135	
22A			310	Hotel	200 Dwelling Unit(s)	1,505	50	35	85	55	53	108	
22B			710	General Office Building	100 1,000 Sq Ft	877	90	14	104	16	88	104	
22C	1	ITE 310/710/220/820	220	Multifamily (low-rise)	150 Dwelling Unit(s)	988	14	48	62	48	28	76	
22D			820	Shopping Center	9 1,000 Sq Ft	289	5	2	7	14	15	29	
				Total		3,659	159	99	258	133	184	317	
23A			445	Multiplex Movie Theater	42 1,000 Sq Ft	1,856	0	0	0	115	70	185	
23B	1	ITE 445/820/220	820	Shopping Center	9 1,000 Sq Ft	289	5	2	7	14	15	29	
23C			220	Multifamily (low-rise)	100 Dwelling Unit(s)	659	10	31	41	32	18	50	
				Total		2,804	15	33	48	161	103	264	
24A			252	Senior Adult Housing-Attached	300 Dwelling Unit(s)	999	19	35	54	39	31	70	
24B	1	ITE 252/820	820	Shopping Center	9 1,000 Sq Ft	289	5	2	7	14	15	29	
				Total		1,288	24	37	61	53	46	99	
				TOTAL TRIPS		34,670	1,417	769	2,186	1,348	1,949	3,297	

Appendix B: Design Year (2040) All-Way Stop & Signal Warrant Analysis



ALL WAY STOP WARRANT

LOCATION: TCAAP
 COUNTY:
 REF. POINT: --
 DATE: 9/19/2018

OPERATOR: JAB

Speed	Approach	Direction	Lanes	
40	Major App1:	EB	Spine Road	2
40	Major App3:	WB	Spine Road	2
25	Minor App2:	NB	North Street	1
25	Minor App4:	SB	North Street	1

0.70 FACTOR USED? No

300

200

HOUR	MAJOR APP. 1	MAJOR APP. 3	MINOR APP. 2	MINOR APP. 4	300		200	
					MAJOR TOTAL Σ (APP. 1 & APP. 3)	MINOR TOTAL APP. 2 + APP. 4		
0:00 - 1:00								
1:00 - 2:00								
2:00 - 3:00								
3:00 - 4:00								
4:00 - 5:00								
5:00 - 6:00								
6:00 - 7:00								
7:00 - 8:00	1475		65	140	1475		205	
8:00 - 9:00	2180		90	135	2180		225	
9:00 - 10:00	2455		130	120	2455		250	
10:00 - 11:00	2035		190	115	2035		305	
11:00 - 12:00								
12:00 - 13:00								
13:00 - 14:00								
14:00 - 15:00	1605		235	120	1605		355	
15:00 - 16:00	1630		235	135	1630		370	
16:00 - 17:00	1890		245	150	1890		395	
17:00 - 18:00	2045		245	160	2045		405	
18:00 - 19:00								
19:00 - 20:00								
20:00 - 21:00								
21:00 - 22:00								
22:00 - 23:00								
23:00 - 24:00								
					Average	1914	Average	314

Observed (vol) Required (Vol)

Allway Stop Major **1914** 300
 Warrant: Minor **314** 200 **Satisfied**

REMARKS: _____

ALL WAY STOP WARRANT

LOCATION: TCAAP
 COUNTY:
 REF. POINT: --
 DATE: 9/19/2018

OPERATOR: JAB

Speed	Approach	Direction	Lanes	
40	Major App1:	EB	Spine Road	2
40	Major App3:	WB	Spine Road	2
25	Minor App2:	NB	Main Street	1
25	Minor App4:	SB	Main Street	1

0.70 FACTOR USED? No

HOUR	MAJOR APP. 1	MAJOR APP. 3	MINOR APP. 2	MINOR APP. 4	300		200	
					MAJOR TOTAL Σ (APP. 1 & APP. 3)	MINOR TOTAL APP. 2 + APP. 4		
0:00 - 1:00								
1:00 - 2:00								
2:00 - 3:00								
3:00 - 4:00								
4:00 - 5:00								
5:00 - 6:00								
6:00 - 7:00								
7:00 - 8:00	1455		85	140	1455		225	
8:00 - 9:00	2160		105	150	2160		255	
9:00 - 10:00	2425		130	150	2425		280	
10:00 - 11:00	2005		175	150	2005		325	
11:00 - 12:00								
12:00 - 13:00								
13:00 - 14:00								
14:00 - 15:00	1545		245	190	1545		435	
15:00 - 16:00	1570		245	195	1570		440	
16:00 - 17:00	1825		250	215	1825		465	
17:00 - 18:00	1975		250	220	1975		470	
18:00 - 19:00								
19:00 - 20:00								
20:00 - 21:00								
21:00 - 22:00								
22:00 - 23:00								
23:00 - 24:00								
					Average	1870	Average	362

Observed (vol) Required (Vol)

Allway Stop	Major	1870	300	Satisfied
Warrant:	Minor	362	200	

REMARKS: _____

ALL WAY STOP WARRANT

LOCATION: TCAAP
 COUNTY:
 REF. POINT: --
 DATE: 9/19/2018

OPERATOR: JAB

Speed	Approach	Direction	Lanes	
40	Major App1:	EB	Spine Road	2
40	Major App3:	WB	Spine Road	2
25	Minor App2:	NB	South Street	1
25	Minor App4:	SB	South Street	1

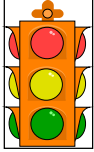
0.70 FACTOR USED? No

HOUR	MAJOR APP. 1	MAJOR APP. 3	MINOR APP. 2	MINOR APP. 4	300		200	
					MAJOR TOTAL Σ (APP. 1 & APP. 3)	MINOR TOTAL APP. 2 + APP. 4		
0:00 - 1:00								
1:00 - 2:00								
2:00 - 3:00								
3:00 - 4:00								
4:00 - 5:00								
5:00 - 6:00								
6:00 - 7:00								
7:00 - 8:00	1495		90	95	1495		185	
8:00 - 9:00	2195		120	95	2195		215	
9:00 - 10:00	2475		140	80	2475		220	
10:00 - 11:00	2040		170	90	2040		260	
11:00 - 12:00								
12:00 - 13:00								
13:00 - 14:00								
14:00 - 15:00	1475		370	95	1475		465	
15:00 - 16:00	1500		370	95	1500		465	
16:00 - 17:00	1755		370	105	1755		475	
17:00 - 18:00	1930		330	105	1930		435	
18:00 - 19:00								
19:00 - 20:00								
20:00 - 21:00								
21:00 - 22:00								
22:00 - 23:00								
23:00 - 24:00								
					Average	1858	Average	340

Observed (vol) Required (Vol)

Allway Stop	Major	1858	300	Satisfied
Warrant:	Minor	340	200	

REMARKS: _____



SIGNAL WARRANTS ANALYSIS

LOCATION: TCAAP
 COUNTY: -
 REF. POINT: -
 DATE: 9/19/2018
 OPERATOR: JAB

Speed	Approach Description	Direction	Existing 2015 Volumes	Lanes
40	Major App1:	NB	Spine Road	2
40	Major App3:	SB	Spine Road	2
25	Minor App2:	EB	North Street (Lefts Only)	1
25	Minor App4:	WB	North Street (Lefts Only)	1

0.70 FACTOR USED? no
 POPULATION < 10,000? no
 EXISTING SIGNAL ? no

THRESHOLDS 1A/1B:			600		900		150		75		150		75	
	MAJOR APP. 1	MAJOR APP. 3	TOTAL 1+3	MAJOR 1A	MAJOR 1B	MINOR APP. 2	MINOR 2 1A	MINOR 2 1B	MINOR APP. 4	MINOR 4 1A	MINOR 4 1B	MAJ & MIN 1A	MAJ & MIN 1B	
0:00 - 1:00			0											
1:00 - 2:00			0											
2:00 - 3:00			0											
3:00 - 4:00			0											
4:00 - 5:00			0											
5:00 - 6:00			0											
6:00 - 7:00			0											
7:00 - 8:00	1475		1475	X	X	20			35					
8:00 - 9:00	2180		2180	X	X	35			35					
9:00 - 10:00	2455		2455	X	X	60			30					
10:00 - 11:00	2035		2035	X	X	95		X	30				X	
11:00 - 12:00			0											
12:00 - 13:00			0											
13:00 - 14:00			0											
14:00 - 15:00	1605		1605	X	X	105		X	35				X	
15:00 - 16:00	1630		1630	X	X	105		X	40				X	
16:00 - 17:00	1890		1890	X	X	110		X	45				X	
17:00 - 18:00	2045		2045	X	X	110		X	45				X	
18:00 - 19:00			0											
19:00 - 20:00			0											
20:00 - 21:00			0											
21:00 - 22:00			0											
22:00 - 23:00			0											
23:00 - 24:00			0											

	Met (Hr)	Required (Hr)	
Warrant 1a	0	8	Not satisfied
Warrant 1b	5	8	Not satisfied
Warrant 2	5	4	Satisfied
Warrant 3	2	1	Satisfied

* SBR turn movements were removed due to exclusive right turn lane of the minor approach

LOCATION: TCAAP

COUNTY:

REF. POINT: -

DATE: 9/19/2018

OPERATOR: JAB

0.70 FACTOR USED? no

POPULATION < 10,000? no

EXISTING SIGNAL ? no

Speed	Approach Description	Lanes
40	Major App1: Spine Road	2
40	Major App3: Spine Road	2
25	Minor App2: North Street (Lefts Only)	1
25	Minor App4: North Street (Lefts Only)	1

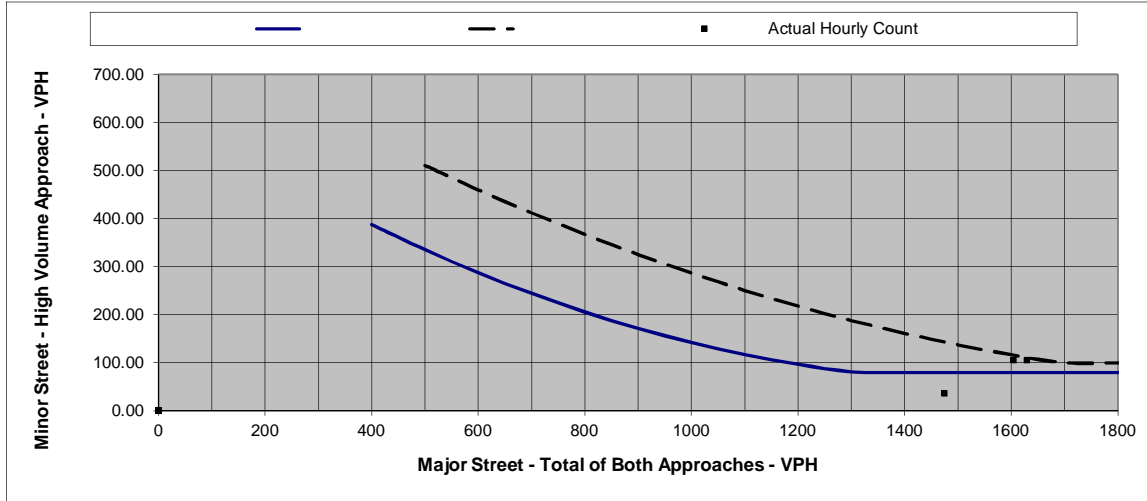
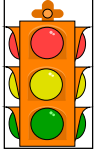


Figure 1. Four Hour and Peak Hour Warrant Analysis

Note: For data points outside the graph range, check the minor street volume against the lower thresholds



SIGNAL WARRANTS ANALYSIS



LOCATION: TCAAP
 COUNTY: -
 REF. POINT: -
 DATE: 9/19/2018
 OPERATOR: JAB

Speed	Approach Description	Direction	Existing 2015 Volumes	Lanes
40	Major App1:	NB	Spine Road	2
40	Major App3:	SB	Spine Road	2
25	Minor App2:	EB	Main Street (Lefts Only)	1
25	Minor App4:	WB	Main Street (Lefts Only)	1

0.70 FACTOR USED? no
 POPULATION < 10,000? no
 EXISTING SIGNAL ? no

THRESHOLDS 1A/1B:			600	900	150	75	150	75					
	MAJOR APP. 1	MAJOR APP. 3	TOTAL 1+3	MAJOR 1A	MAJOR 1B	MINOR APP. 2	MINOR 2 1A	MINOR 2 1B	MINOR APP. 4	MINOR 4 1A	MINOR 4 1B	MAJ & MIN 1A	MAJ & MIN 1B
0:00 - 1:00			0										
1:00 - 2:00			0										
2:00 - 3:00			0										
3:00 - 4:00			0										
4:00 - 5:00			0										
5:00 - 6:00			0										
6:00 - 7:00			0										
7:00 - 8:00	1455		1455	X	X	10			80		X		X
8:00 - 9:00	2160		2160	X	X	20			80		X		X
9:00 - 10:00	2425		2425	X	X	30			80		X		X
10:00 - 11:00	2005		2005	X	X	50			75		X		X
11:00 - 12:00			0										
12:00 - 13:00			0										
13:00 - 14:00			0										
14:00 - 15:00	1545		1545	X	X	55			85		X		X
15:00 - 16:00	1570		1570	X	X	55			90		X		X
16:00 - 17:00	1825		1825	X	X	55			100		X		X
17:00 - 18:00	1975		1975	X	X	55			105		X		X
18:00 - 19:00			0										
19:00 - 20:00			0										
20:00 - 21:00			0										
21:00 - 22:00			0										
22:00 - 23:00			0										
23:00 - 24:00			0										

	Met (Hr)	Required (Hr)	
Warrant 1a	0	8	Not satisfied
Warrant 1b	8	8	Satisfied
Warrant 2	7	4	Satisfied
Warrant 3	2	1	Satisfied

* SBR turn movements were removed due to exclusive right turn lane of the minor approach

LOCATION: TCAAP

COUNTY:

REF. POINT: -

DATE: 9/19/2018

OPERATOR: JAB

0.70 FACTOR USED? no

POPULATION < 10,000? no

EXISTING SIGNAL ? no

Speed	Approach Description	Lanes
40	Major App1: Spine Road	2
40	Major App3: Spine Road	2
25	Minor App2: Main Street (Lefts Only)	1
25	Minor App4: Main Street (Lefts Only)	1

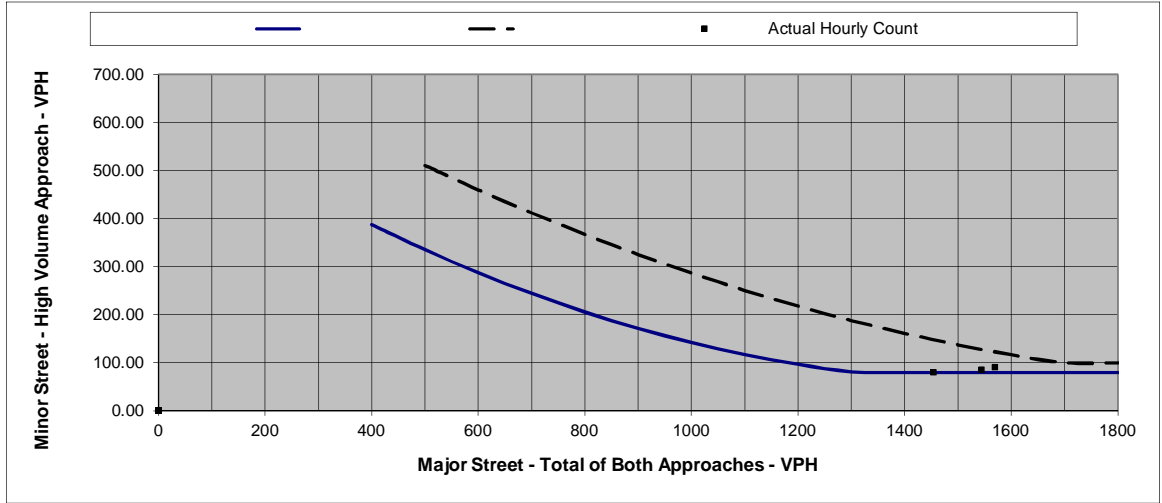
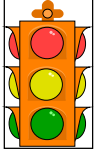


Figure 1. Four Hour and Peak Hour Warrant Analysis

Note: For data points outside the graph range, check the minor street volume against the lower thresholds



SIGNAL WARRANTS ANALYSIS



LOCATION: TCAAP
 COUNTY: -
 REF. POINT: -
 DATE: 9/19/2018
 OPERATOR: JAB

Speed	Approach Description	Direction	Existing 2015 Volumes	Lanes
40	Major App1:	NB	Spine Road	2
40	Major App3:	SB	Spine Road	2
25	Minor App2:	EB	South Street (Lefts Only)	1
25	Minor App4:	WB	South Street (Lefts Only)	1

0.70 FACTOR USED? no
 POPULATION < 10,000? no
 EXISTING SIGNAL ? no

THRESHOLDS 1A/1B:	600			900		150		75		150		75		MAJ & MIN 1A	MAJ & MIN 1B
	MAJOR APP. 1	MAJOR APP. 3	TOTAL 1+3	MAJOR 1A	MAJOR 1B	MINOR APP. 2	MINOR 2 1A	MINOR 2 1B	MINOR APP. 4	MINOR 4 1A	MINOR 4 1B				
0:00 - 1:00			0												
1:00 - 2:00			0												
2:00 - 3:00			0												
3:00 - 4:00			0												
4:00 - 5:00			0												
5:00 - 6:00			0												
6:00 - 7:00			0												
7:00 - 8:00	1495		1495	X	X	35			45						
8:00 - 9:00	2195		2195	X	X	55			45						
9:00 - 10:00	2475		2475	X	X	65			40						
10:00 - 11:00	2040		2040	X	X	85		X	45						X
11:00 - 12:00			0												
12:00 - 13:00			0												
13:00 - 14:00			0												
14:00 - 15:00	1475		1475	X	X	185	X	X	45				X	X	
15:00 - 16:00	1500		1500	X	X	185	X	X	45				X	X	
16:00 - 17:00	1755		1755	X	X	185	X	X	50				X	X	
17:00 - 18:00	1930		1930	X	X	160	X	X	50				X	X	
18:00 - 19:00			0												
19:00 - 20:00			0												
20:00 - 21:00			0												
21:00 - 22:00			0												
22:00 - 23:00			0												
23:00 - 24:00			0												

	Met (Hr)	Required (Hr)	
Warrant 1a	4	8	Not satisfied
Warrant 1b	5	8	Not satisfied
Warrant 2	5	4	Satisfied
Warrant 3	4	1	Satisfied

* SBR turn movements were removed due to exclusive right turn lane of the minor approach

LOCATION: TCAAP

COUNTY:

REF. POINT: -

DATE: 9/19/2018

OPERATOR: JAB

0.70 FACTOR USED? no

POPULATION < 10,000? no

EXISTING SIGNAL ? no

Speed	Approach Description	Lanes
40	Major App1: Spine Road	2
40	Major App3: Spine Road	2
25	Minor App2: South Street (Lefts Only)	1
25	Minor App4: South Street (Lefts Only)	1

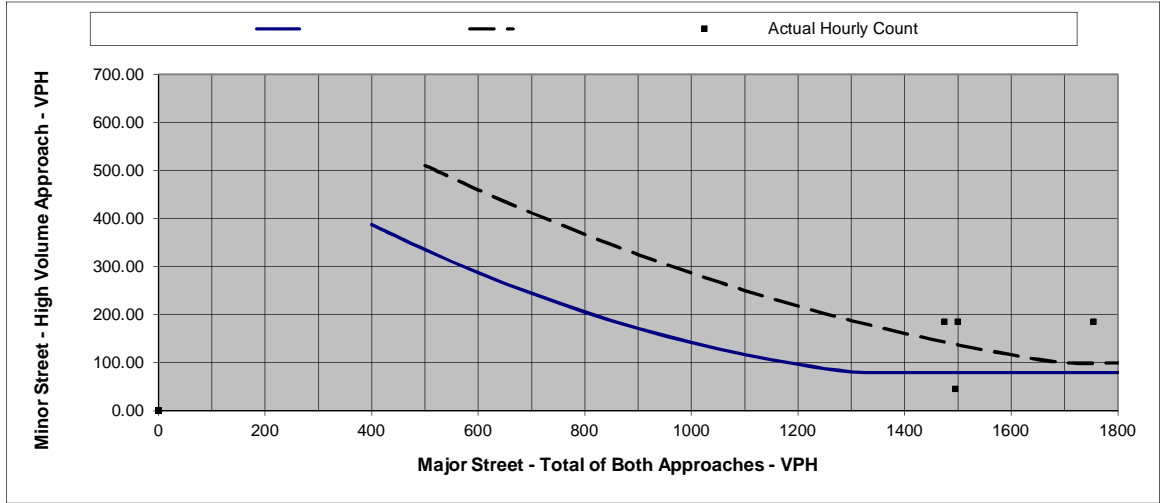


Figure 1. Four Hour and Peak Hour Warrant Analysis

Note: For data points outside the graph range, check the minor street volume against the lower thresholds

Appendix C: Design Year (2040) SimTraffic Analysis Outputs

300: Spine Road & North Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.1	0.8	0.0	0.6	0.4
Total Del/Veh (s)	20.2	13.1	0.8	1.0	2.4

400: Spine Road & Main Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	1.9	2.1	0.0	0.0	0.2
Total Del/Veh (s)	12.0	36.5	0.7	0.9	4.2

500: Spine Road & South Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.2	1.3	0.6	0.0	0.4
Total Del/Veh (s)	17.3	16.0	1.0	0.9	2.4

Total Network Performance

Denied Del/Veh (s)	0.8
Total Del/Veh (s)	7.5

Intersection: 300: Spine Road & North Street

Movement	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	L	TR	L	TR	L	R	L	R
Maximum Queue (ft)	59	57	86	88	29	4	64	4
Average Queue (ft)	14	11	25	34	6	0	28	0
95th Queue (ft)	42	36	68	64	26	3	55	3
Link Distance (ft)		801		1091				
Upstream Blk Time (%)								
Queuing Penalty (veh)								
Storage Bay Dist (ft)	150		150		200	200	200	200
Storage Blk Time (%)			0					
Queuing Penalty (veh)			1					

Intersection: 400: Spine Road & Main Street

Movement	EB	EB	WB	WB	NB	NB	SB
Directions Served	L	TR	L	TR	L	R	L
Maximum Queue (ft)	43	46	197	132	57	18	69
Average Queue (ft)	9	9	67	28	20	1	24
95th Queue (ft)	30	31	150	89	48	8	58
Link Distance (ft)		554		958			
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)	150		150		200	200	200
Storage Blk Time (%)			7	0			
Queuing Penalty (veh)			4	0			

Intersection: 500: Spine Road & South Street

Movement	EB	EB	WB	WB	NB	NB	SB	SB	SB
Directions Served	L	TR	L	TR	L	R	L	T	R
Maximum Queue (ft)	78	57	73	49	82	4	34	12	40
Average Queue (ft)	24	16	28	22	30	0	8	0	1
95th Queue (ft)	56	41	61	42	63	3	29	9	14
Link Distance (ft)		721		1031				569	
Upstream Blk Time (%)									
Queuing Penalty (veh)									
Storage Bay Dist (ft)	150		150		200	200	200		200
Storage Blk Time (%)									
Queuing Penalty (veh)									

Network Summary

Network wide Queuing Penalty: 5

300: Spine Road & North Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	141.0	0.9	0.0	0.8	11.8
Total Del/Veh (s)	417.8	87.8	1.4	1.7	37.7

400: Spine Road & Main Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	1.8	118.0	0.0	0.0	11.9
Total Del/Veh (s)	90.7	376.4	1.6	1.7	42.5

500: Spine Road & South Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	803.9	1.5	0.7	0.0	96.3
Total Del/Veh (s)	680.4	66.2	1.0	1.5	53.8

Total Network Performance

Denied Del/Veh (s)	87.5
Total Del/Veh (s)	99.3

Intersection: 300: Spine Road & North Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	R
Maximum Queue (ft)	250	789	189	266	58	4	18	4	94	9
Average Queue (ft)	209	436	93	67	20	0	1	0	41	0
95th Queue (ft)	312	983	204	213	46	3	10	4	74	5
Link Distance (ft)		801		1091		509	509			
Upstream Blk Time (%)		27								
Queuing Penalty (veh)		0								
Storage Bay Dist (ft)	150		150		200			200	200	200
Storage Blk Time (%)	79	0	18	0						
Queuing Penalty (veh)	60	0	21	0						

Intersection: 400: Spine Road & Main Street

Movement	EB	EB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	R	L	T	R
Maximum Queue (ft)	200	226	250	902	92	4	18	89	4	13
Average Queue (ft)	96	45	203	523	36	0	1	41	0	1
95th Queue (ft)	197	136	322	1198	71	3	10	76	5	7
Link Distance (ft)		554		958		569			509	
Upstream Blk Time (%)				34						
Queuing Penalty (veh)				0						
Storage Bay Dist (ft)	150		150		200		200	200		200
Storage Blk Time (%)	18	0	75	0						
Queuing Penalty (veh)	13	0	87	0						

Intersection: 500: Spine Road & South Street

Movement	EB	EB	WB	WB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	R	L	T	T	R
Maximum Queue (ft)	250	777	166	82	69	4	12	75	9	9	22
Average Queue (ft)	247	719	63	23	26	0	0	30	0	0	2
95th Queue (ft)	256	856	148	52	54	3	3	62	3	4	11
Link Distance (ft)		721		1031		566			569	569	
Upstream Blk Time (%)		91									
Queuing Penalty (veh)		0									
Storage Bay Dist (ft)	150		150		200		200	200			200
Storage Blk Time (%)	100	0	7	0							
Queuing Penalty (veh)	110	0	4	0							

Network Summary

Network wide Queuing Penalty: 295

300: Spine Road & North Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.1	0.7	0.0	0.7	0.4
Total Del/Veh (s)	4.4	4.9	12.5	9.9	10.5

400: Spine Road & Main Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	1.6	2.0	0.0	0.0	0.2
Total Del/Veh (s)	3.9	5.3	12.0	12.2	11.4

500: Spine Road & South Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.4	1.4	0.6	0.0	0.5
Total Del/Veh (s)	5.0	4.9	10.4	11.6	10.4

Total Network Performance

Denied Del/Veh (s)	0.9
Total Del/Veh (s)	27.4

Queuing and Blocking Report
 AWSC AM

10/04/2018

Intersection: 300: Spine Road & North Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	35	50	54	92	38	101	101	31	65	98	105	56
Average Queue (ft)	12	12	19	33	12	55	58	5	31	61	52	25
95th Queue (ft)	32	37	44	66	38	84	86	23	55	91	83	50
Link Distance (ft)		801		1091		509	509			755	755	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)	0											
Queuing Penalty (veh)	0											

Intersection: 400: Spine Road & Main Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	41	50	76	58	54	106	99	65	58	93	111	55
Average Queue (ft)	7	10	29	23	25	56	54	33	29	52	57	15
95th Queue (ft)	28	33	56	45	48	88	80	52	50	80	89	44
Link Distance (ft)		554		958		569	569			509	509	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)												
Queuing Penalty (veh)												

Intersection: 500: Spine Road & South Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	44	32	61	64	68	146	104	48	39	95	98	72
Average Queue (ft)	18	13	22	22	35	70	53	22	15	49	59	36
95th Queue (ft)	40	32	45	47	58	113	84	47	41	75	86	57
Link Distance (ft)		721		1031		566	566			569	569	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)	0											
Queuing Penalty (veh)	0											

Network Summary

Network wide Queuing Penalty: 0

300: Spine Road & North Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.2	0.9	0.0	0.9	0.6
Total Del/Veh (s)	7.5	7.1	17.0	15.6	15.0

400: Spine Road & Main Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	1.8	1.8	0.0	0.0	0.3
Total Del/Veh (s)	7.0	7.8	15.4	15.9	14.5

500: Spine Road & South Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.5	1.5	0.8	0.0	0.7
Total Del/Veh (s)	8.4	6.3	15.3	16.3	14.5

Total Network Performance

Denied Del/Veh (s)	1.2
Total Del/Veh (s)	34.6

Queuing and Blocking Report
AWSC PM

10/04/2018

Intersection: 300: Spine Road & North Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	88	65	68	79	63	156	169	61	139	226	190	66
Average Queue (ft)	38	27	24	34	25	82	90	15	49	119	87	33
95th Queue (ft)	67	53	52	65	55	129	139	46	97	199	155	57
Link Distance (ft)		801		1091		509	509			755	755	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)							0			1	0	
Queuing Penalty (veh)							0			1	0	

Intersection: 400: Spine Road & Main Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	55	70	97	78	69	131	152	90	104	157	159	66
Average Queue (ft)	24	28	40	34	39	73	78	39	44	79	87	29
95th Queue (ft)	47	53	72	63	61	115	126	64	76	129	134	56
Link Distance (ft)		554		958		569	569			509	509	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)							0			0	0	
Queuing Penalty (veh)							0			0	0	

Intersection: 500: Spine Road & South Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	102	72	55	80	123	256	206	85	73	148	170	65
Average Queue (ft)	48	31	24	25	33	110	81	40	35	79	88	34
95th Queue (ft)	84	58	46	53	79	195	153	67	61	123	137	56
Link Distance (ft)		721		1031		566	566			569	569	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)							1	0				0
Queuing Penalty (veh)							1	0				0

Network Summary

Network wide Queuing Penalty: 2

300: Spine Road & North Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.2	0.9	0.0	0.7	0.4
Total Del/Veh (s)	22.6	16.2	2.6	2.2	4.1

400: Spine Road & Main Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	1.7	2.4	0.0	0.0	0.2
Total Del/Veh (s)	19.7	31.6	2.8	2.9	5.5

500: Spine Road & South Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.4	1.5	0.6	0.0	0.4
Total Del/Veh (s)	27.4	20.6	2.3	2.6	4.3

Total Network Performance

Denied Del/Veh (s)	0.9
Total Del/Veh (s)	11.6

Queuing and Blocking Report

Signal AM

10/04/2018

Intersection: 300: Spine Road & North Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	49	52	83	86	42	73	78	6	65	90	69	41
Average Queue (ft)	15	12	27	38	7	25	21	0	26	28	18	5
95th Queue (ft)	42	37	68	69	29	64	62	5	55	72	57	25
Link Distance (ft)		801		1091		509	509			755	755	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)												
Queuing Penalty (veh)												

Intersection: 400: Spine Road & Main Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	46	47	140	81	67	112	110	39	79	76	94	28
Average Queue (ft)	9	10	63	24	20	38	24	10	30	26	27	2
95th Queue (ft)	32	32	120	60	51	87	72	34	63	63	72	15
Link Distance (ft)		554		958		569	569			509	509	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)			1	0								
Queuing Penalty (veh)			0	0								

Intersection: 500: Spine Road & South Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	88	52	72	58	77	107	81	32	34	83	92	55
Average Queue (ft)	28	16	29	21	34	29	19	4	11	24	21	15
95th Queue (ft)	65	39	64	43	67	77	58	20	34	65	64	42
Link Distance (ft)		721		1031		566	566			569	569	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)												
Queuing Penalty (veh)												

Network Summary

Network wide Queuing Penalty: 0

300: Spine Road & North Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.5	1.0	0.0	0.8	0.6
Total Del/Veh (s)	33.3	17.9	4.9	5.0	8.0

400: Spine Road & Main Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	1.8	1.9	0.0	0.0	0.3
Total Del/Veh (s)	22.5	27.8	4.8	4.9	8.0

500: Spine Road & South Street Performance by approach

Approach	EB	WB	NB	SB	All
Denied Del/Veh (s)	2.5	1.8	0.7	0.0	0.7
Total Del/Veh (s)	36.3	22.7	5.1	4.8	9.4

Total Network Performance

Denied Del/Veh (s)	1.2
Total Del/Veh (s)	19.8

Queuing and Blocking Report

Signal PM

10/04/2018

Intersection: 300: Spine Road & North Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	159	131	87	91	56	142	160	30	113	178	153	50
Average Queue (ft)	77	33	34	40	22	44	51	2	49	67	44	12
95th Queue (ft)	140	83	71	75	49	103	116	15	89	139	106	39
Link Distance (ft)		801		1091		509	509			755	755	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)	2	0					0			0		
Queuing Penalty (veh)	1	0					0			0		

Intersection: 400: Spine Road & Main Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	94	94	149	130	83	146	129	52	102	114	110	52
Average Queue (ft)	40	31	74	42	39	47	35	13	44	47	44	9
95th Queue (ft)	82	67	131	90	70	105	92	39	80	98	99	34
Link Distance (ft)		554		958		569	569			509	509	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)		0	1	0								
Queuing Penalty (veh)		0	1	0								

Intersection: 500: Spine Road & South Street

Movement	EB	EB	WB	WB	NB	NB	NB	NB	SB	SB	SB	SB
Directions Served	L	TR	L	TR	L	T	T	R	L	T	T	R
Maximum Queue (ft)	196	257	108	63	62	191	155	58	98	116	128	43
Average Queue (ft)	112	64	38	25	25	81	38	18	38	42	51	10
95th Queue (ft)	201	193	82	53	52	160	101	47	74	91	108	33
Link Distance (ft)		721		1031		566	566			569	569	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	150		150		200			200	200			200
Storage Blk Time (%)	9	0	0			0	0					
Queuing Penalty (veh)	10	0	0			0	0					

Network Summary

Network wide Queuing Penalty: 12

Appendix D: Design Year (2040) RODEL Analysis Outputs



Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	Spine Road SB	0	0	24.00	2	28.00	2	164.00	66.00	30.00
2	North Street EB	90	0	12.00	1	14.00	1	164.00	66.00	30.00
3	Spine Road NB	180	0	24.00	2	28.00	2	164.00	66.00	30.00
4	North Street WB	270	0	12.00	1	14.00	1	164.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	Spine Road SB	165.00	15.00	1	28.00	2	24.00	2
2	North Street EB	165.00	30.00	2	14.00	1	12.00	1
3	Spine Road NB	165.00	15.00	1	28.00	2	24.00	2
4	North Street WB	165.00	30.00	2	14.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	Spine Road SB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
2	North Street EB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0
3	Spine Road NB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
4	North Street WB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0

Operational Results

2040 AM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry
1	Spine Road SB	None	780		50		805	2271		0.3435
2	North Street EB	None	35		770		60	825		0.0424
3	Spine Road NB	None	700		95		710	2226		0.3145
4	North Street WB	None	140		715		80	845		0.1658

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.46		2.46	1.58		A		A
2	North Street EB	None	4.29		4.29	0.12		A		A
3	Spine Road NB	None	2.23		2.23	1.29		A		A
4	North Street WB	None	4.77		4.77	0.56		A		A

2040 AM Peak - 15 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry
1	Spine Road SB	None	848		54		875	2266		0.3741
2	North Street EB	None	38		837		65	801		0.0475
3	Spine Road NB	None	761		103		772	2217		0.3432
4	North Street WB	None	152		777		87	823		0.1850

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.48		2.48	1.58		A		A
2	North Street EB	None	4.29		4.29	0.12		A		A
3	Spine Road NB	None	2.24		2.24	1.29		A		A
4	North Street WB	None	4.81		4.81	0.56		A		A

Global Results

Performance and Accidents

2040 AM Peak Global Performance

Parameter	Units	Entries	Bypasses	Total
Arrive Flows	veh/hr	1655		1655
Capacity	veh/hr	6166		6166
Average Delay	sec/veh	2.60		2.60
L.O.S. (Signal)	A – F	A		A
L.O.S. (Unsig)	A – F	A		A
Total Delay	veh.hrs	1.19		1.19

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	Spine Road SB	0	0	24.00	2	28.00	2	164.00	66.00	30.00
2	North Street EB	90	0	12.00	1	14.00	1	164.00	66.00	30.00
3	Spine Road NB	180	0	24.00	2	28.00	2	164.00	66.00	30.00
4	North Street WB	270	0	12.00	1	14.00	1	164.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	Spine Road SB	165.00	15.00	1	28.00	2	24.00	2
2	North Street EB	165.00	30.00	2	14.00	1	12.00	1
3	Spine Road NB	165.00	15.00	1	28.00	2	24.00	2
4	North Street WB	165.00	30.00	2	14.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	Spine Road SB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
2	North Street EB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0
3	Spine Road NB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
4	North Street WB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)				
			Arrival Flow		Opposing Flow		Capacity		Average VCR		
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry	Bypass
1	Spine Road SB	None	1115		80		1105	2241		0.4976	
2	North Street EB	None	185		1065		130	721		0.2567	
3	Spine Road NB	None	930		240		1010	2080		0.4472	
4	North Street WB	None	160		1025		145	735		0.2177	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	3.26		3.26	3.07		A		A
2	North Street EB	None	6.23		6.23	1.00		A		A
3	Spine Road NB	None	2.96		2.96	2.33		A		A
4	North Street WB	None	5.82		5.82	0.80		A		A

2040 PM Peak - 15 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry
1	Spine Road SB	None	1212		87		1201	2234		0.5426
2	North Street EB	None	201		1157		141	688		0.2923
3	Spine Road NB	None	1011		261		1097	2059		0.4910
4	North Street WB	None	174		1114		158	703		0.2472

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	3.38		3.38	3.07		A		A
2	North Street EB	None	6.45		6.45	1.00		A		A
3	Spine Road NB	None	3.06		3.06	2.33		A		A
4	North Street WB	None	5.99		5.99	0.80		A		A

Global Results

Performance and Accidents

2040 PM Peak Global Performance

Parameter	Units	Entries	Bypasses	Total
Arrive Flows	veh/hr	2390		2390
Capacity	veh/hr	5776		5776
Average Delay	sec/veh	3.54		3.54
L.O.S. (Signal)	A – F	A		A
L.O.S. (Unsig)	A – F	A		A
Total Delay	veh.hrs	2.35		2.35

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	Spine Road SB	0	0	24.00	2	28.00	2	164.00	66.00	30.00
2	Main Street EB	90	0	12.00	1	14.00	1	164.00	66.00	30.00
3	Spine Road NB	180	0	24.00	2	28.00	2	164.00	66.00	30.00
4	Main Street WB	270	0	12.00	1	14.00	1	164.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	Spine Road SB	165.00	15.00	1	28.00	2	24.00	2
2	Main Street EB	165.00	30.00	2	14.00	1	12.00	1
3	Spine Road NB	165.00	15.00	1	28.00	2	24.00	2
4	Main Street WB	165.00	30.00	2	14.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	Spine Road SB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
2	Main Street EB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0
3	Spine Road NB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
4	Main Street WB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0

Operational Results

2040 AM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry
1	Spine Road SB	None	710		125		700	2195		0.3234
2	Main Street EB	None	25		770		65	825		0.0303
3	Spine Road NB	None	755		75		720	2246		0.3362
4	Main Street WB	None	140		685		145	855		0.1637

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.46		2.46	1.45		A		A
2	Main Street EB	None	4.24		4.24	0.09		A		A
3	Spine Road NB	None	2.49		2.49	1.55		A		A
4	Main Street WB	None	4.70		4.70	0.55		A		A

2040 AM Peak - 15 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry
1	Spine Road SB	None	772		136		761	2184		0.3533
2	Main Street EB	None	27		837		71	801		0.0339
3	Spine Road NB	None	821		82		782	2239		0.3665
4	Main Street WB	None	152		744		158	834		0.1824

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.48		2.48	1.45		A		A
2	Main Street EB	None	4.23		4.23	0.09		A		A
3	Spine Road NB	None	2.51		2.51	1.55		A		A
4	Main Street WB	None	4.73		4.73	0.55		A		A

Global Results

Performance and Accidents

2040 AM Peak Global Performance

Parameter	Units	Entries	Bypasses	Total
Arrive Flows	veh/hr	1630		1630
Capacity	veh/hr	6121		6121
Average Delay	sec/veh	2.69		2.69
L.O.S. (Signal)	A – F	A		A
L.O.S. (Unsig)	A – F	A		A
Total Delay	veh.hrs	1.22		1.22

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	Spine Road SB	0	0	24.00	2	28.00	2	164.00	66.00	30.00
2	Main Street EB	90	0	12.00	1	14.00	1	164.00	66.00	30.00
3	Spine Road NB	180	0	24.00	2	28.00	2	164.00	66.00	30.00
4	Main Street WB	270	0	12.00	1	14.00	1	164.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	Spine Road SB	165.00	15.00	1	28.00	2	24.00	2
2	Main Street EB	165.00	30.00	2	14.00	1	12.00	1
3	Spine Road NB	165.00	15.00	1	28.00	2	24.00	2
4	Main Street WB	165.00	30.00	2	14.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	Spine Road SB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
2	Main Street EB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0
3	Spine Road NB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
4	Main Street WB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry
1	Spine Road SB	None	1015		200		930	2120		0.4788
2	Main Street EB	None	130		1070		145	719		0.1808
3	Spine Road NB	None	965		185		1015	2135		0.4520
4	Main Street WB	None	220		910		240	776		0.2837

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	3.38		3.38	2.91		A		A
2	Main Street EB	None	5.70		5.70	0.64		A		A
3	Spine Road NB	None	3.15		3.15	2.57		A		A
4	Main Street WB	None	5.99		5.99	1.13		A		A

2040 PM Peak - 15 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)				
			Arrival Flow		Opposing Flow		Capacity		Average VCR		
			Entry	Bypass	Entry	Bypass	Exit Flow	Entry	Bypass	Entry	Bypass
1	Spine Road SB	None	1103		217		1010	2103		0.5247	
2	Main Street EB	None	141		1163		158	686		0.2059	
3	Spine Road NB	None	1049		201		1103	2119		0.4950	
4	Main Street WB	None	239		989		261	748		0.3198	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	3.51		3.51	2.91		A		A
2	Main Street EB	None	5.85		5.85	0.64		A		A
3	Spine Road NB	None	3.25		3.25	2.57		A		A
4	Main Street WB	None	6.18		6.18	1.13		A		A

Global Results

Performance and Accidents

2040 PM Peak Global Performance

Parameter	Units	Entries	Bypasses	Total
Arrive Flows	veh/hr	2330		2330
Capacity	veh/hr	5749		5749
Average Delay	sec/veh	3.66		3.66
L.O.S. (Signal)	A – F	A		A
L.O.S. (Unsig)	A – F	A		A
Total Delay	veh.hrs	2.37		2.37

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	Spine Road SB	0	0	24.00	2	28.00	2	164.00	66.00	30.00
2	South Street EB	90	0	12.00	1	14.00	1	164.00	66.00	30.00
3	Spine Road NB	180	0	24.00	2	28.00	2	164.00	66.00	30.00
4	South Street WB	270	0	12.00	1	14.00	1	164.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	Spine Road SB	165.00	15.00	1	28.00	2	24.00	2
2	South Street EB	165.00	30.00	2	14.00	1	12.00	1
3	Spine Road NB	165.00	15.00	1	28.00	2	24.00	2
4	South Street WB	165.00	30.00	2	14.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	Spine Road SB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
2	South Street EB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0
3	Spine Road NB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
4	South Street WB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0

Operational Results

2040 AM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Entry	Bypass	Entry	Bypass
1	Spine Road SB	None	720		125		755	2195		0.3280
2	South Street EB	None	60		645		200	869		0.0690
3	Spine Road NB	None	780		55		650	2266		0.3443
4	South Street WB	None	95		785		50	820		0.1159

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.70		2.70	1.61		A		A
2	South Street EB	None	4.18		4.18	0.21		A		A
3	Spine Road NB	None	2.49		2.49	1.60		A		A
4	South Street WB	None	4.65		4.65	0.37		A		A

2040 AM Peak - 15 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	Spine Road SB	None	783		136		820	2184		0.3583	
2	South Street EB	None	65		701		217	850		0.0768	
3	Spine Road NB	None	848		60		706	2261		0.3750	
4	South Street WB	None	103		853		54	796		0.1298	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.73		2.73	1.61		A		A
2	South Street EB	None	4.17		4.17	0.21		A		A
3	Spine Road NB	None	2.51		2.51	1.60		A		A
4	South Street WB	None	4.68		4.68	0.37		A		A

Global Results

Performance and Accidents

2040 AM Peak Global Performance

Parameter	Units	Entries	Bypasses	Total
Arrive Flows	veh/hr	1655		1655
Capacity	veh/hr	6150		6150
Average Delay	sec/veh	2.76		2.76
L.O.S. (Signal)	A – F	A		A
L.O.S. (Unsig)	A – F	A		A
Total Delay	veh.hrs	1.27		1.27

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	Spine Road SB	0	0	24.00	2	28.00	2	164.00	66.00	30.00
2	South Street EB	90	0	12.00	1	14.00	1	164.00	66.00	30.00
3	Spine Road NB	180	0	24.00	2	28.00	2	164.00	66.00	30.00
4	South Street WB	270	0	12.00	1	14.00	1	164.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	Spine Road SB	165.00	15.00	1	28.00	2	24.00	2
2	South Street EB	165.00	30.00	2	14.00	1	12.00	1
3	Spine Road NB	165.00	15.00	1	28.00	2	24.00	2
4	South Street WB	165.00	30.00	2	14.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	Spine Road SB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
2	South Street EB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0
3	Spine Road NB	0	1.000	0	1.000	20.00	3584	0	24.00	3584	0
4	South Street WB	0	1.000	0	1.000	20.00	1792	0	12.00	1792	0

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)				Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass	Entry	Bypass	Entry	Bypass
1	Spine Road SB	None	1015		105		965	2215		0.4581
2	South Street EB	None	270		985		135	749		0.3605
3	Spine Road NB	None	925		245		1010	2075		0.4458
4	South Street WB	None	105		965		205	756		0.1389

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	2.97		2.97	2.53		A		A
2	South Street EB	None	6.89		6.89	1.63		A		A
3	Spine Road NB	None	3.27		3.27	2.56		A		A
4	South Street WB	None	5.17		5.17	0.46		A		A

2040 PM Peak - 15 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	Spine Road SB	None	1103		114		1048	2206		0.5000	
2	South Street EB	None	293				1070	719		0.4083	
3	Spine Road NB	None	1005		266		1097	2053		0.4896	
4	South Street WB	None	114				1048	727		0.1571	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	Spine Road SB	None	3.05		3.05	2.53		A		A
2	South Street EB	None	7.22		7.22	1.63		A		A
3	Spine Road NB	None	3.38		3.38	2.56		A		A
4	South Street WB	None	5.25		5.25	0.46		A		A

Global Results

Performance and Accidents

2040 PM Peak Global Performance

Parameter	Units	Entries	Bypasses	Total
Arrive Flows	veh/hr	2315		2315
Capacity	veh/hr	5795		5795
Average Delay	sec/veh	3.65		3.65
L.O.S. (Signal)	A – F	A		A
L.O.S. (Unsig)	A – F	A		A
Total Delay	veh.hrs	2.34		2.34

SIGNAL JUSTIFICATION REPORT
for
CR 96 and Spine Road Access
In the City of Arden Hills, Minnesota

Proposed Letting Date: **February 2016**

I hereby certify that this report was prepared by me or under my supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Brandon Bourdon	43709	
	Reg. No.	Date

APPROVED:

City of Arden Hills	
	Date

Ramsey County	
	Date

Metro District Assistant State Aid Engineer	
	Date

Metro District Traffic Engineer – Program Support	
	Date

PROJECT DESCRIPTION

Ramsey County has purchased and is cleaning 427 acres of fallow land in Arden Hills to spur regional development and put unproductive land back on the tax rolls. The project, when completed, will generate millions of dollars annually in county and state property taxes. This addition to the tax base will benefit the entire county, including the city of St. Paul and suburban taxpayers.

Development of TCAAP will include a mix of residential, commercial, light industrial and other uses. In addition, the remediation project will clean up the state's largest Superfund site for a fixed price, to be recovered when the land is ultimately sold for private development.

Nearby highway improvements to Interstate 35W, I-694, Highway 10, Highway 96 and other roadways will benefit 240,000 commuters per day. These highway and bridge improvements are needed whether TCAAP is redeveloped or not.

The purpose of this report is to document the need for a signalized intersection at the County Road 96 and Spine Road Access intersection in the City of Arden Hills, Minnesota. This report also includes a summary of the existing geometry, the proposed geometry, an operations analysis, a warrant analysis, and a crash analysis. The intersection location is shown in **Figure 1**.

EXISTING CONDITIONS

CR 96 is an east-west oriented roadway with a four lane cross section divided by a center median within the study area. The speed limit on CR 96 is 50 miles per hour (mph). The subject intersection currently operates as a stop control intersection for the local property, located on the south side CR 96. The existing lane geometrics are shown in **Figure 2** and described below:

- The northbound approach currently consists of a shared right/left-turn lane.
- The eastbound approach currently consists of two through lanes and a right-turn lane.
- The westbound approach currently two through lanes and a left-turn lane.

PROPOSED CONDITIONS

As part of the TCAAP reconstruction project, the existing in-place stop controlled intersection will be reconfigured as a four-legged intersection, with signalized control. The improved intersection is expected to maintain adequate traffic operations and enhance safety at this location. The proposed Spine Road Access is to be a 4-lane divided roadway with a speed limit of 45 mph. The new traffic signal will be fully-actuated with detection on each approach. The proposed lane uses for the intersection of CR 96 and Spine Road Access are shown in **Figure 3** and described as follows:

- The northbound approach geometry includes a shared through/right lane and a left-turn lane.
- The southbound approach geometry includes dual left-turn lanes, a through lane, and right-turn lane.
- The eastbound approach geometry includes dual left-turn lanes, two through lanes, and a right-turn lane.
- The westbound approach geometry includes dual left-turn lanes, two through lanes, and a right-turn lane.



Figure 1: Intersection Location



Figure 2: Existing Geometrics

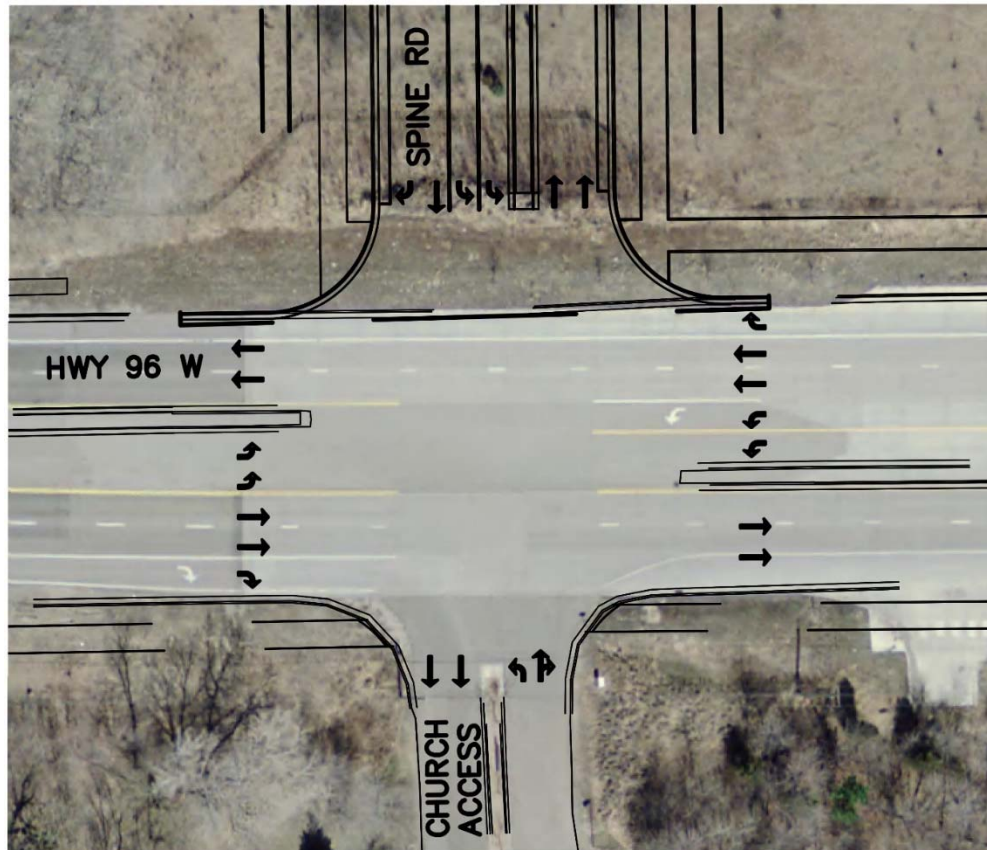


Figure 3: Proposed Geometrics

SCHEDULE AND PROJECT MANAGER

City of Arden Hills Contact:	Ramsey County Contact:	Consultant Contact:
		William Klingbeil, P.E. Kimley-Horn and Associates, Inc. 2550 University Avenue W., Suite 238 N St. Paul, MN 55114 William.Klingbeil@kimley-horn.com (612) 294-7275
Proposed Letting Date:	February, 2016	
Proposed Construction Completion Date:	Summer, 2016	

NEED FOR PROJECT/PROJECT DISCUSSION

As part of the project, the existing stop-controlled intersection of CR 96 at Spine Road Access located in the City of Arden Hills, Ramsey County, Minnesota will be modified and reconfigured. The intersection will be modified as part of the TCAAP redevelopment project which includes geometric and operational changes from the existing condition. The intersection is proposed to operate as a signalized intersection. The signal is warranted based on the information and assumptions below.

DESIGN AND CRITERIA EXCEPTIONS

No design exceptions to MnDOT or AASHTO Standards are required.

JUSTIFICATION

Traffic signal justification is based on applying the applicable warrants for signal installation as outlined in the 2013 Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD) using:

- Proposed approach volumes
- Recent turning movement counts (TMCs)
- Proposed lane uses
- Proposed speed limits
- Sound traffic engineering judgment

ASSUMPTIONS

Forecasted traffic volumes for the future analysis years of 2020 and 2036 were developed in order to perform a traffic signal warrant analysis. The forecasted 2036 peak hour TMCs at the intersection of CR 96 and Spine Road were used from SEH's I-35W/CR H Interchange Reconstruction Study Traffic Forecast Memorandum dated 12/26/2014. The 2011 traffic volumes at the intersection of CR 96 and Church Access (future Spine Road) were used to determine the hourly distribution of traffic over 24 hours. A daily total number of vehicles was calculated for each approach using the peak hour TMCs and the

percentage of total daily traffic that occurs in the peak hours. The hourly distribution was then applied to the forecasted 2036 approach volumes to extrapolate the hourly volumes for each hour of the day.

2020 peak hour TMCs were developed by interpolating between the 2016 Build and 2036 Build volumes provided by SEH's aforementioned Traffic Memorandum. Hourly volumes were then developed following the same methodology as used to develop the 2036 hourly volumes. The forecast year 2020 and 2036 traffic volumes were used in conjunction with the proposed lane configurations for the purposes of the intersection operations analysis and the signal warrant analysis.

INTERSECTION OPERATIONS ANALYSIS

An operational analysis was performed at the intersection of CR 96 and Spine Road for the years 2020 and 2036 to determine if operational concerns would be anticipated in the future with the addition of the proposed Spine Road. The a.m. and p.m. peak hours were analyzed for both analysis years under two-way stop controlled and signalized conditions. The delay and level of service (LOS) results for the two-way stop control condition are shown **Table 1**, and the results for the signalized condition are shown in **Table 2**.

Table 1: 2020 and 2036 Two-Way Stop Control Condition Delay and LOS

Movement	AM Peak Hour				PM Peak Hour			
	Year 2020		Year 2036		Year 2020		Year 2036	
	Delay [s/veh]	LOS	Delay [s/veh]	LOS	Delay [s/veh]	LOS	Delay [s/veh]	LOS
EBL	10.1	B	15.7	C	7.9	A	15.7	C
EBT	1	A	0.7	A	1.5	A	1.4	A
EBR	0.3	A	0.4	A	0.9	A	1.2	A
WBL	6	A	4.3	A	7.4	A	12.1	B
WBT	2.8	A	3.4	A	3.3	A	2.8	A
WBR	2.4	A	4	A	4.9	A	5.9	A
NBL	40.2	E	82.2	F	49.5	E	99.2	F
NBT	-	-	-	-	-	-	-	-
NBR	5.5	A	6.4	A	9.7	A	8	A
SBL	871.9	F	1800.3	F	388.9	F	1606.3	F
SBT	-	-	-	-	-	-	-	-
SBR	30.6	D	766.3	F	5.4	A	434.2	F

Table 2: 2020 and 2036 Signalized Condition Delay and LOS

Movement	AM Peak Hour				PM Peak Hour			
	Year 2020		Year 2036		Year 2020		Year 2036	
	Delay [s/veh]	LOS	Delay [s/veh]	LOS	Delay [s/veh]	LOS	Delay [s/veh]	LOS
EBL	27.5	B	28	C	26	C	28.5	C
EBT	8	A	7.6	A	8.7	A	10.2	B
EBR	1.4	A	1.8	A	2.1	A	2.8	A
WBL	30.5	C	33.5	C	29.4	C	32.1	C
WBT	14.9	B	21.9	C	12.8	B	17.4	B
WBR	5.7	A	10	A	9.1	A	16.9	B
NBL	19.1	B	12.4	B	20	B	17.6	B
NBT	-	-	-	-	-	-	-	-
NBR	4.4	A	4.2	A	5.6	A	5.9	A
SBL	23.2	C	26.1	C	23.3	C	26.7	C
SBT	-	-	-	-	-	-	-	-
SBR	7.6	A	9.1	A	5.1	A	5.5	A
Intersection	14.1	B	18	B	12.4	B	17.9	B

As shown in **Table 1**, the left-turning movements on the stop-controlled side streets (northbound and southbound) are anticipated to reach unacceptable levels of service by 2020. The left-turning movements on the side streets and the southbound right are expected to reach LOS F by 2036.

As shown in **Table 2**, all movements at the intersection are anticipated to operate at LOS C or better in both 2020 and 2036 under signalized intersection control operations. The traffic signal effectively mitigates the anticipated delays shown in the two-way stop control intersection control condition.

WARRANT ANALYSIS RESULTS

The warrant requirements outlined in chapter four of the MnMUTCD used the 70% column based on the speed of the roadway. The right turn volumes on all approaches were removed from the analysis as each approach enables vehicles to turn right without the assistance of the signal. This methodology is consistent with the practices of Metro Traffic Signal Justification Methodology. Assumptions used for the lane approaches used in the warrant analysis are shown in **Table 3**.

Table 3: Approach Lane Assumptions

Approach	Lane Usage	Posted Speed
Eastbound CR 96 (Major Approach)	2 or more approach lanes	50 miles per hour
Westbound CR 96 (Major Approach)	2 or more approach lanes	50 miles per hour
Southbound Spine Road (Minor Approach)	2 or more approach lanes	30 miles per hour

Traffic signal warrant analyses were completed based on the proposed geometric conditions using the projected 2020 and 2036 vehicular volumes that were adjusted to remove the right turning vehicles on all approaches. The warrant analyses results for the 2020 analysis are shown in **Table 4**. The results for the 2036 analysis are shown in **Table 5**.

Table 4: 2020 Traffic Signal Warrant Analysis Results

MnMUTCD Warrant	Hours Met	Hours Required to be Met	Warrant Met
Warrant 1A: Minimum Vehicular Volume	13	8	Yes
Warrant 1B: Interruption of Continuous Traffic	13	8	Yes
Warrant 2: Four-Hour Vehicular Volume	13	4	Yes
Warrant 3: Peak Hour	8	1	Yes

As shown in Table 4, the CR 96 and Spine Road intersection meets Warrants 1A, 1B, 2 and 3 with the forecast year 2020 traffic volumes. A summary of the 2020 traffic warrant analysis are provided in **Figures 4 and 5** in the attached **Appendix**.

Table 5: 2036 Traffic Signal Warrant Analysis Results

MNMUTCD Warrant	Hours Met	Hours Required to be Met	Warrant Met
Warrant 1A: Minimum Vehicular Volume	13	8	Yes
Warrant 1B: Interruption of Continuous Traffic	13	8	Yes
Warrant 2: Four-Hour Vehicular Volume	13	4	Yes
Warrant 3: Peak Hour	8	1	Yes

As shown in Table 5, the CR 96 and Spine Road intersection continues to meet Warrants 1A, 1B, 2 and 3 with the forecast year 2036 traffic volumes. A summary of the 2036 traffic warrant analysis are provided in **Figures 6 and 7** in the attached **Appendix**.

CRASH ANALYSIS

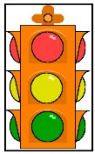
A crash analysis was performed for the intersection of CR 96 and the North Heights Lutheran Church access. Crash data at the intersection for the past five years was taken from the Minnesota Crash Mapping Analysis Tool (MnCMAT) website, provided on the Minnesota Department of Transportation (MnDOT) website. The most current version available (2013) of the MnDOT Green Sheet crash analysis tool for intersections was used to evaluate the safety of the intersection. The crash analysis summary is provided in **Figure 8** in the attached **Appendix**.

There were three recorded crashed at the intersection within the past five years, including one possible injury and two property damage only crashed. The observed crash rate for the intersection is 0.08 per million entering vehicles (MEV). The critical crash rate for the intersection is 0.38 per MEV. Based on similar statewide intersections, the analysis intersection operates within the normal range.

CONCLUSIONS AND RECOMMENDATIONS

Based on the 2020 and 2036 signal warrant analyses and the traffic operations analysis performed, a signal is warranted at the intersection of CR 96 and Spine Road. A signal warrant analysis consistent with the methods and procedures outlined in the MnMUTCD indicates that 1 hour of data meets Warrants 1A, 13 hours of data meet 1B and 2, and eight hours of data meet Warrant 3. It is recommended that the intersection be modified and a signal be installed to allow for acceptable operations and levels of safety in the future traffic conditions.

Appendix



Kimley-Horn and Associates

2020 Signal Warrant Analysis

LOCATION: Arden Hills
 COUNTY: Ramsey
 REF. POINT:
 DATE: 6/9/2015
 OPERATOR:

Speed	Approach Description	Lanes
50	Major App1: EB CR 96	2
50	Major App3: WB CR 96	2
30	Minor App2: Spine Rd.	2
	Minor App4:	

0.70 FACTOR USED? **yes**
 POPULATION < 10,000? **no**
 EXISTING SIGNAL ? **no**

HOUR	THRESHOLDS 1A/1B:		420		630		140		70		140		70	
	MAJOR APP. 1	MAJOR APP. 3	TOTAL 1+3	MAJOR 1A	MAJOR 1B	MINOR APP. 2	MINOR 2 1A	MINOR 2 1B	MINOR APP. 4	MINOR 4 1A	MINOR 4 1B	MAJ & MIN 1A	MAJ & MIN 1B	
0:00 - 1:00	49	40	88			25								
1:00 - 2:00	40	32	72			20								
2:00 - 3:00	32	26	58			16								
3:00 - 4:00	25	20	46			13								
4:00 - 5:00	51	42	93			26								
5:00 - 6:00	181	147	329			91		X						
6:00 - 7:00	417	338	756	X	X	210	X	X				X	X	
7:00 - 8:00	570	714	1284	X	X	403	X	X				X	X	
8:00 - 9:00	572	464	1036	X	X	288	X	X				X	X	
9:00 - 10:00	439	356	796	X	X	221	X	X				X	X	
10:00 - 11:00	372	302	674	X	X	187	X	X				X	X	
11:00 - 12:00	411	334	745	X	X	207	X	X				X	X	
12:00 - 13:00	490	397	887	X	X	247	X	X				X	X	
13:00 - 14:00	451	366	818	X	X	227	X	X				X	X	
14:00 - 15:00	548	445	994	X	X	276	X	X				X	X	
15:00 - 16:00	586	476	1062	X	X	295	X	X				X	X	
16:00 - 17:00	894	474	1368	X	X	334	X	X				X	X	
17:00 - 18:00	779	632	1412	X	X	392	X	X				X	X	
18:00 - 19:00	420	341	761	X	X	212	X	X				X	X	
19:00 - 20:00	263	214	477	X		132		X						
20:00 - 21:00	228	185	414			115		X						
21:00 - 22:00	185	150	335			93		X						
22:00 - 23:00	119	96	215			60								
23:00 - 24:00	68	55	124			34								

	Met (Hr)	Required (Hr)	
Warrant 1a	13	8	Satisfied
Warrant 1b	13	8	Satisfied
Warrant 2	13	4	Satisfied
Warrant 3	8	1	Satisfied
Warrant 7	0	8	Not satisfied

Figure 4: 2020 Warrant Analysis Table

LOCATION: Arden Hills
 COUNTY: Ramsey
 REF. POINT:
 DATE: 6/9/2015

Speed	Approach Description	Lanes
50	Major App1: EB CR 96	2
50	Major App3: WB CR 96	2
30	Minor App2: Spine Rd.	2
	Minor App4:	

0.70 FACTOR USED? yes
 POPULATION < 10,000? no
 EXISTING SIGNAL ? no

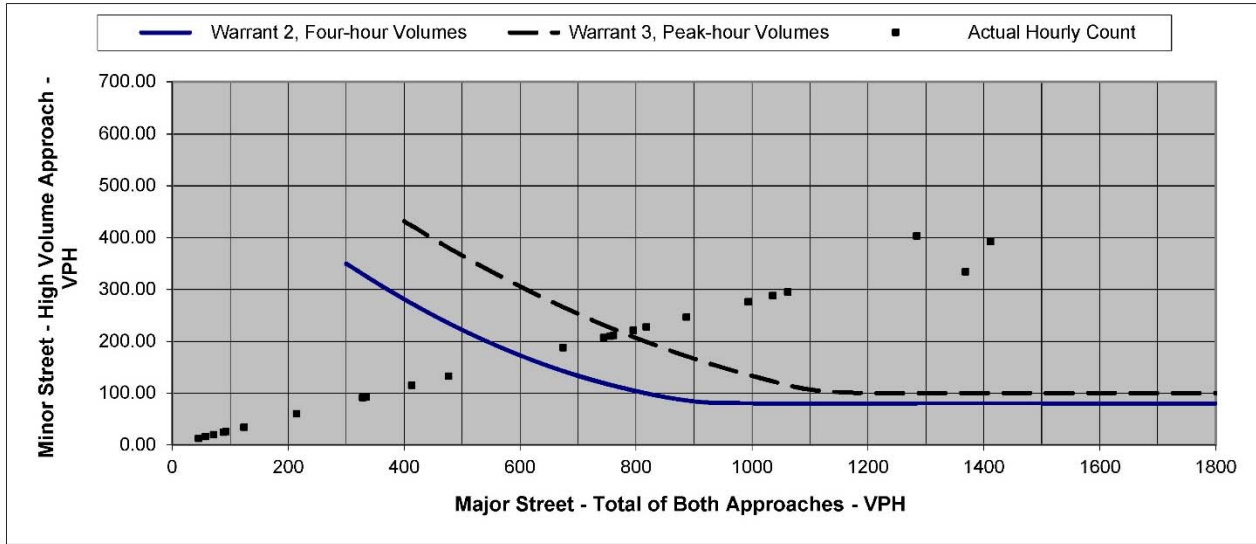
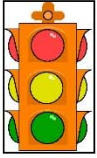


Figure 1. Four Hour and Peak Hour Warrant Analysis

Note: For data points outside the graph range, check the minor street volume against the lower thresholds

Major	Warrant Criteria		Actual Hourly Count	
	warrant 2, 4-hour	warrant 3, Peak-hour volume	Major	Actual Hourly Count
200			88	25
300	349.59		72	20
400	280.802	431.302	58	16
500	221.819	365.115	46	13
600	172.636	305.528	93	26
700	133.253	252.541	329	91
800	103.67	206.154	756	210
900	83.887	166.367	1284	403
1000	80	133.18	1036	288
1100	80	106.593	796	221
1200	80	100	674	187
1300	80	100	745	207
1400	80	100	887	247
1500	80	100	818	227
1600	80	100	994	276
1700	80	100	1062	295
1800	80	100	1368	334
			1412	392
			761	212
			477	132
			414	115
			335	93
			215	60
			124	34

Figure 5: 2020 Warrant Analysis Graph



Kimley-Horn and Associates

2036 Signal Warrant Analysis

LOCATION: Arden Hills
 COUNTY: Ramsey
 REF. POINT:
 DATE: 6/9/2015
 OPERATOR:

Speed	Approach Description	Lanes
50	Major App1: EB CR 96	2
50	Major App3: WB CR 96	2
30	Minor App2: Spine Rd.	2
	Minor App4:	

0.70 FACTOR USED? **yes**
 POPULATION < 10,000? **no**
 EXISTING SIGNAL ? **no**

HOUR	THRESHOLDS 1A/1B:			420	630	140	70	140	70	MAJ & MIN 1A	MAJ & MIN 1B
	MAJOR APP. 1	MAJOR APP. 3	TOTAL 1+3	MAJOR 1A	MAJOR 1B	MINOR APP. 2	MINOR 2 1A	MINOR 2 1B	MINOR APP. 4		
0:00 - 1:00	57	41	98			39					
1:00 - 2:00	47	34	80			31					
2:00 - 3:00	37	27	64			25					
3:00 - 4:00	30	21	51			20					
4:00 - 5:00	60	43	104			41					
5:00 - 6:00	213	154	367			144	X	X			
6:00 - 7:00	490	353	843	X	X	332	X	X			X
7:00 - 8:00	670	770	1440	X	X	575	X	X			X
8:00 - 9:00	672	484	1156	X	X	455	X	X			X
9:00 - 10:00	516	372	888	X	X	350	X	X			X
10:00 - 11:00	437	315	753	X	X	296	X	X			X
11:00 - 12:00	483	348	831	X	X	327	X	X			X
12:00 - 13:00	575	415	990	X	X	390	X	X			X
13:00 - 14:00	530	382	913	X	X	359	X	X			X
14:00 - 15:00	644	465	1109	X	X	436	X	X			X
15:00 - 16:00	689	497	1185	X	X	467	X	X			X
16:00 - 17:00	1050	470	1520	X	X	590	X	X			X
17:00 - 18:00	916	660	1576	X	X	620	X	X			X
18:00 - 19:00	494	356	849	X	X	334	X	X			X
19:00 - 20:00	309	223	532	X		209	X	X			X
20:00 - 21:00	268	193	462	X		182	X	X			X
21:00 - 22:00	217	157	374			147	X	X			
22:00 - 23:00	140	101	240			94		X			
23:00 - 24:00	80	58	138			54					

	Met (Hr)	Required (Hr)	
Warrant 1a	15	8	Satisfied
Warrant 1b	13	8	Satisfied
Warrant 2	13	4	Satisfied
Warrant 3	13	1	Satisfied
Warrant 7	0	8	Not satisfied

Figure 6: 2036 Warrant Analysis Table

LOCATION: Arden Hills
 COUNTY: Ramsey
 REF. POINT:
 DATE: 6/9/2015

Speed	Approach Description	Lanes
50	Major App1: EB CR 96	2
50	Major App3: WB CR 96	2
30	Minor App2: Spine Rd.	2
	Minor App4:	

0.70 FACTOR USED? yes
 POPULATION < 10,000? no
 EXISTING SIGNAL ? no

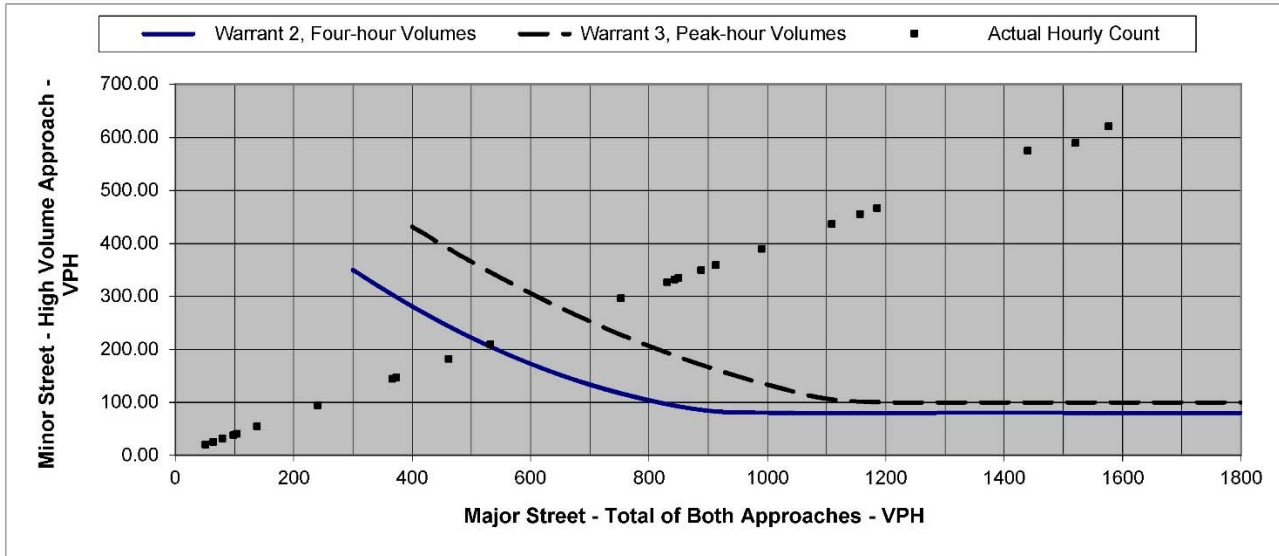


Figure 1. Four Hour and Peak Hour Warrant Analysis

Note: For data points outside the graph range, check the minor street volume against the lower thresholds

Major	Warrant Criteria		Actual Hourly Count	
	warrant 2, 4-hour volume	warrant 3, peak-hour volume	Major	Actual Hourly Count
200			98	39
300	349.59		80	31
400	280.802	431.302	64	25
500	221.819	385.115	51	20
600	172.636	305.528	104	41
700	133.253	252.541	367	144
800	103.67	206.154	843	332
900	83.887	166.367	1440	575
1000	80	133.18	1156	455
1100	80	106.593	888	350
1200	80	100	753	296
1300	80	100	831	327
1400	80	100	990	390
1500	80	100	913	359
1600	80	100	1109	436
1700	80	100	1185	467
1800	80	100	1520	590
			1576	620
			849	334
			532	209
			462	182
			374	147
			240	94
			138	54

Figure 7: 2036 Warrant Analysis Graph

Intersection Safety Screening

Intersection: CR 96 & Noth Heights Lutheran Church Access (Future Spine Road)



Crash Data, 2009-2013.

Crashes by Crash Severity		Intersection Characteristics	
Fatal	0	Entering Volume	20,900
Incapacitating Injury	0	Traffic Control	Thru / stop
Non-incapacitating Injury	0	Environment	Suburban
Possible Injury	1	Speed Limit	50 mph
Property Damage	2		
Total Crashes	3		

Annual crash cost = \$19,160

Statewide Comparison

Urban Thru / Stop

Total Crash Rate		Fatal & Serious Injury Crash Rate	
Observed	0.08	Observed	0.00
Critical Rate	0.38	Critical Rate	2.77
Critical Index	0.21	Critical Index	0.00

The observed crash rate is the number of crashes per million entering vehicles (MEV). The critical rate is a statistical comparison based on similar intersections statewide. An observed crash rate greater than the critical rate indicates that the intersection operates outside the expected, normal range. The critical index reports the magnitude of this difference.

The observed total crash rate for this period is 0.08 per MEV; this is 79% below the critical rate. Based on similar statewide intersections, an additional 12 crashes over the five years would indicate this intersection operates outside the normal range.

The observed fatal and serious injury crash rate for this period is 0.00 per 100 MEV; this is 100% below the critical rate. The intersection operates within the normal range.

Figure 8: Crash Analysis