Westwood

TRAFFIC IMPACT STUDY

KENWOOD VILLAGE

Duluth, MN

April 10, 2015

Prepared For:

UNITED PROPERTIES

Westwood

Traffic Impact Study for

Kenwood Village

Prepared for:
United Properties
3600 American Boulevard West
Suite 750
Minneapolis, MN 55431

Prepared by:
Westwood Professional Services
7699 Anagram Drive
Eden Prairie, MN 55344
(952) 937-5150

Project Number: 0004765.00
Date: 04/10/2015

Traffic Impact Study for

Kenwood Village

Duluth, MN

April 10, 2015

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

Print Name: _____Stephen J. Manhart_____

Signature: _____

Date: __04/10/2015_____ License # _____22428_____

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1.0 Executive Summary

Westwood Professional Services, Inc., has been requested by United Properties to analyze the traffic impacts of their proposed retail/residential development called Kenwood Village in the southwest quadrant of the intersection of West Arrowhead Road and Kenwood Avenue in Duluth, Minnesota (see Figure 1.1). This report will review the level of trip generation for the proposed project and determine the traffic impacts on the local study network that the development may cause.

The objectives of this study are to determine the traffic impacts of the proposed development on the surrounding study area and to determine whether mitigation measures are necessary.

a. Site Location and Study Area – The project location is the 1.2 acre site south of W Arrowhead Road and west of Kenwood Avenue in Duluth, MN.

   The study area includes the following intersections:
   - W Arrowhead Road and Kenwood Avenue
   - E Cleveland Street and Kenwood Avenue

b. Development Description – The parcel is currently zoned as "Mixed–Use Neighborhood", which means, "A transitional use between more intensive commercial uses and purely residential neighborhoods"[1]

   The development consists of an L-shaped building that encompasses 14,177 sq. ft. of retail use and 85 units of residential use.

c. Principal Findings – The mixed use development is proposed to be built out in 2015. Westwood projected the traffic conditions in the study area one year after the proposed build-out of the development (2016 Build Condition). Westwood also looked at projected traffic conditions in the study area without the development (2016 No-Build Condition).

   The principal findings included:
   - The intersection of Kenwood Avenue & Arrowhead Road operates at a Level of Service B (LOS-B) in the Existing, 2016 No-Build, and 2016 Build conditions.
   - The intersection of Kenwood Ave & Cleveland St operates at a Level of Service A (LOS-A) in all conditions including signalized and unsignalized Build conditions..
   - Trip distribution determined that 55% of development traffic will enter and exit from the north access (Arrowhead Road).

d. Conclusions/Recommendations – Conclusions and recommendations of the site include:
   - The traffic generated by this development in the AM and PM Peak Hours will have nominal impact the traffic operation of the nearby intersections.

[1] http://www.duluthmn.gov/media/121164/4_LUMfinal-edit-web.pdf

- In the Build condition, the intersection of Kenwood Ave & Cleveland St will not meet the warrants for signalization. Therefore, side street stop control is recommended at this time.
- Yield or stop control is recommended for both egress driveways from the site.
- Northbound queue lengths on Kenwood Avenue can sometimes extend back to the intersection of Kenwood Ave & Cleveland St. These can be shortened by reducing the maximum signal cycle length for Kenwood Ave & Arrowhead Rd.

2.0 Introduction

The project location is the 1.2 acre site south of W Arrowhead Road and west of Kenwood Avenue in Duluth, MN. The site location is shown on Figure 1. The parcel is currently zoned as "Mixed-Use Neighborhood", which is defined as "A transitional use between more intensive commercial uses and purely residential neighborhoods"[2]

The development consists of a four-level L-shaped building consisting of 14,177 gross square feet of commercial use and 85 apartment units. Figure 2 shows the proposed site layout for the retail development.

One site access is proposed on Arrowhead Road. This access is proposed to include one inbound lane and one outbound lane. The access is proposed as a right-in/right-out access only.

Two access drives are proposed on Cleveland. Both accesses are proposed with one inbound lane and one outbound lane, and both provide full turning movements to and from Cleveland.

The westerly driveway provides through access between Cleveland and Arrowhead. The westerly drive also provides access to the 57-stall surface parking lot for the retail and residential uses.

The easterly driveway provides access to and from the 135-stall lower level parking lot. The easterly drive provides structured parking for the residential uses.

The developer proposes a single development phase for retail and residential development. It is intended that the development will be constructed in 2015.

[2] http://www.duluthmn.gov/media/121164/4_LUMfinal-edit-web.pdf

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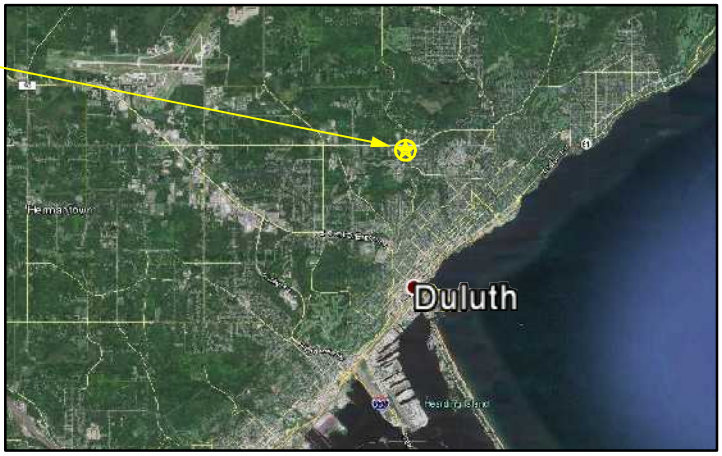
SITE LOCATION



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Date: 4/10/15

Westwood

Phone (952) 937-5150
Fax (952) 937-5822
Toll Free (888) 937-5150

7699 Anagram Drive
Eden Prairie, MN 55344
westwoodps.com

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Kenwood Village

Duluth, MN

Site Location

Figure 2-1

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- A Entry to Lower Level Parking
- B Patio
- C Interior Sidewalk
- D Drive-thru
- E Structured Parking
- F Delivery/Service Entry
- G Walkway to Lower Level Parking

Landscape Buffer
(min. 10' wide for adjacent R-1)
Required Trees: 8
Required Shrubs: 32 large

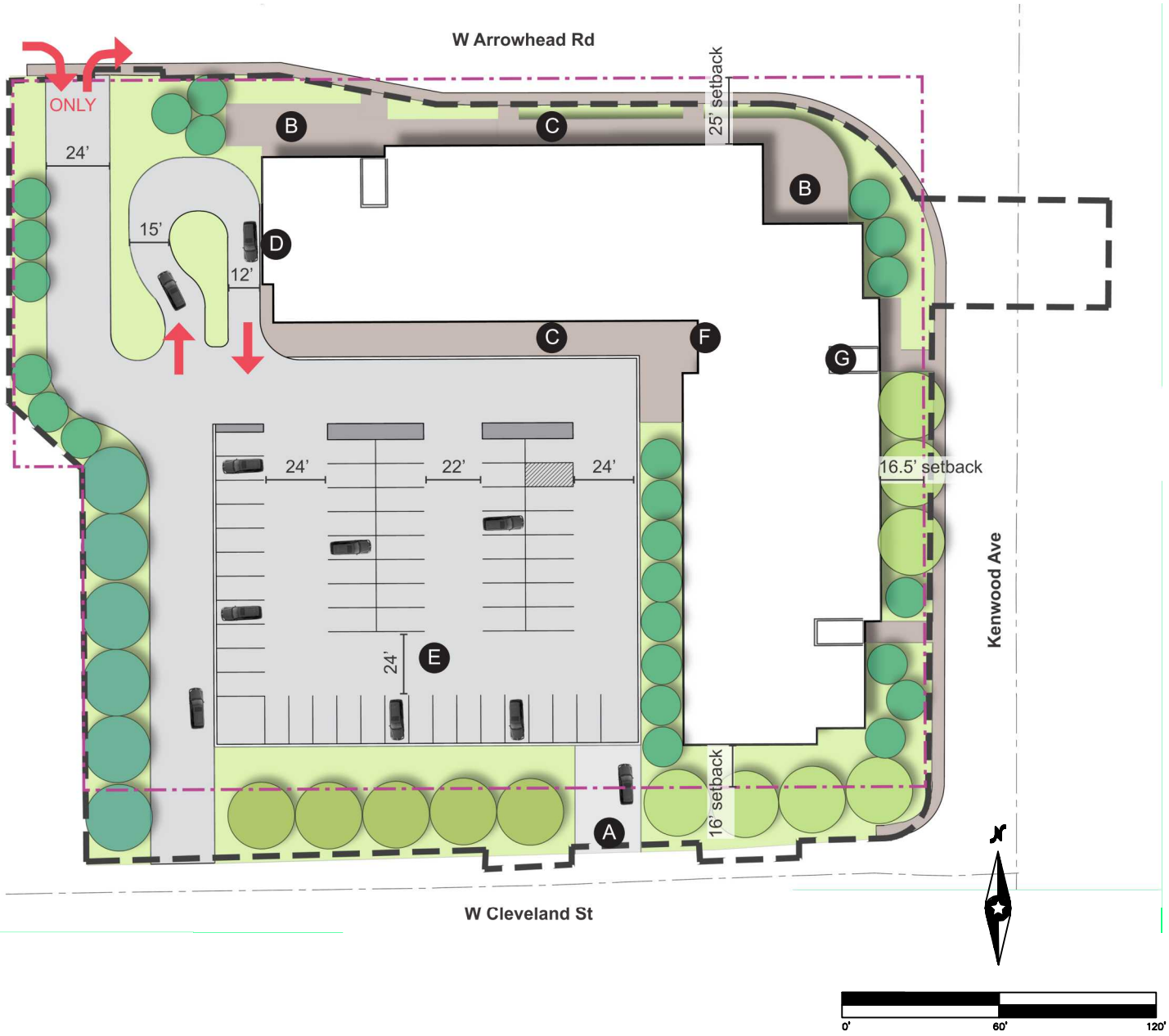
Tree Replacement
Required Trees: ??

General Notes:
Zone Districts: R-1 & MU-N, Higher Education Overlay District

Total Allowable Parking Commercial:
52 Minimum, 78 Maximum

Total Allowable Parking Residential:
85 Minimum, No Maximum (?)

Total Parking Count: 192 Spaces



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Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Prepared for:
United Properties
Minneapolis, MN

Kenwood Village
Duluth, MN

Concept Site Plan

Figure 2-2

3.0 Existing Condition

Much of the site is currently undeveloped. One house exists in the most northwest corner of the parcel, while two houses occupy the southern portion of the parcel. The site has noticeable slopes to take into account.

A residential neighborhood is located to the south and west of this parcel. Existing retail developments lie to the north and east of this property.

3.1 Existing Intersection Geometry

Along the north side of the development parcel, Arrowhead Road is a 42-foot wide east-west collector roadway with four lanes and 2-foot shoulders on each side. It then expands to 52-feet toward the intersection with Kenwood to accommodate a right turn lane. There are no medians on this section of Arrowhead Road.

To the east of the development, Kenwood Ave is a 52-foot wide north-south collector roadway with four lanes and 2-foot shoulders between Cleveland Street and Arrowhead Road. There are no medians on this section of Kenwood Avenue.

Along the south side of the development parcel, Cleveland Street is a 24-foot wide east-west residential roadway with no marked lanes. Cleveland St is a dead end to the west of the property, so all traffic must enter and exit the roadway from the east.

Figure 3-1 illustrates existing lane configurations at the study intersections.

The following traffic control exists:

- Kenwood Avenue and Arrowhead Road –signalized
- Kenwood Avenue and Cleveland Street/Kenwood Plaza –side street (Cleveland St/Kenwood Plaza) stop

Prevailing speed limits:

- W Arrowhead Road– 30 mph (posted)
- Kenwood Avenue– 30 mph (posted)
- Cleveland Street – 30 mph (statutory)
- Kenwood Plaza– 10 mph

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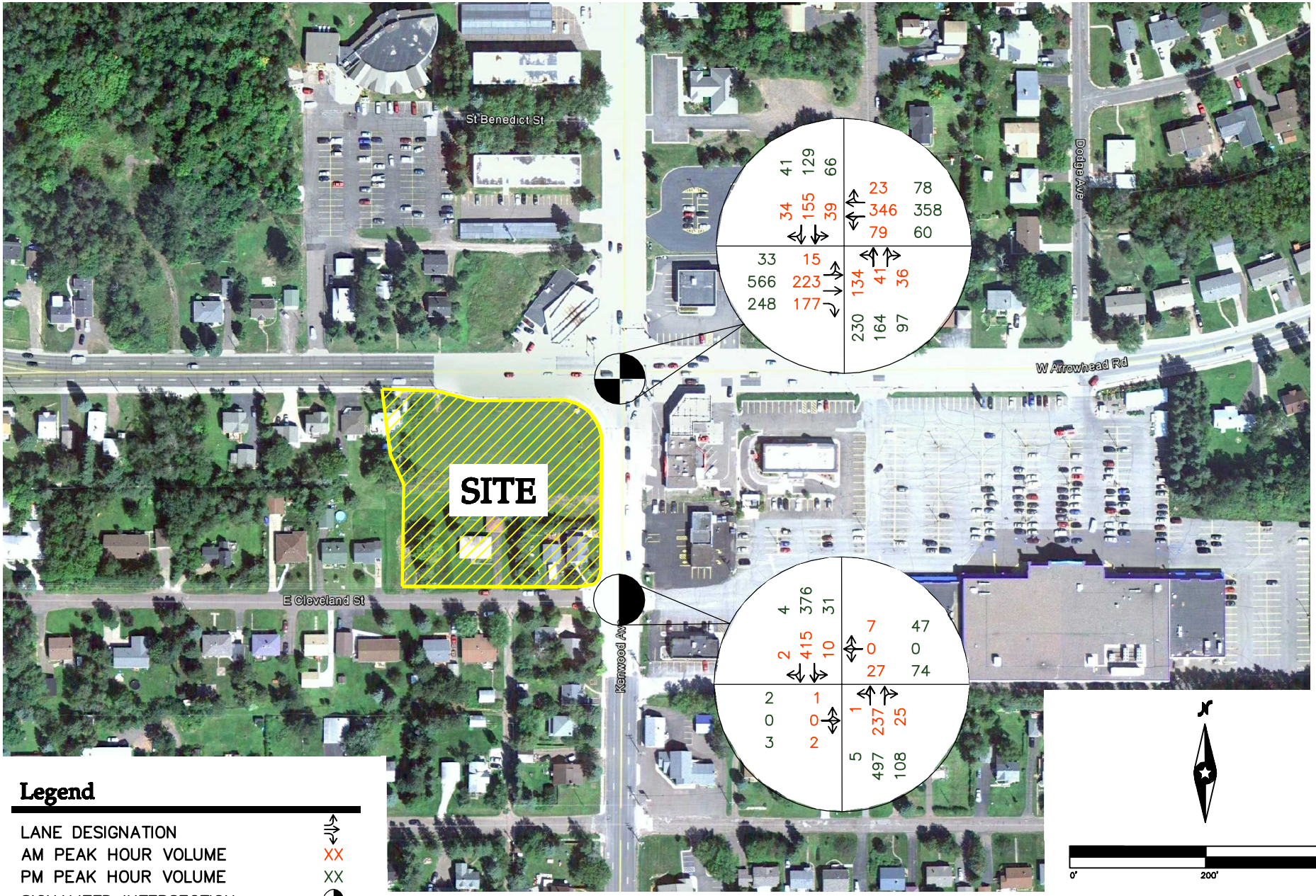

Legend

LANE DESIGNATION	⇉ ⇊
AM PEAK HOUR VOLUME	XX
PM PEAK HOUR VOLUME	XX
SIGNALIZED INTERSECTION	◔
UNSIGNALIZED INTERSECTION	◑

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Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
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Duluth, MN

Existing Peak Hour Traffic Volumes

Figure 3-1

3.2 Existing Alternative Modes of Transit

There are bus stops at both Kenwood Ave & Cleveland St and Kenwood Ave & Arrowhead Rd. Routes 11K, 12, and 18 serve these intersections.

There is a sidewalk along the west side of Kenwood Avenue along with sidewalks on both the north and south sides of Arrowhead Rd. The proposed development will continue to provide sidewalks along the west side of Kenwood Ave and the south side of Arrowhead Rd along its frontage.

3.3 Existing Traffic Volumes

Annualized average daily traffic (AADT) volumes for the following roadways were found on the MnDOT 2012 Publication Traffic Volumes Metro Street Series Map[3]:

- Kenwood Ave north of Arrowhead Rd – 5,000 veh/day
- Kenwood Ave south of Arrowhead Rd – 11,100 veh/day
- Arrowhead Rd east of Kenwood Ave – 14,000 veh/day
- Arrowhead Rd west of Kenwood Ave– 16,800 veh/day
- Cleveland St – N/A

Westwood conducted AM and PM peak period turning movement counts at Arrowhead Road & Kenwood Ave in July 2014. Twenty-four hour counts were taken at Cleveland St & Kenwood Ave.

The MnDOT State Aid website lists 2011 traffic projection factors for each county in the state.[4] For St. Louis County, that traffic projection factor is 1.2. Westwood used this projection factor to model the current year traffic from the counts provided. Figure 3-1 shows the peak hour movements at each intersection.

3.4 Existing Traffic Operation

Traffic operations for the AM and PM peak hour conditions within the study area were analyzed using the industry-standard *Synchro/SimTraffic Version 9* software package, which uses the data and methodology contained in the 2010 Highway Capacity Manual (2010 HCM), published by the Transportation Research Board. The software model was calibrated to replicate existing

[3] 2012 Publication Traffic Volumes Metro Street Series Map, Minnesota Department of Transportation Office of Transportation Data and Analysis Traffic Volume Program, 2011 AADT Product.

[4] http://www.dot.state.mn.us/stateaid/csah/TrafficFactors2011.pdf

conditions as accurately as possible before being used to assess future conditions. A full discussion of the methodology used to assess traffic operation appears in the Appendix of this report.

3.5 Existing Operational Results

Westwood analyzed traffic existing traffic conditions based on turning movement counts, existing lane geometrics and traffic control in the study area. The operational analyses for Existing A.M. and P.M. peak hour conditions are summarized in Table 3.1.

Existing traffic signal timing plans were obtained from the City of Duluth. The cycle length for the signalized intersection of Arrowhead Rd & Kenwood Ave varies, but can be as long as 105 seconds in the existing AM condition and 150 seconds in the existing PM condition.

Table 3.1: Existing Peak Hour Traffic Operation Summary

Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	15.3 sec	LOS-B	WB Left	30.1 sec	LOS-C	204 ft
			EB Left	32.4 sec	LOS-C	128 ft
			NB Left	7.7 sec	LOS-A	32 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	0.4 sec	LOS-A	WB Left	6.9 sec	LOS-A	53 ft
P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	23.7 sec	LOS-C	WB Left	79.3 sec	LOS-E	279 ft
			EB Left	53.6 sec	LOS-D	292 ft
			NB Left	5.5 sec	LOS-A	33 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	2.0 sec	LOS-A	WB Left	10.7 sec	LOS-B	96 ft

1. Overall Intersection LOS using 2010 HCM methodology as determined by Intersection Control Delay and as reported by Synchro 9/SimTraffic 9 analysis.
2. 95th Percentile queues as reported by average of five runs of SimTraffic 9

It is noted that while overall intersection levels of service are within acceptable limits (i.e., LOS-D or better), individual lane groups at the intersection of Arrowhead and Kenwood experience significant delay and excessive queue lengths. In the P.M. Peak Hour specifically, eastbound and westbound left turn movements on Arrowhead at Kenwood record queue lengths approaching 300 feet. These movements also record approach delay nearing a minute or longer.

4.0 No-Build Condition

The MnDOT State Aid website lists 2011 traffic projection factors for each county in the state.[5] For St. Louis County, that traffic projection factor is 1.2. Westwood used this projection factor to model future year traffic conditions.

Background traffic in the area was projected upward to the year 2016, the design year that represents the first year after full build-out of the development. This background traffic for 2016 represent the "No-Build" condition – or that which would be present in the design year without the development. This No-Build traffic scenario has been shown in Figure 4.1.

Table 4.1 summarizes the operational findings projected for A.M. and P.M. Peak Hours in 2016 at the study area intersections without the development. The cycle length for the signalized intersection of Arrowhead Rd & Kenwood Ave was optimized to 65 seconds for the No Build Condition.

Table 4.1: 2016 No-Build Peak Hour Traffic Operation Summary

Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	10.9 sec	LOS-B	WB Left	21.6 sec	LOS-C	194 ft
			EB Left	20.9 sec	LOS-C	100 ft
Kenwood Ave & Cleveland St/Kenwood Plaza	0.4 sec	LOS-A	WB Left	6.9 sec	LOS-A	54 ft
P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	12.8 sec	LOS-B	WB Left	37.0 sec	LOS-D	189 ft
			EB Left	27.3 sec	LOS-C	203 ft
Kenwood Ave & Cleveland St/Kenwood Plaza	1.9 sec	LOS-A	WB Left	14.7 sec	LOS-B	99 ft

1. Overall Intersection LOS using 2010 HCM methodology as determined by Intersection Control Delay and as reported by Synchro 9/SimTraffic 9 analysis.
2. 95th Percentile queues as reported by average of five runs of SimTraffic 9

The No-Build Peak Hour traffic operation for the study area intersections is the same or better than recorded for Existing conditions. This is primarily due to the optimized traffic signal timings that were utilized in this scenario.

[5] http://www.dot.state.mn.us/stateaid/csah/TrafficFactors2011.pdf

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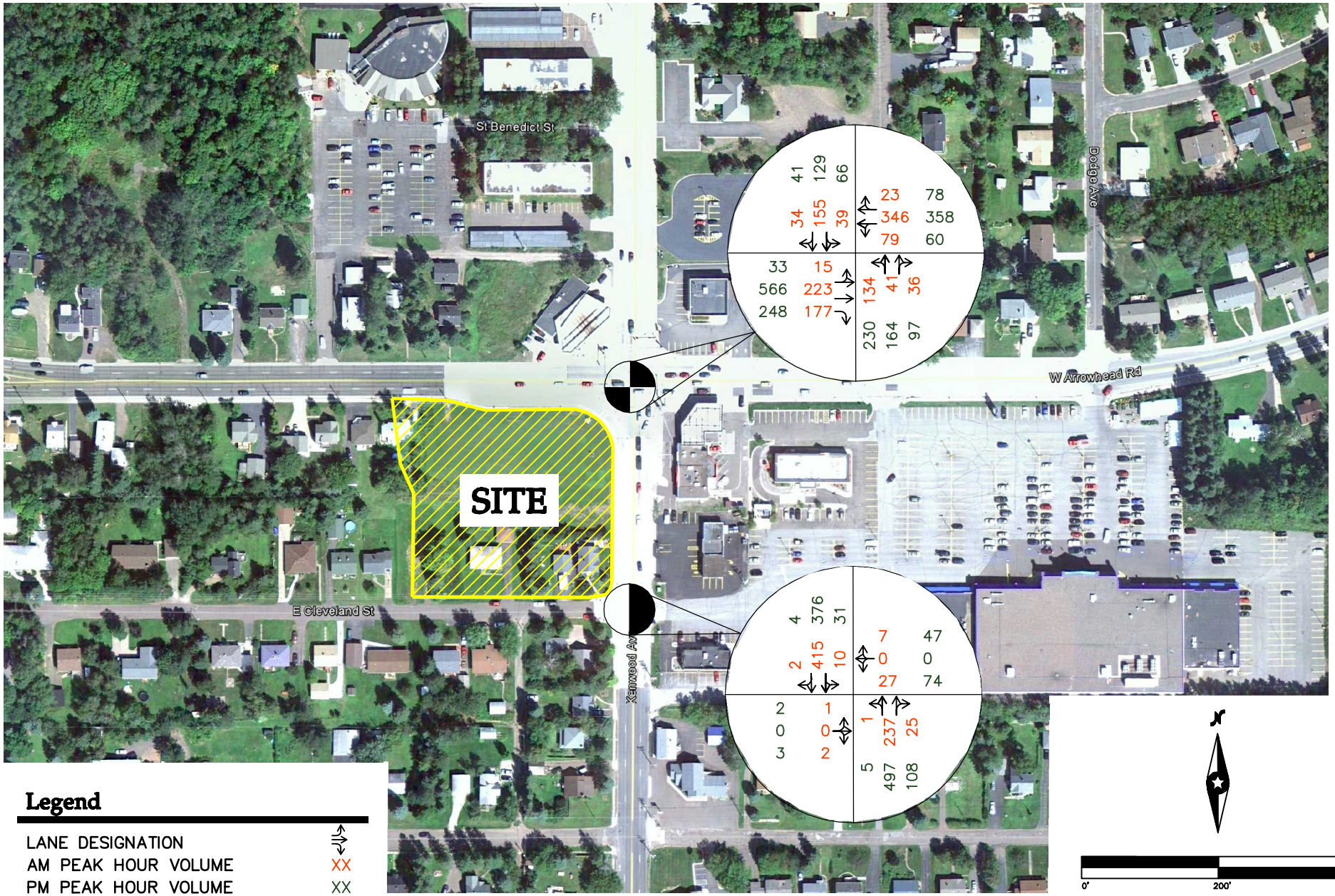

Legend

LANE DESIGNATION	⇉
AM PEAK HOUR VOLUME	XX
PM PEAK HOUR VOLUME	XX
SIGNALIZED INTERSECTION	◔
UNSIGNALIZED INTERSECTION	◑

Westwood

Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
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Kenwood Village

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2016 No-Build Peak Hour Traffic Volume Projections

Figure 4-1

5.0 Build Condition

To model the traffic conditions in the Build scenario, Westwood utilized the standard rates and equations from the Institute of Transportation Engineers (ITE) Trip Generation Manual, 9th Edition. Proposed land uses were determined from concept plans provided to Westwood by the client. Table 5.1 illustrates these potential trips.

Table 5.1: Gross Trip Generation Estimates

Land Use	Size	Daily Trips	Peak Period Trips Generated[1]:			
			Weekday AM		Weekday PM	
			Enter	Exit	Enter	Exit
Mid-Rise Apartment	85 units	566	8	18	19	14
Specialty Retail Center	14.177 k.s.f.	628	47	50	17	22
Total Trips		**1,194**	**55**	**68**	**36**	**36**
			123		**72**	

Note: Per the data and methodologies in Trip Generation Manual, 9th Edition, published by ITE.

Two site access points are proposed from Cleveland Street and one site access point is proposed on Arrowhead Road. The Cleveland Street access closest to the intersection with Kenwood Avenue actually feeds directly to and from the underground parking structure serving the site. The westerly access driveway from Cleveland Street provides through access to the driveway at Arrowhead Road, and also provides access to the surface parking lot serving the retail uses and guest parking for the residential uses.

It is projected the development trips will distribute in generally the same pattern as background traffic flows to and from the area today. Westwood used the calculated inbound and outbound flow of the background traffic on the roadway system based on the traffic counts taken in the area. These have been shown on Figure 5-1. Trip distribution in to and out of the site was determined based on the land uses and their proximity to each entrance/exit. The trip assignment calculated off of the distribution percentages and current traffic volumes is shown in Figure 5-2.

The total traffic combines the trip assignment with the No-Build traffic for the study area. This becomes the “Build” condition. The Build Conditions for the 2016 A.M. and P.M. traffic volumes are shown in Figure 5-3.

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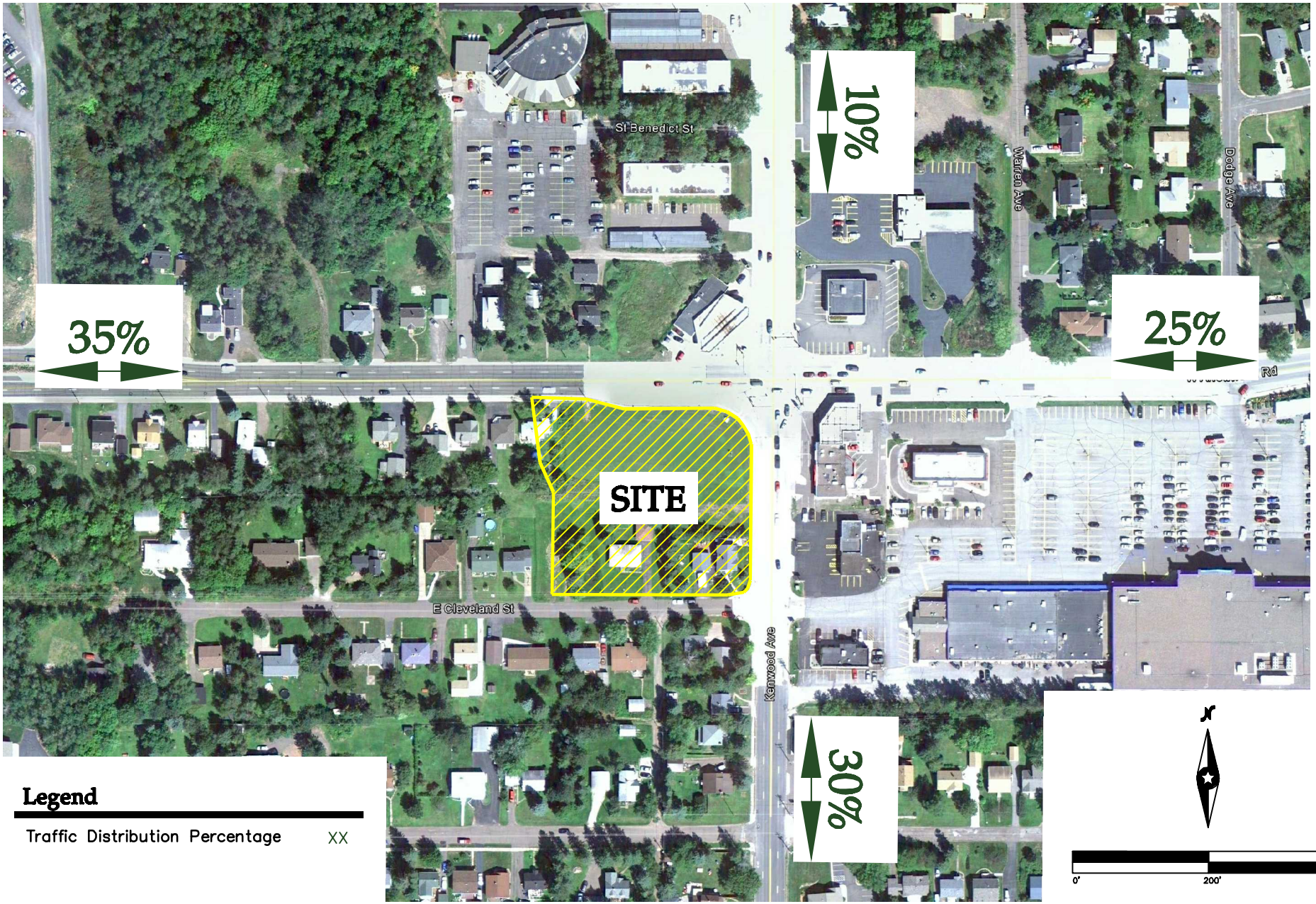

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Traffic Distribution Percentage XX

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Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
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Traffic Distribution Percentage
Figure 5-1

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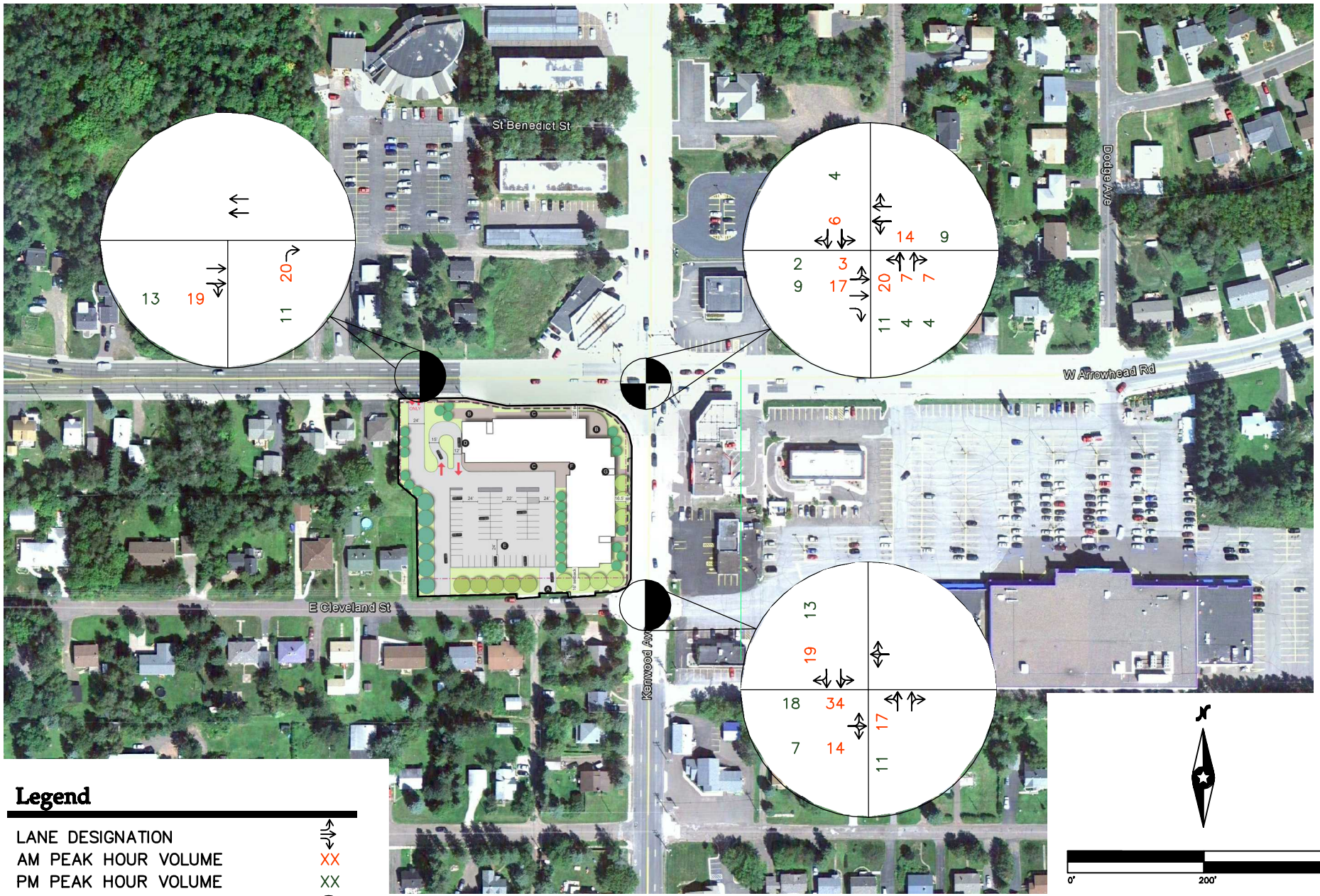

Legend

LANE DESIGNATION	
AM PEAK HOUR VOLUME	XX
PM PEAK HOUR VOLUME	XX
SIGNALIZED INTERSECTION	
UNSIGNALIZED INTERSECTION	

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Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
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Trip Assignment

Figure 5-2

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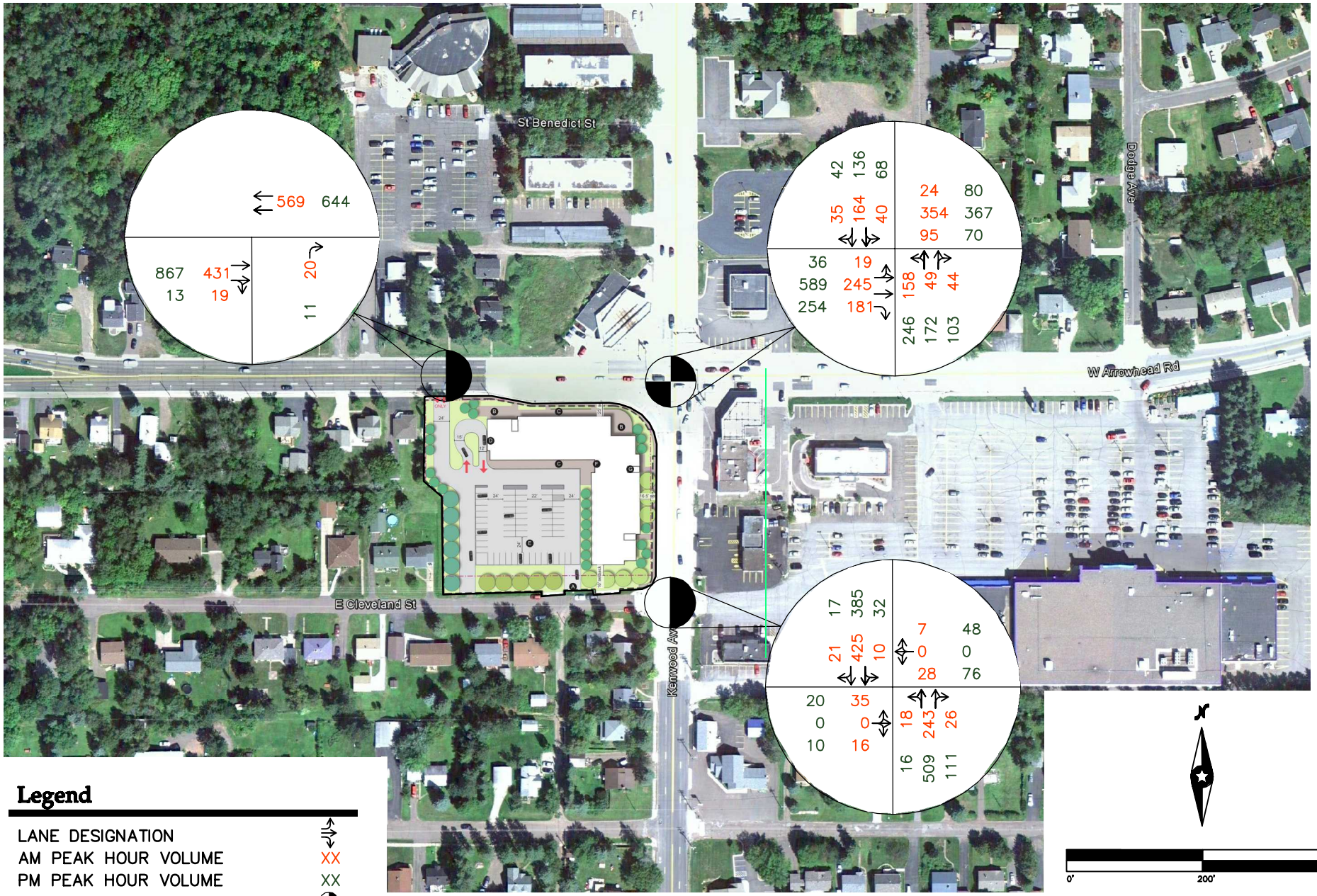

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LANE DESIGNATION	⇉
AM PEAK HOUR VOLUME	XX
PM PEAK HOUR VOLUME	XX
SIGNALIZED INTERSECTION	◒
UNSIGNALIZED INTERSECTION	◑

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Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
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2016 Build Peak Hour Traffic Volume Projections

Figure 5-3

Table 5.3 summarizes the operational findings projected for 2016 A.M. and P.M. Peak Hour Build condition at the study area intersections. This scenario assumes the existing traffic control (i.e., side street stop condition at Kenwood Ave & Cleveland St) has remained in place.

Table 5.3: 2016 Build Peak Hour Traffic Operation

Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	15.3 sec	LOS-B	WB Left	28.7 sec	LOS-C	223 ft
			EB Left	31.2 sec	LOS-C	145 ft
			NB Left	6.9 sec	LOS-A	44 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	0.9 sec	LOS-A	WB Left	6.4 sec	LOS-A	45 ft
			EB Left	7.9 sec	LOS-A	47 ft
Arrowhead Rd & North Access	0.9 sec	LOS-A	NB Right	2.8 sec	LOS-A	37 ft
P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	23.9 sec	LOS-C	WB Left	64.5 sec	LOS-E	290 ft
			EB Left	48.1 sec	LOS-D	262 ft
			NB Left	5.8 sec	LOS-A	51 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	3.0 sec	LOS-A	WB Left	13.4 sec	LOS-B	79 ft
			EB Left	23.5 sec	LOS-C	41 ft
Arrowhead Rd & North Access	1.6 sec	LOS-A	NB Right	4.4 sec	LOS-A	69 ft

1. Overall Intersection LOS using 2010 HCM methodology as determined by Intersection Control Delay and as reported by Synchro 9/SimTraffic 9 analysis.
2. 95th Percentile queues as reported by average of five runs of SimTraffic 9

The operational analysis of the Build condition yielded some very similar results to the existing condition and no-build conditions. Some of the delays and queue lengths are less than the existing and no-build conditions. The variation between the analyses of the three conditions is most likely small discrepancies in the seeding of the simulation models. All of the simulation settings were the same for both scenarios.

5.2 Traffic Operational Improvements

There exist tight geometrics along the eastbound and northbound approaches to this intersection. The City of Duluth had requested additional frontage along Kenwood Avenue be dedicated directly to the east of the proposed development. This frontage would facilitate a future widening of Kenwood Ave for a northbound left turn lane at Arrowhead Rd. The timeline for this project is unknown.

Nevertheless, other operational improvements may be considered, Westwood recommends optimizing the signal timings at the intersection of Arrowhead and Kenwood. Westwood used the traffic engineering software package *Synchro/SimTraffic, Version 9.0* to model and optimize the timings based on volume and capacity at different peak hours. The results show the intersection performing at the same levels of service or better during the peak hours, and with the added traffic from the Kenwood Village development.

Westwood was able to reduce the signal cycle lengths to 70 seconds in the AM Peak Hour and 75 seconds in the PM Peak Hour. By optimizing and shortening the maximum cycle length, the intersection will operate in a "snappier" manner, which will result in a decrease queue lengths and an improved LOS with or without the development. Table 5.4 illustrates improved levels of service with optimized timings for the 2016 Build networks.

Table 5.4: 2016 Build Peak Hour Traffic Operation -- Optimized

Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	10.7 sec	LOS-B	WB Left	19.4 sec	LOS-B	184 ft
			EB Left	21.3 sec	LOS-C	110 ft
			NB Left	5.7 sec	LOS-A	43 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	1.0 sec	LOS-A	WB Left	7.4 sec	LOS-A	47 ft
			EB Left	11.5 sec	LOS-B	56 ft
Arrowhead Rd & North Access	0.9 sec	LOS-A	NB Right	2.7 sec	LOS-A	39 ft
P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	14.6 sec	LOS-B	WB Left	42.9 sec	LOS-D	241 ft
			EB Left	38.3 sec	LOS-D	218 ft
			NB Left	5.8 sec	LOS-A	20 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	2.6 sec	LOS-A	WB Left	14.8 sec	LOS-B	96 ft
			EB Left	11.2 sec	LOS-B	45 ft
Arrowhead Rd & North Access	0.9 sec	LOS-A	NB Right	5.8 sec	LOS-A	23 ft

1. Overall Intersection LOS using 2010 HCM methodology as determined by Intersection Control Delay and as reported by Synchro 9/SimTraffic 9 analysis.
2. 95th Percentile queues as reported by average of five runs of SimTraffic 9

5.1 Warrant Analysis

Westwood performed a signal warrant analysis for the intersection of Kenwood Avenue and Cleveland Street. After completing the twenty four hour count for Kenwood Ave & Cleveland St, and projecting the volumes for the year after build out (2016), as well as adding in the trip generation for the proposed development, it has been determined that the intersection does not meet signal warrants, as identified by the Minnesota Manual on Uniform Traffic Control Devices. Side-street stop control remains the only warranted traffic control at the intersection.

The list of warrants and traffic volumes for the intersection can be found in the Appendix.

Despite there being a lack of warrants for signalization, Westwood tested whether a signal at Cleveland and Kenwood would improve traffic operation through coordination with the existing signal at Arrowhead and Kenwood. Westwood found the only improvement occurred with the northbound left turn movement on Kenwood at Arrowhead. Otherwise, the

5.3 Site Circulation & Parking

The site has been designed with access to parking from the north and from the south. This access driveway provides through access between Arrowhead Road and Cleveland Street along the west edge of the development.

The site has been designed to accommodate:

- Access to lower level garage via south side of development.
- Deliveries to the front doors of the retail stores.
- Access by moving trucks to the residential units from the ground floor parking area.
- Retail garbage pick-up from a trash room in the northeast corner of the ground floor.
- Residential garbage pick-up in from lower level garage.
- Retail parking on ground floor lot.
- Residential parking in north portion of lower level garage with door separation.
- Residential visitor parking on ground floor and in lower level garage.

The development has been designed with 188 parking stalls – 57 stalls on the ground floor level and 135 stalls in the lower level parking area. According to Table 50-24-1: Off-Street Parking Spaces Required, the City of Duluth requires the following stalls for this development:

- Multi-Family Residential Uses = 1.25 spaces per dwelling unit
- Retail Store = 3 spaces per 1,000 square feet of gross floor area

Therefore, for this development, the 85 multi-family residential units will require 106 stalls, and the 14,177 square feet of retail use will require 43 parking stalls. This translates to a requirement of 149 stalls for the development. The planned 192 stalls exceed this requirement.

6.0 Conclusions

Trip generation of the proposed Kenwood Village has a nominal impact on traffic in the study area. There are 123 total trips projected by the site for the A.M. Peak Hour and 72 trips projected in the P.M. Peak Hour. Traffic is projected to be 57% outbound and 43% inbound during the A.M. Peak Hour, while the P.M. Peak Hour is 49% outbound and 51% inbound.

The principal findings of the analysis included:

- The intersection of Kenwood Avenue & Arrowhead Road operates at a Level of Service B (LOS-B) in the existing, 2016 No-Build, and 2016 Build conditions.
- The intersection of Kenwood Ave & Cleveland St operates at a Level of Service A (LOS-A) in all conditions including signalized and not signalized Build conditions.
- No additional roadway mitigation is necessary based on projected traffic for this development.
- Trip distribution determined that 55% of development traffic will enter and exit from the north access (Arrowhead Road).
- The signal maximum cycle length at Kenwood Ave and Arrowhead Rd (105 to 150 seconds) is excessive.
- The proposed parking exceeds the City's off-street parking requirements for the land uses.

7.0 Recommendations

Recommendations include the following:

- The intersection of Kenwood Ave & Cleveland St does not meet warrants for signalization; therefore it is recommended to have it remain a two way stop controlled intersection.
- Yield or stop control for both egress driveways from the site.
- Reduce maximum signal cycle length and optimize signal operation at the intersection of Kenwood Ave & Arrowhead Rd. This will mitigate queues backing up into the intersection of Kenwood Ave & Cleveland St.

References Cited

Trip Generation, 7th Edition, Institute of Transportation Engineers, Washington DC, 2003

Trip Generation Manual, 9th Edition, Institute of Transportation Engineers, Washington, DC, 2012

Trip Generation Handbook, Third Edition, Institute of Transportation Engineers, Washington, DC, 2014

Appendices

Appendix A: Operational Methodology

Appendix B: Signal Warrant Analysis

Appendix C: SimTraffic Reports

APPENDIX A

Operational Analysis Methodology

Traffic operations for the AM and PM peak hour conditions within the study area were analyzed using the industry-standard Synchro/SimTraffic Version 9 software package, which uses the data and methodology contained in the 2010 Highway Capacity Manual (2010 HCM), published by the Transportation Research Board. The software model was calibrated to replicate existing conditions as accurately as possible before being used to assess future conditions.

The operating conditions of transportation facilities, such as traffic signals, stop-controlled intersections and roundabouts, are evaluated based on the relationship of the theoretical capacity of a facility to the actual traffic volumes on that facility. Various factors affect capacity, including travel speed, roadway geometry, grade, number and width of travel lanes, and intersection control. The current standards for evaluating capacity and operating conditions are contained in the 2010 HCM. The procedures describe operating conditions in terms of a Level of Service (LOS). Facilities are given letter designations from A, representing the best operating conditions, to F, representing the worst. Generally, Level of Service D (LOS-D) represents the threshold for acceptable overall intersection operating conditions during a peak hour.

At intersections, Levels of Service are assigned differently for signalized or unsignalized intersections (which include Two-Way Stop Control [TWSC], All-Way Stop Control [AWSC] and Roundabouts). For signalized intersections, Level of Service is calculated by taking the total Intersection Delay and converting it to a letter grade as shown in the left side of Table A.1. For an unsignalized intersection, Level of Service is calculated by taking the Intersection Delay and converting it to a letter grade, as shown in the right side of Table A.1. While similar, the signalized control delay totals are higher than that of unsignalized intersections. In any condition, when the LOS by Volume to Capacity Ratio exceeds 1.0, the LOS is always F.

Table A.1: Level of Service vs. Control Delay – Signalized and Unsignalized Intersections (TWSC, AWSC & Roundabouts)

TWSC, AWSC & Roundabouts	
LOS by Volume to Capacity Ratio (≤ 1)*	Control Delay per Vehicle (Seconds)
A	≤10
B	>10 and ≤15
C	>15 and ≤25
D	>25 and ≤35
E	>35 and ≤50
F	>50

Signalized Intersections	
LOS by Volume to Capacity Ratio (≤ 1)*	Control Delay per Vehicle (Seconds)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

Source: 2010 Highway Capacity Manual, published by the Transportation Research Board.
(NOTE: When LOS by Volume to Capacity Ratio >1.00, LOS is F.)*

Under the 2010 HCM, common movements are included into lane groups. Control Delay is then determined for each lane group and Levels of Service are based on this Control Delay. For each lane group, Control Delay is quantified by number of seconds. Control Delay is measured by comparison with the uncontrolled condition. It is the difference between the travel time that would have occurred in the absence of the intersection control, and the travel time that results because of the presence of the intersection control. Levels of Service are then based on the control delay per vehicle.

The acceptable Level of Service threshold for a particular movement at an intersection depends on both the priority assigned to that movement and its traffic volume. In general, the higher the priority and the higher the traffic volume, the more stringent the acceptable threshold will be. For example, the acceptable threshold for a high-priority/high-volume rural movement might be C, while LOS F on a low-priority/low-volume urban movement might be appropriate.

For two-way stop-controlled intersections, a key measure of operational effectiveness is the side street LOS. Since the mainline traffic does not have to stop, the majority of delay is attributed to traffic from the side-street/minor approaches. Long delays and poor LOS can sometimes result on the side street, even if the overall intersection is functioning well, making it a valuable design criterion. As the side-street/minor approach delay approaches and exceeds 60 seconds per vehicle, drivers may divert to another route or become impatient and accept gaps in the mainline traffic that are less than acceptable/safe gaps resulting in the potential for traffic safety concerns. Therefore, depending on priority and traffic volume, acceptable side-street LOS can range from D to F. Side streets can operate at LOS F without the intersection warranting a change in traffic control.

A final fundamental component of operational analyses is a study of vehicular queuing, or the line of vehicles waiting to pass through an intersection. An intersection can operate with an acceptable Level of Service, but if queues from the intersection extend back to block entrances to turn lanes or accesses to adjacent land uses, unsafe operating conditions could result.

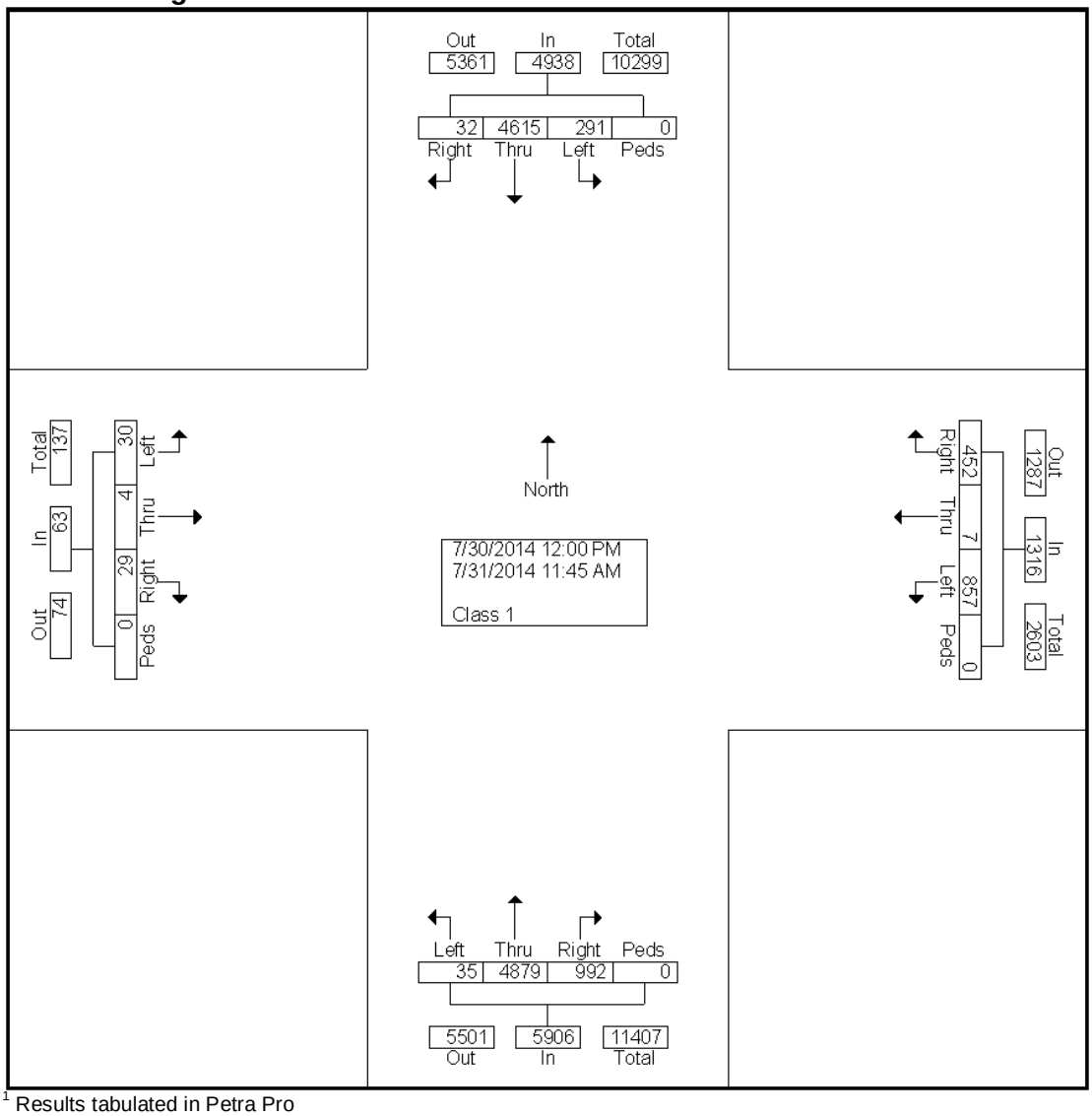
In reporting Levels of Service, the information from the signalized intersection analysis comes directly from the Synchro 9 and SimTraffic 9 reports (found in the Appendix). Intersection Levels of Service are reported based on the Control Delay calculated for the overall intersection and for each critical movement as determined by SimTraffic 9.

For queuing, SimTraffic reports found in the Appendix list the Mean Queue, the 95th Percentile and the Maximum Queue Lengths that are generated after five runs. In this report, the 95th Percentile Queue Length is used to discern adequate lengths of turn lanes. The 95th Percentile Queue Length refers to that length of queue that has only a five-percent probability of being exceeded during an analysis period. This is the standard factor used to determine optimal turn lane lengths.

APPENDIX B

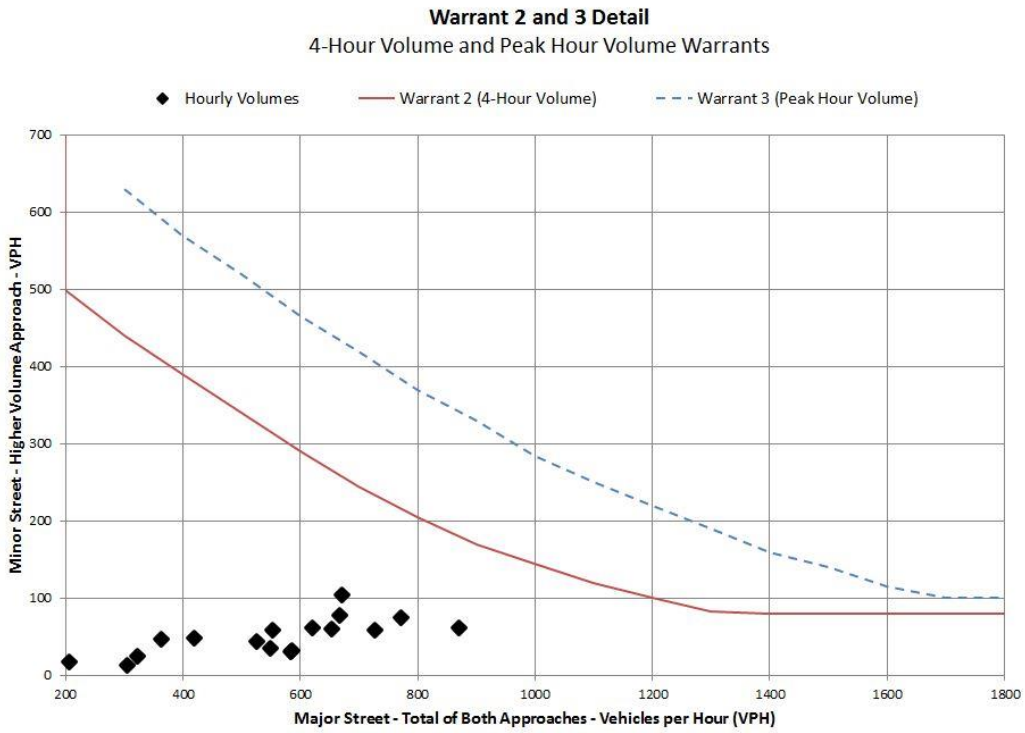
Figure A-1

Total Turning Movements for a 24 Hour Period at Kenwood Ave & Cleveland St[1]



[1] Results tabulated in Petra Pro

Figure A-2: Warrant 2 and 3 Results



Westwood recommends a yield or stop control for both of the egress driveways from the site.

Sight distance was evaluated and all intersections within the study area have adequate sight distance

Kenwood Ave & Cleveland Ave Warrant Results

		Hours Met:	Hours Required:	Result:
Warrant 1A	(8-Hr. Minimum Volumes)	0	8	Not satisfied
Warrant 1B	(8-Hr. Interruption of Continuous Traffic)	0	8	Not satisfied
Warrant 1C	(80% of both 1a and 1b)	0	8	Not satisfied
Warrant 2	(4-Hour Volumes)	0	4	Not satisfied
Warrant 3	(Peak Hour Volumes)	0	1	Not satisfied
Warrant 7	(80% of Warrant 1 + 5 crashes)	0	8	Not satisfied

Westwood checked the crash data using the Minnesota Crash Mapping Analysis Tool (Mn CMAT) to assess intersection crash history at the intersection of Kenwood & Cleveland. Mn CMAT is a dataset of crashes that are reported to the Minnesota Department of Public Safety (which includes those reported by Saint Louis County).

The Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD) specifies the following warrant for signalization based on crash experience:

The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:

A. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and

B. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and

C. For each of any 8 hours of an average day, the vehicles per hour (vph) given is 480 veh/hr or greater (for this condition) on the major-street and the higher-volume minor-street approach is 120 veh/hr or greater (for this condition). These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

According to the NCHRP Report 491 – Crash Experience Warrant for Traffic Signals, the types of crashes reducible by signalization at an intersection include:

Reducible: Right-angle vehicle collisions; Left-turn collisions; Right-angle; Pedestrian collisions, and; Parking collisions

Non-reducible: Rear-end collisions; Side-swipe collisions; Head-on collisions

Weather-related or health-related (including DUI) collisions are not considered reducible by signals.

One period between June 1, 2013 and May, 31, 2014 recorded seven (7) crashes that would be reducible by signalization. However, the volumes at the intersection of Kenwood and Cleveland are not anywhere near the volumes that would warrant signalization. Both crash history and volumes must meet the prescribed thresholds before warrants for signalization are satisfied, according to the MnMUTCD.

Table A-3 shows the 2016 Build traffic operations if a traffic signal at Kenwood Ave & Cleveland St. were to be installed. For this analysis, all signals were optimized to 65 seconds.

Table A-3: 2016 Build Peak Hour Traffic Operation (Signalization at Kenwood Ave & Cleveland St)

Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	15.9 sec	LOS-B	WB Left	32.7 sec	LOS-C	224 ft
			EB Left	32.0 sec	LOS-C	123 ft
			NB Left	8.1 sec	LOS-A	45 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	1.7 sec	LOS-A	WB Left	4.5 sec	LOS-A	46 ft
			EB Left	5.9 sec	LOS-A	49 ft
Arrowhead Rd & North Access	0.9 sec	LOS-A	NB Right	3.0 sec	LOS-A	41 ft
P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	23.0 sec	LOS-C	WB Left	66.2 sec	LOS-E	269 ft
			EB Left	50.9 sec	LOS-D	253 ft
			NB Left	5.6 sec	LOS-A	53 ft.
Kenwood Ave & Cleveland St/Kenwood Plaza	5.3 sec	LOS-A	WB Left	6.7 sec	LOS-A	66 ft
			EB Left	10.8 sec	LOS-B	42 ft
Arrowhead Rd & North Access	1.7 sec	LOS-A	NB Right	5.3 sec	LOS-A	27 ft

1. Overall Intersection LOS using 2010 HCM methodology as determined by Intersection Control Delay and as reported by Synchro 9/SimTraffic 9 analysis.
2. 95th Percentile queues as reported by average of five runs of SimTraffic 9

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.3	0.1	0.3	0.0	0.0	0.0	0.2	0.1	0.1
Total Del/Veh (s)	32.4	22.0	1.5	30.1	25.4	13.9	7.7	5.3	0.7	8.4	8.4	2.0

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	15.3

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBR	WBL	WBR	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1
Total Del/Veh (s)	2.5	6.9	3.0	0.2	0.1	1.2	0.1	0.0	0.4

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	6.4	0.8	3.0

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.3	0.6	0.5

Total Network Performance

Denied Del/Veh (s)	0.1
Total Del/Veh (s)	16.8

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	R	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	139	103	55	202	180	54	55	101	32
Average Queue (ft)	86	38	2	147	78	30	9	57	18
95th Queue (ft)	128	90	19	204	156	41	32	95	42
Link Distance (ft)	228	228		720	720	20	20	484	484
Upstream Blk Time (%)						30	4		
Queuing Penalty (veh)						32	5		
Storage Bay Dist (ft)			175						
Storage Blk Time (%)									
Queuing Penalty (veh)									

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	SB	SB
Directions Served	LTR	LTR	LT	TR
Maximum Queue (ft)	31	54	38	28
Average Queue (ft)	4	25	1	1
95th Queue (ft)	21	53	13	9
Link Distance (ft)	397	172	38	38
Upstream Blk Time (%)			0	0
Queuing Penalty (veh)			0	0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 10: Kenwood Ave

Movement	NB	SB
Directions Served	T	T
Maximum Queue (ft)	143	80
Average Queue (ft)	48	11
95th Queue (ft)	100	43
Link Distance (ft)	134	20
Upstream Blk Time (%)	1	1
Queuing Penalty (veh)	1	2
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 11: Kenwood Ave

Movement	NB
Directions Served	T
Maximum Queue (ft)	31
Average Queue (ft)	1
95th Queue (ft)	10
Link Distance (ft)	38
Upstream Blk Time (%)	0
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 40

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.3	0.3	3.0	0.3	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.1
Total Del/Veh (s)	53.6	38.0	4.4	79.3	41.8	17.8	5.5	4.4	2.8	18.0	11.8	2.3

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.5
Total Del/Veh (s)	23.7

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.2	0.2	0.1	0.2	0.3	0.0	0.0	0.0	0.1
Total Del/Veh (s)	14.1	3.9	10.7	12.0	1.2	1.6	0.7	5.5	0.1	0.0	2.0

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	12.2	0.7	7.1

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	1.4	0.9	1.2

Total Network Performance

Denied Del/Veh (s)	0.5
Total Del/Veh (s)	27.1

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	R	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	297	276	175	322	276	30	31	140	50
Average Queue (ft)	203	172	73	195	153	29	28	64	13
95th Queue (ft)	292	252	212	279	252	33	41	127	39
Link Distance (ft)	982	982		720	720	20	20	484	484
Upstream Blk Time (%)						40	18		
Queuing Penalty (veh)						104	48		
Storage Bay Dist (ft)			150						
Storage Blk Time (%)		10	0						
Queuing Penalty (veh)		23	0						

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	NB	SB
Directions Served	LTR	LTR	LT	TR	LT
Maximum Queue (ft)	31	117	157	20	51
Average Queue (ft)	7	51	25	1	17
95th Queue (ft)	28	96	91	7	48
Link Distance (ft)	397	172	377	377	38
Upstream Blk Time (%)					1
Queuing Penalty (veh)					3
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB
Directions Served	T	T	T
Maximum Queue (ft)	142	134	80
Average Queue (ft)	116	61	15
95th Queue (ft)	177	135	58
Link Distance (ft)	134	134	20
Upstream Blk Time (%)	9	0	1
Queuing Penalty (veh)	25	1	2
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 11: Kenwood Ave

Movement	NB	SB
Directions Served	T	T
Maximum Queue (ft)	53	31
Average Queue (ft)	22	3
95th Queue (ft)	59	18
Link Distance (ft)	38	134
Upstream Blk Time (%)	6	
Queuing Penalty (veh)	16	
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 221

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1
Total Del/Veh (s)	19.8	16.0	1.4	24.7	18.6	4.4	6.1	4.7	1.3	9.9	6.5	1.4

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	11.7

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.1
Total Del/Veh (s)	5.5	4.1	6.3	3.4	2.5	0.2	0.1	2.3	0.0	0.0	0.4

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	4.7	0.7	2.2

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.2	0.6	0.5

Total Network Performance

Denied Del/Veh (s)	0.1
Total Del/Veh (s)	13.2

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	139	130	216	178	30	73	119	32
Average Queue (ft)	75	34	122	66	27	14	42	12
95th Queue (ft)	122	91	182	150	41	49	80	36
Link Distance (ft)	228	228	720	720	20	20	484	484
Upstream Blk Time (%)					25	1		
Queuing Penalty (veh)					27	2		
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	SB
Directions Served	LTR	LTR	LT
Maximum Queue (ft)	31	54	38
Average Queue (ft)	4	23	3
95th Queue (ft)	21	48	19
Link Distance (ft)	397	172	38
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Kenwood Ave

Movement	NB	SB
Directions Served	T	T
Maximum Queue (ft)	116	69
Average Queue (ft)	35	6
95th Queue (ft)	88	35
Link Distance (ft)	134	20
Upstream Blk Time (%)	0	0
Queuing Penalty (veh)	0	1
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 11: Kenwood Ave

Movement
Directions Served
Maximum Queue (ft)
Average Queue (ft)
95th Queue (ft)
Link Distance (ft)
Upstream Blk Time (%)
Queuing Penalty (veh)
Storage Bay Dist (ft)
Storage Blk Time (%)
Queuing Penalty (veh)

Network Summary

Network wide Queuing Penalty: 29

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.6	0.2	2.5	0.2	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1
Total Del/Veh (s)	23.4	18.4	2.9	27.9	19.7	5.8	5.7	4.0	2.6	15.8	11.4	4.3

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.4
Total Del/Veh (s)	12.2

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.0	0.0	0.0	0.1
Total Del/Veh (s)	4.9	3.4	11.6	8.0	2.0	1.2	0.7	3.7	0.1	0.0	1.8

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	10.1	0.9	6.0

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.9	1.0	0.9

Total Network Performance

Denied Del/Veh (s)	0.5
Total Del/Veh (s)	15.9

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	R	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	244	185	56	247	187	30	68	112	78
Average Queue (ft)	144	91	6	127	73	30	28	58	25
95th Queue (ft)	222	171	34	196	153	31	48	97	60
Link Distance (ft)	982	982		720	720	20	20	484	484
Upstream Blk Time (%)						42	13		
Queuing Penalty (veh)						110	34		
Storage Bay Dist (ft)			150						
Storage Blk Time (%)		0							
Queuing Penalty (veh)		1							

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	NB	SB
Directions Served	LTR	LTR	LT	TR	LT
Maximum Queue (ft)	31	143	95	25	66
Average Queue (ft)	5	48	15	2	17
95th Queue (ft)	24	101	57	13	50
Link Distance (ft)	397	172	377	377	38
Upstream Blk Time (%)					1
Queuing Penalty (veh)					2
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	142	134	44	80
Average Queue (ft)	101	36	2	17
95th Queue (ft)	159	103	15	64
Link Distance (ft)	134	134	20	20
Upstream Blk Time (%)	4	0	0	1
Queuing Penalty (veh)	11	0	0	3
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 11: Kenwood Ave

Movement	NB	SB
Directions Served	T	T
Maximum Queue (ft)	53	31
Average Queue (ft)	13	4
95th Queue (ft)	49	22
Link Distance (ft)	38	134
Upstream Blk Time (%)	2	
Queuing Penalty (veh)	6	
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 167

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.3	0.1	0.2	0.4	0.0	0.1	0.1	0.1	0.2
Total Del/Veh (s)	31.2	21.9	1.6	28.7	25.6	7.5	6.9	4.6	1.8	12.4	8.1	2.7

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	15.3

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.0	0.0	0.0	0.1
Total Del/Veh (s)	7.9	3.6	6.4	2.6	4.3	0.5	0.2	2.6	0.1	0.1	0.9

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	6.1	0.7	2.8

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.3	0.7	0.6

14: W Arrowhead Rd Performance by movement

Movement	EBT	EBR	WBT	NBR	All
Denied Del/Veh (s)	0.2	0.2	0.0	0.1	0.1
Total Del/Veh (s)	0.3	0.2	1.2	2.8	0.9

Total Network Performance

Denied Del/Veh (s)	0.2
Total Del/Veh (s)	16.4

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	R	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	179	140	56	228	175	54	62	95	115
Average Queue (ft)	93	54	2	155	97	28	15	39	23
95th Queue (ft)	145	114	19	223	175	43	44	82	63
Link Distance (ft)	228	228		720	720	20	20	484	484
Upstream Blk Time (%)						31	4		
Queuing Penalty (veh)						36	4		
Storage Bay Dist (ft)			175						
Storage Blk Time (%)									
Queuing Penalty (veh)									

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LT	LT
Maximum Queue (ft)	50	54	75	38
Average Queue (ft)	23	20	10	7
95th Queue (ft)	47	45	43	29
Link Distance (ft)	397	172	377	38
Upstream Blk Time (%)				0
Queuing Penalty (veh)				1
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB
Directions Served	T	T	T
Maximum Queue (ft)	134	31	80
Average Queue (ft)	52	1	12
95th Queue (ft)	112	10	47
Link Distance (ft)	134	134	20
Upstream Blk Time (%)	0		1
Queuing Penalty (veh)	0		3
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 11: Kenwood Ave

Movement	NB
Directions Served	T
Maximum Queue (ft)	38
Average Queue (ft)	1
95th Queue (ft)	13
Link Distance (ft)	38
Upstream Blk Time (%)	0
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 14: W Arrowhead Rd

Movement	NB
Directions Served	R
Maximum Queue (ft)	29
Average Queue (ft)	14
95th Queue (ft)	37
Link Distance (ft)	69
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 45

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.4	0.1	0.2	0.3	0.0	0.0	0.2	0.1	0.3
Total Del/Veh (s)	48.1	34.5	3.0	64.5	44.9	21.6	5.8	4.8	3.7	14.6	15.1	3.5

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	23.9

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.2	0.1	0.3	0.2	0.2	0.0	0.0	0.0	0.1
Total Del/Veh (s)	23.5	3.0	13.4	10.6	6.1	2.3	0.5	4.0	0.2	0.0	3.0

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	11.8	0.8	6.9

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	1.5	1.0	1.3

14: W Arrowhead Rd Performance by movement

Movement	EBT	EBR	WBT	NBR	All
Denied Del/Veh (s)	0.2	0.1	0.0	0.2	0.1
Total Del/Veh (s)	1.7	0.3	1.3	4.4	1.6

Total Network Performance

Denied Del/Veh (s)	0.2
Total Del/Veh (s)	27.4

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	R	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	244	251	200	315	290	66	53	138	54
Average Queue (ft)	207	188	64	213	187	34	29	77	18
95th Queue (ft)	262	253	213	290	262	51	42	128	45
Link Distance (ft)	228	228		720	720	20	20	484	484
Upstream Blk Time (%)	5	2				42	18		
Queuing Penalty (veh)	24	10				108	48		
Storage Bay Dist (ft)			175						
Storage Blk Time (%)		6	0						
Queuing Penalty (veh)		16	0						

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	NB	SB
Directions Served	LTR	LTR	LT	TR	LT
Maximum Queue (ft)	31	78	153	122	49
Average Queue (ft)	18	54	33	8	22
95th Queue (ft)	41	79	109	56	52
Link Distance (ft)	397	172	377	377	38
Upstream Blk Time (%)					1
Queuing Penalty (veh)					3
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	141	134	20	81
Average Queue (ft)	117	53	1	16
95th Queue (ft)	169	130	7	61
Link Distance (ft)	134	134	20	20
Upstream Blk Time (%)	10	0	0	2
Queuing Penalty (veh)	27	1	0	4
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 11: Kenwood Ave

Movement	NB	SB
Directions Served	T	T
Maximum Queue (ft)	53	51
Average Queue (ft)	25	3
95th Queue (ft)	65	20
Link Distance (ft)	38	134
Upstream Blk Time (%)	7	
Queuing Penalty (veh)	19	
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 14: W Arrowhead Rd

Movement	EB	EB	NB
Directions Served	T	TR	R
Maximum Queue (ft)	184	174	54
Average Queue (ft)	27	10	11
95th Queue (ft)	101	67	37
Link Distance (ft)	697	697	69
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

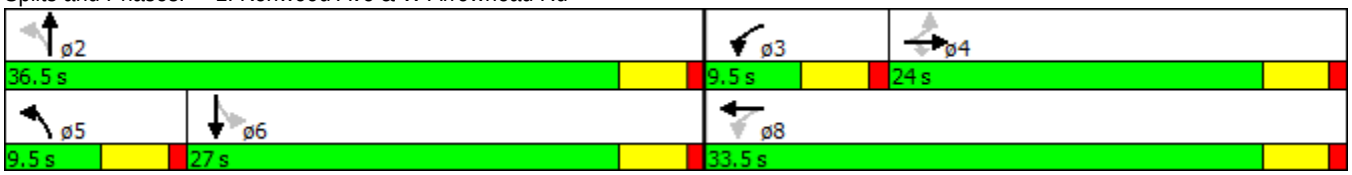
Network Summary

Network wide Queuing Penalty: 259

Lane Group	EBL	EBT	EBR	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations									
Volume (vph)	18	244	181	93	354	156	48	40	163
Turn Type	Perm	NA	Perm	pm+pt	NA	pm+pt	NA	Perm	NA
Protected Phases		4		3	8	5	2		6
Permitted Phases	4		4	8		2		6	
Detector Phase	4	4	4	3	8	5	2	6	6
Switch Phase									
Minimum Initial (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Minimum Split (s)	23.5	23.5	23.5	9.5	23.5	9.5	23.5	23.5	23.5
Total Split (s)	24.0	24.0	24.0	9.5	33.5	9.5	36.5	27.0	27.0
Total Split (%)	34.3%	34.3%	34.3%	13.6%	47.9%	13.6%	52.1%	38.6%	38.6%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lost Time Adjust (s)		0.0	0.0		0.0		0.0		0.0
Total Lost Time (s)		4.5	4.5		4.5		4.5		4.5
Lead/Lag	Lag	Lag	Lag	Lead		Lead		Lag	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes		Yes		Yes	Yes
Recall Mode	None	None	None	None	None	None	Max	Max	Max
Act Effct Green (s)		15.9	15.9		15.9		32.2		32.2
Actuated g/C Ratio		0.28	0.28		0.28		0.56		0.56
v/c Ratio		0.32	0.34		0.64		0.32		0.15
Control Delay		16.9	4.5		21.4		8.2		6.4
Queue Delay		0.0	0.0		0.0		0.0		0.0
Total Delay		16.9	4.5		21.4		8.2		6.4
LOS		B	A		C		A		A
Approach Delay		11.8			21.4		8.2		6.4
Approach LOS		B			C		A		A

Intersection Summary	
Cycle Length: 70	
Actuated Cycle Length: 57.1	
Natural Cycle: 70	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.64	
Intersection Signal Delay: 13.5	Intersection LOS: B
Intersection Capacity Utilization 50.9%	ICU Level of Service A
Analysis Period (min) 15	

Splits and Phases: 1: Kenwood Ave & W Arrowhead Rd



1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.3	0.1	0.1	0.3	0.1	0.0	0.2	0.1	0.1
Total Del/Veh (s)	21.3	13.3	1.4	19.4	17.8	5.7	5.7	6.0	2.0	7.2	8.3	2.1

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	10.7

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.1
Total Del/Veh (s)	11.5	4.4	7.4	4.1	2.3	0.3	0.0	1.3	0.2	0.0	1.0

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	5.7	0.8	2.6

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.3	0.7	0.6

14: W Arrowhead Rd Performance by movement

Movement	EBT	EBR	WBT	NBR	All
Denied Del/Veh (s)	0.2	0.1	0.0	0.1	0.1
Total Del/Veh (s)	0.3	0.3	1.3	2.7	0.9

Total Network Performance

Denied Del/Veh (s)	0.2
Total Del/Veh (s)	12.3

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	118	99	223	165	54	52	75	53
Average Queue (ft)	67	31	126	56	32	18	37	15
95th Queue (ft)	110	68	184	130	43	43	68	43
Link Distance (ft)	228	228	720	720	20	20	484	484
Upstream Blk Time (%)					28	4		
Queuing Penalty (veh)					33	5		
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LT	LT
Maximum Queue (ft)	71	49	28	38
Average Queue (ft)	27	22	1	4
95th Queue (ft)	56	47	9	23
Link Distance (ft)	397	172	377	38
Upstream Blk Time (%)				0
Queuing Penalty (veh)				0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB
Directions Served	T	T	T
Maximum Queue (ft)	137	31	84
Average Queue (ft)	43	4	13
95th Queue (ft)	96	19	53
Link Distance (ft)	134	134	20
Upstream Blk Time (%)	0		1
Queuing Penalty (veh)	0		3
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 11: Kenwood Ave

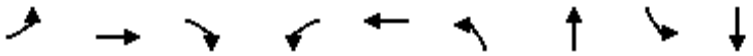
Movement	NB
Directions Served	T
Maximum Queue (ft)	50
Average Queue (ft)	2
95th Queue (ft)	17
Link Distance (ft)	38
Upstream Blk Time (%)	0
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 14: W Arrowhead Rd

Movement	NB
Directions Served	R
Maximum Queue (ft)	29
Average Queue (ft)	16
95th Queue (ft)	39
Link Distance (ft)	69
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

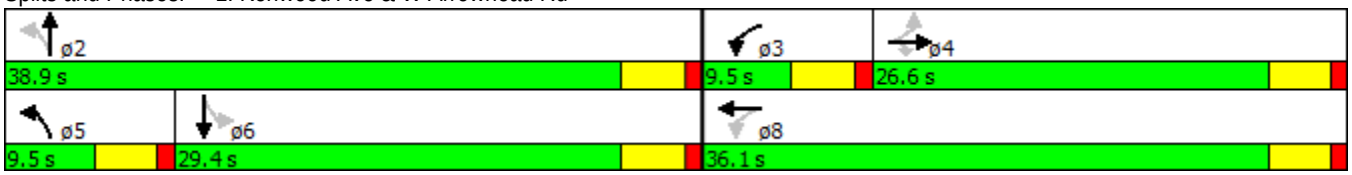
Network wide Queuing Penalty: 41



Lane Group	EBL	EBT	EBR	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations									
Volume (vph)	35	588	254	70	367	245	171	68	136
Turn Type	Perm	NA	Perm	pm+pt	NA	pm+pt	NA	Perm	NA
Protected Phases		4		3	8	5	2		6
Permitted Phases	4		4	8		2		6	
Detector Phase	4	4	4	3	8	5	2	6	6
Switch Phase									
Minimum Initial (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Minimum Split (s)	26.5	26.5	26.5	9.5	26.5	9.5	26.5	26.5	26.5
Total Split (s)	26.6	26.6	26.6	9.5	36.1	9.5	38.9	29.4	29.4
Total Split (%)	35.5%	35.5%	35.5%	12.7%	48.1%	12.7%	51.9%	39.2%	39.2%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lost Time Adjust (s)		0.0	0.0		0.0		0.0		0.0
Total Lost Time (s)		4.5	4.5		4.5		4.5		4.5
Lead/Lag	Lag	Lag	Lag	Lead		Lead		Lag	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes		Yes		Yes	Yes
Recall Mode	None	None	None	None	None	None	Max	Max	Max
Act Effct Green (s)		21.1	21.1		21.1		34.6		34.6
Actuated g/C Ratio		0.33	0.33		0.33		0.53		0.53
v/c Ratio		0.65	0.39		0.67		0.68		0.21
Control Delay		21.7	4.0		21.7		17.2		8.3
Queue Delay		0.0	0.0		0.0		0.0		0.0
Total Delay		21.7	4.0		21.7		17.2		8.3
LOS		C	A		C		B		A
Approach Delay		16.6			21.7		17.2		8.3
Approach LOS		B			C		B		A

Intersection Summary	
Cycle Length: 75	
Actuated Cycle Length: 64.7	
Natural Cycle: 75	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.68	
Intersection Signal Delay: 17.0	Intersection LOS: B
Intersection Capacity Utilization 69.2%	ICU Level of Service C
Analysis Period (min) 15	

Splits and Phases: 1: Kenwood Ave & W Arrowhead Rd



1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.3	0.1	0.1
Total Del/Veh (s)	38.3	20.3	2.1	42.9	25.3	6.8	5.8	5.4	2.8	14.0	11.0	2.2

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	14.6

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.0	0.0	0.0	0.1
Total Del/Veh (s)	11.2	3.0	14.8	11.9	3.4	1.3	0.4	4.8	0.1	0.0	2.6

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	10.3	0.8	6.0

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	1.0	1.0	1.0

14: W Arrowhead Rd Performance by movement

Movement	EBT	EBR	WBT	NBR	All
Denied Del/Veh (s)	0.2	0.2	0.0	0.1	0.1
Total Del/Veh (s)	0.7	0.2	1.1	5.8	0.9

Total Network Performance

Denied Del/Veh (s)	0.2
Total Del/Veh (s)	18.3

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	242	228	269	242	53	31	120	53
Average Queue (ft)	149	123	150	106	32	28	58	21
95th Queue (ft)	218	209	241	220	43	39	103	48
Link Distance (ft)	228	228	720	720	20	20	484	484
Upstream Blk Time (%)	0	0			46	18		
Queuing Penalty (veh)	2	0			117	45		
Storage Bay Dist (ft)								
Storage Blk Time (%)		1						
Queuing Penalty (veh)		2						

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	53	138	136	141	54	19
Average Queue (ft)	18	54	17	5	23	1
95th Queue (ft)	45	96	66	47	58	6
Link Distance (ft)	397	172	377	377	38	38
Upstream Blk Time (%)					2	0
Queuing Penalty (veh)					5	0
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB
Directions Served	T	T	T
Maximum Queue (ft)	143	128	66
Average Queue (ft)	114	39	13
95th Queue (ft)	159	104	50
Link Distance (ft)	134	134	20
Upstream Blk Time (%)	6	0	1
Queuing Penalty (veh)	18	0	3
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 11: Kenwood Ave

Movement	NB	SB
Directions Served	T	T
Maximum Queue (ft)	74	29
Average Queue (ft)	17	1
95th Queue (ft)	57	10
Link Distance (ft)	38	134
Upstream Blk Time (%)	3	
Queuing Penalty (veh)	8	
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 14: W Arrowhead Rd

Movement	EB	NB
Directions Served	T	R
Maximum Queue (ft)	31	29
Average Queue (ft)	3	5
95th Queue (ft)	19	23
Link Distance (ft)	697	69
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 199

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.2	0.1	0.2	0.5	0.2	0.2	0.2	0.1	0.2
Total Del/Veh (s)	12.0	18.3	1.4	22.8	18.7	3.3	6.1	9.5	2.0	11.0	8.6	2.3

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	12.5

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.0	0.1
Total Del/Veh (s)	34.7	17.3	30.4	3.4	4.2	1.6	0.3	1.5	0.8	0.3	3.6

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	5.5	0.8	2.6

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.4	0.8	0.6

14: W Arrowhead Rd Performance by movement

Movement	EBT	EBR	WBT	NBR	All
Denied Del/Veh (s)	0.2	0.1	0.0	0.1	0.1
Total Del/Veh (s)	0.3	0.1	1.2	3.2	0.8

Total Network Performance

Denied Del/Veh (s)	0.2
Total Del/Veh (s)	15.2

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	118	100	200	194	52	31	135	96
Average Queue (ft)	77	41	128	79	32	19	47	20
95th Queue (ft)	117	88	181	167	45	42	95	59
Link Distance (ft)	228	228	720	720	20	20	484	484
Upstream Blk Time (%)					31	5		
Queuing Penalty (veh)					36	6		
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	76	52	115	29	52	51
Average Queue (ft)	31	21	22	3	15	16
95th Queue (ft)	69	51	68	17	41	46
Link Distance (ft)	397	172	377	377	38	38
Upstream Blk Time (%)					1	1
Queuing Penalty (veh)					1	3
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB
Directions Served	T	T	T
Maximum Queue (ft)	94	31	69
Average Queue (ft)	47	2	13
95th Queue (ft)	89	15	47
Link Distance (ft)	134	134	20
Upstream Blk Time (%)			2
Queuing Penalty (veh)			4
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 11: Kenwood Ave

Movement	SB
Directions Served	T
Maximum Queue (ft)	31
Average Queue (ft)	2
95th Queue (ft)	15
Link Distance (ft)	134
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 14: W Arrowhead Rd

Movement	NB
Directions Served	R
Maximum Queue (ft)	30
Average Queue (ft)	17
95th Queue (ft)	40
Link Distance (ft)	69
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 49

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Del/Veh (s)	0.0	0.0	0.0	0.3	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1
Total Del/Veh (s)	28.5	18.9	2.0	44.0	29.6	12.9	6.6	4.2	1.8	13.3	8.6	2.3

1: Kenwood Ave & W Arrowhead Rd Performance by movement

Movement	All
Denied Del/Veh (s)	0.1
Total Del/Veh (s)	14.8

5: Kenwood Ave & E Cleveland St Performance by movement

Movement	EBL	EBR	WBL	WBR	NBL	NBT	NBR	SBL	SBT	SBR	All
Denied Del/Veh (s)	0.1	0.2	0.2	0.2	0.3	0.3	0.2	0.0	0.0	0.0	0.2
Total Del/Veh (s)	26.9	6.0	32.2	15.2	5.2	2.6	1.2	10.3	1.5	1.5	4.9

10: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	8.3	0.8	5.0

11: Kenwood Ave Performance by movement

Movement	NBT	SBT	All
Denied Del/Veh (s)	0.0	0.0	0.0
Total Del/Veh (s)	0.7	1.3	1.0

14: W Arrowhead Rd Performance by movement

Movement	EBT	EBR	WBT	NBR	All
Denied Del/Veh (s)	0.2	0.1	0.0	0.1	0.1
Total Del/Veh (s)	0.7	0.2	1.3	5.0	0.9

Total Network Performance

Denied Del/Veh (s)	0.2
Total Del/Veh (s)	19.2

Intersection: 1: Kenwood Ave & W Arrowhead Rd

Movement	EB	EB	EB	WB	WB	NB	NB	SB	SB
Directions Served	LT	T	R	LT	TR	LT	TR	LT	TR
Maximum Queue (ft)	203	208	200	270	219	67	50	96	32
Average Queue (ft)	145	109	13	158	111	33	29	54	25
95th Queue (ft)	210	192	95	239	198	48	44	90	44
Link Distance (ft)	228	228		720	720	20	20	484	484
Upstream Blk Time (%)						45	13		
Queuing Penalty (veh)						115	34		
Storage Bay Dist (ft)			175						
Storage Blk Time (%)		0	0						
Queuing Penalty (veh)		1	0						

Intersection: 5: Kenwood Ave & E Cleveland St

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	51	118	115	74	53	50
Average Queue (ft)	15	62	34	25	34	25
95th Queue (ft)	43	112	82	61	63	58
Link Distance (ft)	397	172	377	377	38	38
Upstream Blk Time (%)					6	3
Queuing Penalty (veh)					12	7
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 10: Kenwood Ave

Movement	NB	NB	SB
Directions Served	T	T	T
Maximum Queue (ft)	142	134	68
Average Queue (ft)	94	32	15
95th Queue (ft)	138	93	50
Link Distance (ft)	134	134	20
Upstream Blk Time (%)	1	0	2
Queuing Penalty (veh)	2	0	4
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 11: Kenwood Ave

Movement	NB	NB	SB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	51	20	50	55
Average Queue (ft)	3	1	8	3
95th Queue (ft)	22	7	32	18
Link Distance (ft)	38	38	134	134
Upstream Blk Time (%)	0	0		
Queuing Penalty (veh)	1	0		
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 14: W Arrowhead Rd

Movement	NB
Directions Served	R
Maximum Queue (ft)	29
Average Queue (ft)	9
95th Queue (ft)	31
Link Distance (ft)	69
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 176

Westwood

7699 Anagram Drive
Eden Prairie, MN 55344

Main (952) 937-5150
Fax (952) 937-5822

westwoodps.com
(888) 937-5150

ADDENDUM

Date: May 8, 2015

Re: **Intersection of Arrowhead & Kenwood, Duluth, MN**
-- Impacts Associated with Removal of Dedicated Eastbound Right Turn Lane
File R0004765.00

To: Rick McKelvey, United Properties

From: Steve Manhart, P.E., PTOE, PTP

In response to comments raised by the City of Duluth and residents of the nearly neighborhood, you have asked Westwood to test the performance of the intersection of West Arrowhead Road and Kenwood Avenue adjacent to your proposed Kenwood Village development. It has been suggested that the intersection may perform better if the free right turn eastbound were removed.

To test this hypothesis, Westwood has taken the AM and PM Peak Hour models, and revised the geometry to remove the channelized right turn lane. This was done for the Existing, No-Build and Build scenarios.

The results show that in many cases, the levels of service do not change appreciably, but the 95th percentile queue lengths in the eastbound direction become longer. This is because the eastbound traffic turning right (southbound) at Kenwood must share the outside eastbound approach lane with half of the eastbound through traffic. Therefore, it takes longer for the combined queue of eastbound right-turning traffic and eastbound through traffic sharing the outside lane to clear the intersection.

The levels of service and queue lengths of the eastbound Arrowhead approach during Existing, No-Build and Build scenarios are shown in Appendix A. This comparison uses the existing signal timing for its analysis. It is noted that the distance from the stop bar at the signalized intersection and the proposed driveway into Kenwood Village is approximately 350 feet.

Dedicated turn lanes are typically designed and constructed to provide additional roadway capacity, to improve traffic operations and to decrease delay at intersections. Such is the case at the intersection of Arrowhead and Kenwood. The dedicated right turn lane along eastbound Arrowhead allows right turning traffic to be separated from

the through traffic, thus allowing more traffic to queue and then proceed through the intersection.

Appendix B illustrates the advantages and disadvantages with different types of right turn lanes (from Fitzpatrick, Schneider and Park, 2005). The type of right turn lane at Arrowhead and Kenwood is called the right turn lane with island (also called the channelized right turn lane or the free-flow right turn). Aside from providing improved flow for through movements along Arrowhead, the right turn lane with island provides following advantages:

- Provides relatively free movement for vehicles after yielding to pedestrians and opposing traffic, thus reducing right-turn queues, lowering emissions, and increasing capacity.
- Provision of islands permits its use for placement of traffic control devices or as a pedestrian refuge.
- Removes turning vehicles from through-vehicle lane for improved intersection operations.

Disadvantages include:

- May encourage higher motorist speeds which may present a hazard to pedestrians.
- If signal support is located on island, pedestrians will need to cross uncontrolled lane to reach pedestrian push button.
- The through movement queue may obstruct the throat of the right-turn lane, reducing capacity of the intersection.
- Driver attention is split between looking back to merging traffic and looking forward to pedestrian crossing points that may be present in front of the vehicle.

A review of crash data at the intersection of Arrowhead and Kenwood shows only three crashes were reported in the last ten years that involved either pedestrians or bicyclists. Of that total, two crashes involved bicyclists and one involved a pedestrian. In each case, there were extenuating circumstances that do not appear related to the right turn lane:

- 04/08/08 -- The pedestrian crash occurred at 4:48 a.m., when conditions were dark and the pedestrian was crossing against the signal.
- 10/22/09 -- A bicycle crash involved a bicyclist (reportedly under the influence) in an improper lane making a left turn.

- 01/23/15 – A bicycle crash that occurred at 8:04 p.m., when the roadway was snow and ice packed and the cyclist was slowing, stopping and starting suddenly.

In conclusion, the City of Duluth has expressed comments and concerns regarding the designated right turn lane on Arrowhead approaching Kenwood. There are advantages in traffic operation and vehicular safety in providing a designated right turn lane. There are disadvantages, though, for motorists and non-motorists alike who use this corner of the intersection.

The answer to the question whether the designated right turn lane should be reverted to a shared through/right turn lane lies with which users are to be best served. The dedicated right turn lane affords better levels of service and reduced queues in traffic. On the other hand, the reduction in intersection size by removing the dedicated right turn will degrade levels of service and increase queuing, while providing for a narrower street width for bicyclists and pedestrians to cross. However, there is a low incidence of crashes over the last decade involving pedestrians and bicyclists at this intersection. Further, the pedestrian and bicycle crashes that did occur were not related to the issue of the right turn lane.

Because there are more motorists using the intersection, and the crash history does not indicate a safety problem, it is my recommendation to leave the dedicated right turn lane in place.

APPENDIX A

TRAFFIC OPERATION - ARROWHEAD & KENWOOD
Dedicated Right Turn Lane versus No Right Turn Lane
Levels Of Service & Queue Lengths – Eastbound Approach

Existing

EXISTING VOLUMES AND ALIGNMENT						
Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
EXISTING A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	13.0 sec	LOS-B	EB Left/Thru	32.4 sec	LOS-C	128 ft
			EB Through	22.0 sec	LOS-C	38 ft
			EB Right	1.5 sec	LOS-A	19 ft.
EXISTING P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	23.7 sec	LOS-C	EB Left/Thru	53.6 sec	LOS-D	292 ft
			EB Through	44.8 sec	LOS-D	347 ft
			EB Right	6.5 sec	LOS-A	214 ft.

EXISTING VOLUMES - PROPOSED ALIGNMENT - LEFT/THROUGH LANE PLUS RIGHT/THROUGH LANE						
Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
EXISTING A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	16.3 sec	LOS-B	EB Left/Thru	29.1 sec	LOS-C	138 ft.
			EB Thru/Right	22.4 sec	LOS-C	129 ft.
EXISTING P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	28.8 sec	LOS-C	EB Left/Thru	38.1 sec	LOS-D	366 ft
			EB Thru/Right	40.0 sec	LOS-D	406 ft

No-Build

2016 NO-BUILD VOLUMES AND ALIGNMENT						
Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
2016 NO-BUILD VOLUMES A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	15.6 sec	LOS-B	EB Left/Thru	25.9 sec	LOS-C	131 ft
			EB Through	21.4 sec	LOS-C	119 ft
			EB Right	1.5 sec	LOS-A	19 ft.
2016 NO-BUILD VOLUMES P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	27.6 sec	LOS-C	EB Left/Thru	54.0 sec	LOS-D	317 ft
			EB Through	39.7 sec	LOS-D	294 ft
			EB Right	5.1 sec	LOS-A	161 ft.

2016 NO-BUILD VOLUMES - PROPOSED ALIGNMENT - LEFT/THROUGH LANE PLUS RIGHT/THROUGH LANE						
Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
2016 NO-BUILD VOLUMES A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	15.8 sec	LOS-B	EB Left/Thru	25.2 sec	LOS-C	146 ft.
			EB Thru/Right	30.5 sec	LOS-C	163 ft.
2016 NO-BUILD VOLUMES P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	35.6 sec	LOS-C	EB Left/Thru	51.1 sec	LOS-D	386 ft
			EB Thru/Right	43.6 sec	LOS-D	394 ft

Build

2016 BUILD VOLUMES AND ALIGNMENT						
Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
2016 BUILD A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	16.3 sec	LOS-B	EB Left/Thru	25.9 sec	LOS-C	162 ft
			EB Through	22.3 sec	LOS-C	162 ft
			EB Right	3.2 sec	LOS-A	0 ft.
2016 BUILD P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	23.9 sec	LOS-C	EB Left/Thru	48.1 sec	LOS-D	262 ft
			EB Through	34.5 sec	LOS-D	253 ft
			EB Right	3.0 sec	LOS-A	213 ft.

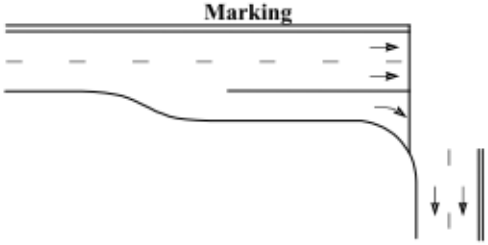
2016 BUILD VOLUMES - PROPOSED ALIGNMENT - LEFT/THROUGH LANE PLUS RIGHT/THROUGH LANE						
Intersection	Intersection		Critical Approach			
	Intersection Control Delay	Overall Intersection LOS	Approach	Lane Group Delay	Lane Group LOS	95th Percentile Queue Length
2016 BUILD A.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	16.0 sec	LOS-B	EB Left/Thru	31.0 sec	LOS-C	134 ft.
			EB Thru/Right	27.0 sec	LOS-C	132 ft.
2016 BUILD P.M. Peak Hour						
Arrowhead Rd & Kenwood Ave	30.7 sec	LOS-D	EB Left/Thru	55.2 sec	LOS-E	274 ft
			EB Thru/Right	74.8 sec	LOS-E	228 ft

APPENDIX B

RIGHT TURN LANE DESIGNS

(Fitzpatrick, Schneider and Park, "Operation and Safety of Right-Turn Lane Designs", 2005)

Right-Turn Lane with a Lane Line Pavement Marking



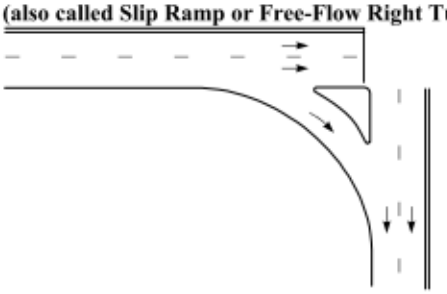
ADVANTAGES

- Allows right-turn-on-red (unless prohibited), reducing right-turn queues.
- Removes turning vehicles from through-vehicle lane for improved intersection operations.
- Lower turning speeds provide a safer pedestrian environment.

DISADVANTAGES

- All vehicles must stop on red, potentially increasing the right-turn queue.
- The absence of an island eliminates its use for:
  - Placement of traffic control devices, and
  - A pedestrian refuge.

Shared Lane with Island (also called Slip Ramp or Free-Flow Right Turn)



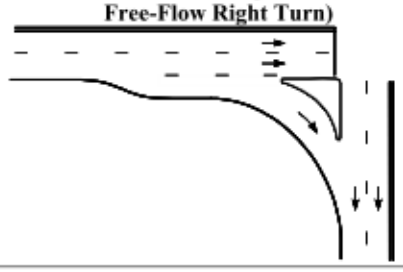
ADVANTAGES

- Provision of islands permits its use for placement of traffic control devices or as a pedestrian refuge.
- Removes turning vehicle from head of queue.

DISADVANTAGES

- May encourage higher motorist speeds which may present a hazard to pedestrians.
- If signal support is located on island, pedestrians will need to cross uncontrolled lane to reach pedestrian push button.
- The through movement queue may obstruct the throat of the right-turn lane, reducing capacity of the intersection.
- Driver attention is split between looking back to merging traffic and looking forward to pedestrian crossing points that may be present in front of the vehicle.

Right-Turn Lane with Island (also called Channelized Right-Turn Lane or Free-Flow Right Turn)



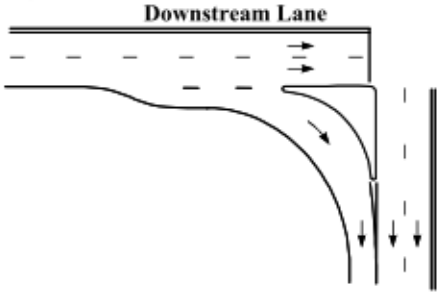
ADVANTAGES

- Provides relatively free movement for vehicles after yielding to pedestrians and opposing traffic, thus reducing right-turn queues, lowering emissions, and increasing capacity.
- Provision of islands permits its use for placement of traffic control devices or as a pedestrian refuge.
- Removes turning vehicles from through-vehicle lane for improved intersection operations.

DISADVANTAGES

- Same as Shared Lane with Island.

Right-Turn Lane with Island and Dedicated Downstream Lane



ADVANTAGES

- Provides relatively free movement for vehicles after yielding to pedestrians, thus reducing right-turn queues, lowering emissions, and increasing capacity.
- Provision of islands permits its use for placement of traffic control devices or as a pedestrian refuge.
- Eliminates need to look for merging vehicles (attention may be focused ahead of vehicle because driver is entering dedicated lane).

DISADVANTAGES

- Same as Shared Lane with Island.
- Vehicles are observed to frequently stop prior to entering the cross street even with an available dedicated lane, because drivers do not know they have a dedicated lane or its length.
- Dedicated downstream lane must be sufficient length for vehicles to merge.
- Access needs to be managed along dedicated downstream lane to ensure proper operation.

Westwood

7699 Anagram Drive
Eden Prairie, MN 55344

Main (952) 937-5150
Fax (952) 937-5822

westwoodps.com
(888) 937-5150

ADDENDUM II

Date: May 26, 2015

Re: Intersection of Arrowhead & Kenwood, Duluth, MN
-- Impacts Associated with Removal of Porkchop at Eastbound Right Turn Lane
File R0004765.00

To: Rick McKelvey, United Properties

From: Steve Manhart, P.E., PTOE, PTP

As a continued investigation of the traffic operation at West Arrowhead Drive and Kenwood Lane, you have requested Westwood to look at the impacts associated with removing the pork chop island in the southwest corner of the intersection. This scenario would leave the dedicated right turn lane intact but would remove the free-flow channelized nature of the right turn movement.

This proposed intersection reduction would result in the following advantages and disadvantages:

Advantages

- Continues to remove the right turning vehicles from the through lanes of traffic for improved intersection operation.
- Allows right turn movements on red, which reduce right turn queues.
- Lowers the turning speeds of vehicles, which provides a safer pedestrian environment.

Disadvantages

- All vehicles must stop on red, which potentially lengthens the right-turning queue.
- The absence of the pork chop island eliminates its use for the placement of signal poles or other traffic control devices.
- The absence of the pork chop island eliminates its use as a pedestrian refuge.

Westwood tested the intersection operation for this scenario (dedicated right turn lane without the pork chop island) under the existing signal timing and optimized signal timing plans. The intersection operation was generally the same with or without the

pork chop channelization island. The tables in the Appendix of this Addendum II illustrate the operation under existing volume, no-build volume and build volume scenarios – both with existing timings and optimized timings.

Another thing to consider would be the cost to reconstruct the signal system at this corner of the intersection. The existing signal pole and mast arm in this corner would likely need to be replaced with a larger pole and mast arm. Also, the underground conduits, handholes and wiring would have to be reconfigured. The cost of this signal pole relocation and reconstruction could exceed $100,000.

Further, should the southwest corner be reconstructed as a simple right turn lane, the curb along the eastbound right turn approach would need to be redesigned to accommodate the smaller turn radius and changes in storm drainage, sidewalks, underground utilities, etc. The extent of these costs is unknown at this time.

If it is determined to keep the pork chop channelization island as it exists, there are a couple of enhancements that could be considered to improve driver awareness of the possible presence of pedestrians:

- The installation of "zebra" crosswalk markings provides thick longitudinal lines that delineate the location of the crosswalk. If installed correctly, the track of vehicle wheels will not cross the pavement marking, thus preserving the crosswalk longer than typical crosswalk lines that are perpendicular to the lanes of travel. Further, the widths of the "zebra" markings are typically two feet or wider, which make these crosswalks much more conspicuous to drivers who are approaching the intersection. (See Figure 1.)

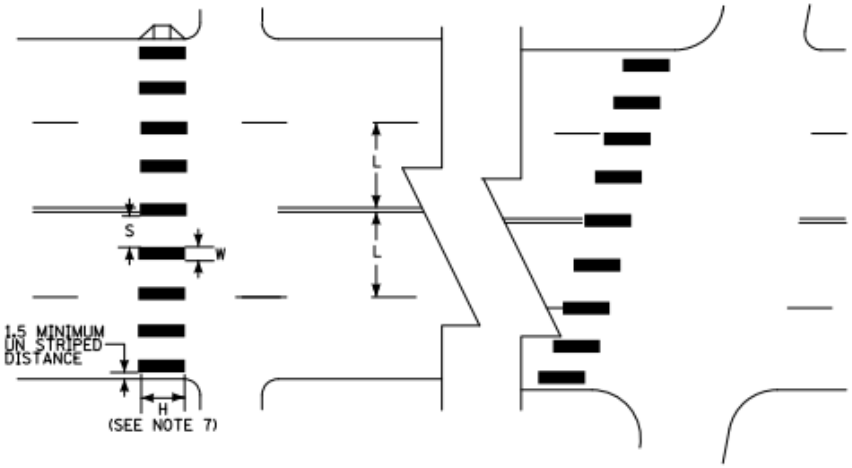
- Another enhancement to pedestrian safety would be the placement of the YIELD sign before the crosswalk. Currently, the YIELD sign is mounted approximately thirty feet beyond the crosswalk. As a result, drivers may be ignoring the crosswalk as they approach the YIELD sign. Consideration should be given to placing the YIELD sign before the crosswalk (as shown in the example to the right).

- There are also a variety of Warning signs that could be installed to enhance driver

Figure 1

MARKINGS FOR PEDESTRIAN CROSSWALKS

(L) WIDTH OF INSIDE LANE	(W) WIDTH OF PAINTED AREA	(S) WIDTH OF SPACE	ALTERNATE (W) WIDTH OF PAINTED AREA	ALTERNATE (S) WIDTH OF PAINTED AREA
9′	2.0′	2.5′	—	—
10′	2.5′	2.5′	2.0′	3.0′
11′	2.5′	3.0′	2.0′	3.5′
12′	3.0′	3.0′	2.5′	3.5′
13′	3.0′	3.5′	—	—



NOTES:

1. PAINTED AREAS TO BE CENTERED ON CENTERLINE AND LANE LINES.
2. A MINIMUM OF 1.5 FT. CLEAR DISTANCE SHALL BE LEFT ADJACENT TO THE CURB. IF LAST PAINTED AREA FALLS INTO THIS DISTANCE IT MUST BE OMITTED.
3. ON TWO LANE TWO WAY STREETS, USE SPACING SHOWN FOR AN 11 FT. INSIDE LANE.
4. FOR DIVIDED ROADWAYS, ADJUSTMENTS IN SPACING OF THE BLOCKS SHOULD BE MADE IN THE MEDIAN SO THAT THE BLOCKS ARE MAINTAINED IN THEIR PROPER LOCATION ACROSS THE TRAVELED PORTION OF THE ROADWAY.
5. AT SKEWED CROSSWALKS, THE BLOCKS ARE TO REMAIN PARALLEL TO THE LANE LINES AS SHOWN.
6. THE BLOCKS SHALL BE PLACED SO THAT THEY ARE NOT LOCATED IN THE WHEEL PATH OF THE VEHICLES
7. THE BLOCKS SHALL BE A MINIMUM OF 6′ LONG AND AT LEAST AS LONG AS THE TRUNCATED DOMES. FOR FANNED TRUNCATED DOMES THE BLOCKS SHALL BE AT LEAST AS LONG AS THE APPROACHING SIDEWALK OR SHARED USE PATH.
8. THE ALTERNATE (W) AND (S) MAY BE USED WHEN BLOCKS LONGER THAN 6′ (H) ARE USED.

Source: MnDOT Pavement Marking Standard Sheets

awareness of pedestrian presence. Care should be given in the deployment of these signs in that drivers may ignore these signs if they see no pedestrians at the crosswalk. Further, the placement of these signs might give pedestrians a false sense of security at the intersection. Any placement of these signs shall comply with the requirements and standards found in the Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD).

In conclusion, comments and concerns have been expressed regarding whether the designated right turn lane without the pork chop channelization island would operate as the right turn lane as it exists today (e.g., with the pork chop island). The operational performance of Existing Volumes, 2016 No-Build Volumes and 2016 Build Volumes have been modeled in the design scenario without the channelizing pork chop island (See Appendix). The operation has been shown with existing signal timings and with optimized signal timings.

When compared with the operation of the intersection with the channelizing island or without a designated right turn lane, the operation is generally the same. The eastbound right turn operation degrades only slightly when the channelizing pork chop is removed and replaced with a standard designated right turn lane at the intersection. When the signal timing is optimized, the intersection operation is improved.

There are other factors, however, that play into the decision whether to remove the pork chop channelization island. Costs of reconstructing the intersection and signal system are chief among those factors.

Westwood suggested other intersection enhancements that could increase pedestrian conspicuity at the eastbound right turn lane. These enhancements include upgrading the pedestrian crosswalk, relocating the YIELD sign and/or adding a pedestrian advance warning sign.

Westwood recommends that the City test these enhancements at the intersection prior to reconstructing the southwest corner of the intersection.

(It is noted that the pedestrian issues at the southwest corner of the intersection were raised by the City and by the nearby residents exclusive of the Kenwood Village development discussion. These comments reflected a perceived existing condition at the intersection. Westwood's analysis indicates that the perceived safety condition is not negatively impacted by the development of Kenwood Village.)

APPENDIX A

TRAFFIC OPERATION - ARROWHEAD & KENWOOD
Dedicated Right Turn Lane with and without Pork Chop Island
Levels Of Service & Queue Lengths – Eastbound Approach

Existing AM Peak Hour

	Intersection Control Delay (sec)	Overall Intersection LOS	Approach	Lane Group Delay (sec)	Lane Group LOS	95th Percentile Queue Length (ft.)
EXISTING AM PEAK & EXISTING SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	15.0	B	EB Left/Thru	24.4	C	123
			EB Thru	22.0	C	81
			EB Right	1.3	A	0
Dedicated Right Turn w/o Pork Chop Island	15.4	B	EB Left/Thru	24.2	C	149
			EB Thru	24.2	C	111
			EB Right	3.7	A	73
EXISTING AM PEAK & OPTIMIZED SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	11.7	B	EB Left/Thru	25.4	C	94
			EB Thru	14.9	B	67
			EB Right	1.4	A	19
Dedicated Right Turn w/o Pork Chop Island	12.4	B	EB Left/Thru	31.9	C	122
			EB Thru	16.9	B	75
			EB Right	3.9	A	73

2016 No-Build AM Peak Hour

2016 NO-BUILD AM PEAK & EXISTING SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	15.3	B	EB Left/Thru	28.5	C	119
			EB Thru	23.6	C	88
			EB Right	1.4	A	18
Dedicated Right Turn w/o Pork Chop Island	15.7	B	EB Left/Thru	22.7	C	125
			EB Thru	21.0	C	91
			EB Right	4.0	A	78
2016 NO-BUILD AM PEAK & OPTIMIZED SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	11.9	B	EB Left/Thru	29.8	C	115
			EB Thru	16.6	B	74
			EB Right	1.6	A	25
Dedicated Right Turn w/o Pork Chop Island	11.9	B	EB Left/Thru	17.9	B	112
			EB Thru	14.7	B	64
			EB Right	3.3	A	70

2016 Build AM Peak Hour

	Intersection Control Delay (sec)	Overall Intersection LOS	Approach	Lane Group Delay (sec)	Lane Group LOS	95th Percentile Queue Length (ft.)
2016 BUILD AM PEAK & EXISTING SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	14.5	B	EB Left/Thru	26.5	C	132
			EB Thru	17.8	B	107
			EB Right	1.4	A	19
Dedicated Right Turn w/o Pork Chop Island	16.1	B	EB Left/Thru	26.6	C	134
			EB Thru	18.8	B	99
			EB Right	3.6	A	65
2016 BUILD AM PEAK & OPTIMIZED SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	11.6	B	EB Left/Thru	22.3	C	126
			EB Thru	14.9	B	84
			EB Right	1.6	A	0
Dedicated Right Turn w/o Pork Chop Island	12.6	B	EB Left/Thru	17.8	B	116
			EB Thru	14.0	B	87
			EB Right	3.3	A	65

Existing PM Peak Hour

	Intersection Control Delay (sec)	Overall Intersection LOS	Approach	Lane Group Delay (sec)	Lane Group LOS	95th Percentile Queue Length (ft.)
EXISTING PM PEAK & EXISTING SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	28.1	C	EB Left/Thru	53.5	D	301
			EB Thru	44.0	D	327
			EB Right	5.0	A	225
Dedicated Right Turn w/o Pork Chop Island	28.0	C	EB Left/Thru	43.3	D	320
			EB Thru	44.6	D	288
			EB Right	7.5	A	227
EXISTING PM PEAK & OPTIMIZED SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	14.5	B	EB Left/Thru	26.4	C	210
			EB Thru	19.6	B	174
			EB Right	3.2	A	69
Dedicated Right Turn w/o Pork Chop Island	15.2	B	EB Left/Thru	28.1	C	208
			EB Thru	19.9	B	177
			EB Right	5.6	A	92

2016 No-Build PM Peak Hour

	Intersection Control Delay (sec)	Overall Intersection LOS	Approach	Lane Group Delay (sec)	Lane Group LOS	95th Percentile Queue Length (ft.)
2016 NO-BUILD PM PEAK & EXISTING SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	27.6	B	EB Left/Thru	54.0	D	317
			EB Thru	39.7	D	294
			EB Right	5.1	A	161
Dedicated Right Turn w/o Pork Chop Island	27.7	B	EB Left/Thru	51.0	D	304
			EB Thru	41.4	D	282
			EB Right	5.9	A	168
2016 NO-BUILD PM PEAK & OPTIMIZED SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	16.1	B	EB Left/Thru	28.7	C	212
			EB Thru	20.6	C	176
			EB Right	2.6	A	0
Dedicated Right Turn w/o Pork Chop Island	15.1	B	EB Left/Thru	33.1	C	228
			EB Thru	19.2	B	182
			EB Right	4.6	A	68

2016 Build PM Peak Hour

2016 BUILD PM PEAK & EXISTING SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	25.5	C	EB Left/Thru	44.6	D	269
			EB Thru	37.8	D	261
			EB Right	3.4	A	244
Dedicated Right Turn w/o Pork Chop Island	25.0	B	EB Left/Thru	47.1	D	255
			EB Thru	36.2	D	248
			EB Right	5.2	A	209
2016 BUILD PM PEAK & OPTIMIZED SIGNAL TIMING						
Dedicated Right Turn w/Pork Chop Island	14.8	B	EB Left/Thru	29.3	C	209
			EB Thru	20.2	C	185
			EB Right	1.9	A	67
Dedicated Right Turn w/o Pork Chop Island	15.0	B	EB Left/Thru	32.6	C	208
			EB Thru	17.9	B	203
			EB Right	4.1	A	132