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TECHNICAL MEMORANDUM

DATE: April 26, 2016

TO: Benton County Public Works
OBEC Consulting Engineers, Inc.

FROM: John Bosket, P.E.
Aaron Berger, P.E.
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SUBJECT: **Addendum to Benton County SW 53rd Street at SW Reservoir Avenue Southbound Right Turn Lane Analysis** P16008-000

This addendum to the previous technical memorandum[1] provides the results of traffic operations and queuing analysis[2] for the forecasted 2040 planning horizon. The 2040 forecasted volumes were estimated using the CALM model[3].

The construction of a separate southbound right turn lane has a significant impact on intersection operations as traffic grows in the future. Without the right turn lane, the intersection will operate very poorly by 2040, with demand exceeding capacity and very high delay (v/c > 1.0 and LOS F). The worst movement would be the southbound shared through-right lane, which could take up to four minutes to get through on average and would queue back nearly ½-mile.

With the southbound right turn lane in place, congestion would be reduced dramatically (v/c = 0.76 and LOS B). The southbound movement would continue to be the worst, but it would take less than 30 seconds to pass through on average and queues would only extend back about 500 feet. The 95th percentile queue length for the southbound right turn movement with a separate right turn lane was estimated to be over 180 feet. Therefore, the construction of a 200-foot right turn lane is recommended to accommodate 2040 traffic volumes.

Detailed analysis outputs are included in the appendix.

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[1] *Benton County SW 53rd Street at SW Reservoir Avenue Southbound Right Turn Lane Analysis.* DKS Associates. February 17, 2016.

[2] Analysis was conducted for the springtime (high) volumes only using the same methodology as the previous memorandum.

[3] CALM (Corvallis, Albany and Lebanon Model) Regional Travel Demand Model. Base and future year volumes pulled 4/25/2016.

Appendix

Level of Service Descriptions

HCM Analysis – Existing Design

HCM Analysis – Planned Design

Queuing Analysis

Level of Service Descriptions

TRAFFIC LEVELS OF SERVICE

Analysis of traffic volumes is useful in understanding the general nature of traffic in an area, but by itself indicates neither the ability of the street network to carry additional traffic nor the quality of service afforded by the street facilities. For this, the concept of level of service has been developed to subjectively describe traffic performance. Level of service can be measured at intersections and along key roadway segments.

Levels of service categories are similar to report card ratings for traffic performance. Intersections are typically the controlling bottlenecks of traffic flow and the ability of a roadway system to carry traffic efficiently is generally diminished in their vicinities. Levels of Service A, B and C indicate conditions where traffic moves without significant delays over periods of peak travel demand. Level of service D and E are progressively worse peak hour operating conditions and F conditions represent where demand exceeds the capacity of an intersection. Most urban communities set level of service D as the minimum acceptable level of service for peak hour operation and plan for level of service C or better for all other times of the day. The Highway Capacity Manual provides level of service calculation methodology for both intersections and arterials[1]. The following two sections provide interpretations of the analysis approaches.

[1] *2000 Highway Capacity Manual*, Transportation Research Board, Washington D.C., 2000, Chapter 16 and 17.

UNSIGNALIZED INTERSECTIONS (Two-Way Stop Controlled)

Unsignalized intersection level of service is reported for the major street and minor street (generally, left turn movements). The method assesses available and critical gaps in the traffic stream which make it possible for side street traffic to enter the main street flow. The 2010 Highway Capacity Manual describes the detailed methodology. It is not unusual for an intersection to experience level of service E or F conditions for the minor street left turn movement. It should be understood that, often, a poor level of service is experienced by only a few vehicles and the intersection as a whole operates acceptably.

Unsignalized intersection levels of service are described in the following table.

Level-of-Service Criteria: Automobile Mode

Control Delay (s/vehicle)	**LOS by Volume-to-Capacity Ratio**	
	***v/c* ≤ 1.0**	***v/c* > 1.0**
0-10	A	F
>10-15	B	F
>15-25	C	F
>25-35	D	F
>35-50	E	F
>50	F	F

Note: The LOS criteria apply to each lane on a given approach and to each approach on the minor street. LOS is not calculated for major-street approaches or for the intersection as a whole

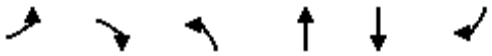
SIGNALIZED INTERSECTIONS

For signalized intersections, level of service is evaluated based upon average vehicle delay experienced by vehicles entering an intersection. Control delay (or signal delay) includes initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay. In previous versions of this chapter of the HCM (1994 and earlier), delay included only stopped delay. As delay increases, the level of service decreases. Calculations for signalized and unsignalized intersections are different due to the variation in traffic control. The 2000 Highway Capacity Manual provides the basis for these calculations.

Level of Service	Delay (secs.)	Description
A	<10.00	**Free Flow/Insignificant Delays:** No approach phase is fully utilized by traffic and no vehicle waits longer than one red indication. Most vehicles do not stop at all. Progression is extremely favorable and most vehicles arrive during the green phase.
B	10.1-20.0	**Stable Operation/Minimal Delays:** An occasional approach phase is fully utilized. Many drivers begin to feel somewhat restricted within platoons of vehicles. This level generally occurs with good progression, short cycle lengths, or both.
C	20.1-35.0	**Stable Operation/Acceptable Delays:** Major approach phases fully utilized. Most drivers feel somewhat restricted. Higher delays may result from fair progression, longer cycle lengths, or both. Individual cycle failures may begin to appear at this level, and the number of vehicles stopping is significant.
D	35.1-55.0	**Approaching Unstable/Tolerable Delays:** The influence of congestion becomes more noticeable. Drivers may have to wait through more than one red signal indication. Longer delays may result from some combination of unfavorable progression, long cycle lengths, or high v/c ratios. The proportion of vehicles not stopping declines, and individual cycle failures are noticeable.
E	55.1-80.0	**Unstable Operation/Significant Delays:** Volumes at or near capacity. Vehicles may wait though several signal cycles. Long queues form upstream from intersection. These high delay values generally indicate poor progression, long cycle lengths, and high v/c ratios. Individual cycle failures are a frequent occurrence.
F	>80.0	**Forced Flow/Excessive Delays:** Represents jammed conditions. Queues may block upstream intersections. This level occurs when arrival flow rates exceed intersection capacity, and is considered to be unacceptable to most drivers. Poor progression, long cycle lengths, and v/c ratios approaching 1.0 may contribute to these high delay levels.

Source: *2000 Highway Capacity Manual*, Transportation Research Board, Washington D.C.

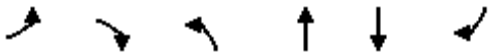
HCM Analysis – Existing Design



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	253	16	36	470	668	477
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750
Lane Width	12	12	12	11	13	12
Total Lost time (s)	4.0	4.0	4.0	4.0	4.0	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	
Frpb, ped/bikes	1.00	1.00	1.00	1.00	0.98	
Flpb, ped/bikes	0.91	1.00	1.00	1.00	1.00	
Frt	1.00	0.85	1.00	1.00	0.94	
Flt Protected	0.95	1.00	0.95	1.00	1.00	
Satd. Flow (prot)	1493	1488	1614	1675	1646	
Flt Permitted	0.95	1.00	0.10	1.00	1.00	
Satd. Flow (perm)	1493	1488	162	1675	1646	
Peak-hour factor, PHF	0.89	0.60	0.71	0.92	0.91	0.89
Adj. Flow (vph)	284	27	51	511	734	536
RTOR Reduction (vph)	0	19	0	0	17	0
Lane Group Flow (vph)	284	8	51	511	1253	0
Confl. Peds. (#/hr)	50					20
Confl. Bikes (#/hr)						10
Heavy Vehicles (%)	1%	0%	3%	1%	1%	2%
Turn Type	NA	custom	pm+pt	NA	NA	
Protected Phases		8	1	6	2	
Permitted Phases	8		6			
Actuated Green, G (s)	20.2	20.2	45.7	45.7	36.0	
Effective Green, g (s)	22.2	22.2	47.7	47.7	38.0	
Actuated g/C Ratio	0.28	0.28	0.61	0.61	0.49	
Clearance Time (s)	6.0	6.0	6.0	6.0	6.0	
Vehicle Extension (s)	2.5	2.5	2.5	0.2	0.2	
Lane Grp Cap (vph)	425	424	205	1025	802	
v/s Ratio Prot		0.01	0.02	c0.31	c0.76	
v/s Ratio Perm	c0.19		0.13			
v/c Ratio	0.67	0.02	0.25	0.50	1.56	
Uniform Delay, d1	24.6	20.0	15.6	8.4	20.0	
Progression Factor	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	3.6	0.0	0.5	0.1	258.9	
Delay (s)	28.2	20.0	16.1	8.6	278.9	
Level of Service	C	C	B	A	F	
Approach Delay (s)	27.5			9.2	278.9	
Approach LOS	C			A	F	

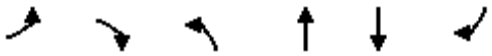
Intersection Summary			
HCM 2000 Control Delay	171.7	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.18		
Actuated Cycle Length (s)	77.9	Sum of lost time (s)	12.0
Intersection Capacity Utilization	92.5%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

HCM Analysis – Planned Design



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	253	16	36	470	668	477
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750
Lane Width	12	12	12	11	13	12
Total Lost time (s)	4.0	4.0	4.0	4.0	4.0	6.0
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frpb, ped/bikes	1.00	1.00	1.00	1.00	1.00	0.95
Flpb, ped/bikes	0.91	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1493	1488	1614	1675	1790	1386
Flt Permitted	0.95	1.00	0.13	1.00	1.00	1.00
Satd. Flow (perm)	1493	1488	227	1675	1790	1386
Peak-hour factor, PHF	0.89	0.60	0.71	0.92	0.91	0.89
Adj. Flow (vph)	284	27	51	511	734	536
RTOR Reduction (vph)	0	19	0	0	0	197
Lane Group Flow (vph)	284	8	51	511	734	339
Confl. Peds. (#/hr)	50					20
Confl. Bikes (#/hr)						10
Heavy Vehicles (%)	1%	0%	3%	1%	1%	2%
Turn Type	NA	custom	pm+pt	NA	NA	Perm
Protected Phases		8	1	6	2	
Permitted Phases	8		6			2
Actuated Green, G (s)	20.2	20.2	45.7	45.7	36.0	36.0
Effective Green, g (s)	22.2	22.2	47.7	47.7	38.0	36.0
Actuated g/C Ratio	0.28	0.28	0.61	0.61	0.49	0.46
Clearance Time (s)	6.0	6.0	6.0	6.0	6.0	6.0
Vehicle Extension (s)	2.5	2.5	2.5	0.2	0.2	0.2
Lane Grp Cap (vph)	425	424	240	1025	873	640
v/s Ratio Prot		0.01	0.02	c0.31	c0.41	
v/s Ratio Perm	c0.19		0.11			0.24
v/c Ratio	0.67	0.02	0.21	0.50	0.84	0.53
Uniform Delay, d1	24.6	20.0	11.3	8.4	17.3	14.9
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	3.6	0.0	0.3	0.1	7.1	0.4
Delay (s)	28.2	20.0	11.6	8.6	24.4	15.3
Level of Service	C	C	B	A	C	B
Approach Delay (s)	27.5			8.8	20.5	
Approach LOS	C			A	C	

Intersection Summary			
HCM 2000 Control Delay	18.5	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.76		
Actuated Cycle Length (s)	77.9	Sum of lost time (s)	12.0
Intersection Capacity Utilization	60.1%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			



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Lane Width	12	12	12	11	13	12
Total Lost time (s)	4.0	4.0	4.0	4.0	4.0	6.0
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frpb, ped/bikes	1.00	1.00	1.00	1.00	1.00	0.95
Flpb, ped/bikes	0.91	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1493	1488	1614	1675	1790	1386
Flt Permitted	0.95	1.00	0.13	1.00	1.00	1.00
Satd. Flow (perm)	1493	1488	227	1675	1790	1386
Peak-hour factor, PHF	0.89	0.60	0.71	0.92	0.91	0.89
Adj. Flow (vph)	284	27	51	511	734	536
RTOR Reduction (vph)	0	19	0	0	0	161
Lane Group Flow (vph)	284	8	51	511	734	375
Confl. Peds. (#/hr)	50					20
Confl. Bikes (#/hr)						10
Heavy Vehicles (%)	1%	0%	3%	1%	1%	2%
Turn Type	NA	custom	pm+pt	NA	NA	Perm
Protected Phases		8	1	6	2	
Permitted Phases	8		6			2
Actuated Green, G (s)	20.2	20.2	45.7	45.7	36.0	36.0
Effective Green, g (s)	22.2	22.2	47.7	47.7	38.0	36.0
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Clearance Time (s)	6.0	6.0	6.0	6.0	6.0	6.0
Vehicle Extension (s)	2.5	2.5	2.5	0.2	0.2	0.2
Lane Grp Cap (vph)	425	424	240	1025	873	640
v/s Ratio Prot		0.01	0.02	c0.31	c0.41	
v/s Ratio Perm	c0.19		0.11			0.27
v/c Ratio	0.67	0.02	0.21	0.50	0.84	0.59
Uniform Delay, d1	24.6	20.0	11.3	8.4	17.3	15.5
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	3.6	0.0	0.3	0.1	7.1	0.9
Delay (s)	28.2	20.0	11.6	8.6	24.4	16.3
Level of Service	C	C	B	A	C	B
Approach Delay (s)	27.5			8.8	21.0	
Approach LOS	C			A	C	

Intersection Summary			
HCM 2000 Control Delay	18.7	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.76		
Actuated Cycle Length (s)	77.9	Sum of lost time (s)	12.0
Intersection Capacity Utilization	60.1%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			

Queuing Analysis

Intersection: 1: 53rd Street & Reservoir Avenue

Movement	EB	EB	NB	NB	SB
Directions Served	L	R	L	T	TR
Maximum Queue (ft)	257	118	75	286	2353
Average Queue (ft)	141	16	27	132	2309
95th Queue (ft)	227	94	63	228	2365
Link Distance (ft)		1034		1227	2286
Upstream Blk Time (%)					97
Queuing Penalty (veh)					0
Storage Bay Dist (ft)	200		215		
Storage Blk Time (%)	2			1	
Queuing Penalty (veh)	0			0	

Network Summary

Network wide Queuing Penalty: 1

Intersection: 1: 53rd Street & Reservoir Avenue

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	236	69	71	245	559	248
Average Queue (ft)	128	8	26	126	271	101
95th Queue (ft)	207	38	61	220	519	183
Link Distance (ft)		1021		1227	2286	2286
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	200		215			
Storage Blk Time (%)	1	0		1		
Queuing Penalty (veh)	0	0		0		

Network Summary

Network wide Queuing Penalty: 1