MEMORANDUM

Project:	US 6 / 19th Street Interchange
To:	Dan Hartman, PE – City of Golden Joe Puhr, PE – City of Golden
From:	John Hausman, PE, PTOE – Muller Engineering Company
Date:	December 13, 2017
Subject:	19th Street Traffic Volume and Level of Service Comparison

The completion of the US 6 / 19th Street interchange provides the opportunity to conduct an "after" analysis of traffic volumes along 19th Street. Given the unique configuration of the new interchange, the City of Golden has requested a follow-up study of existing traffic volumes and intersection operations compared to the conditions documented in the System Level Feasibility Study conducted for the planning and design of the interchange.

The *US 6 and 19th Street Interchange System Level Feasibility Study* (Muller, Sept 2015) documented existing 2015 and future 2035 traffic volumes which were used to plan and design the interchange. The 2015 volumes presented in the study were counts from June 2015 that were adjusted to account for both the seasonal Colorado School of Mines traffic demands and the reconfiguration of the intersection to a grade-separated interchange. This memo will compare the planning level volumes to traffic counts taken on November 14, 2017, approximately four months after the final interchange configuration opened to traffic. The purpose of the comparison is to gauge the existing traffic operations compared to those forecast to occur with the new interchange. **Figure 1** presents the peak hour turning movement volumes along 19th Street for the years 2015, 2017 and 2035.

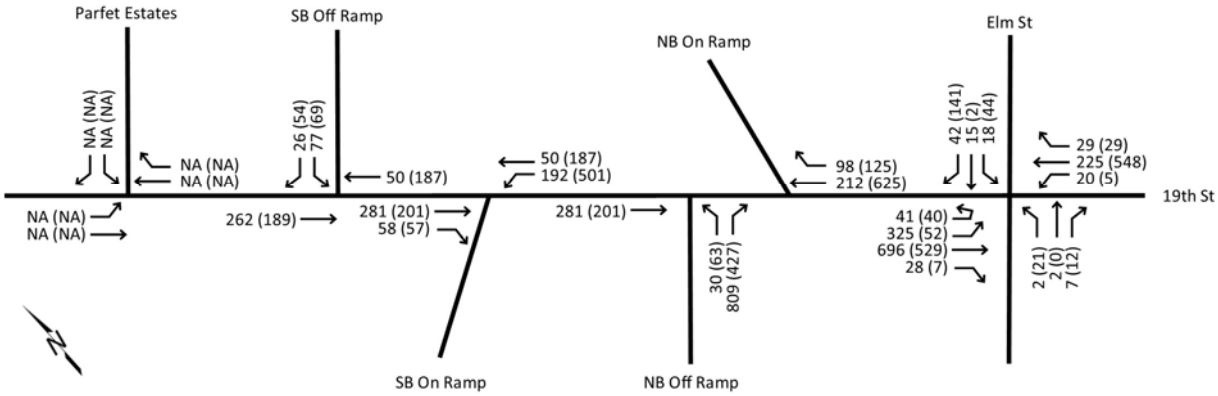
In general, the 2017 traffic counts were found to be equal to or less than the 2015 volumes. This is likely a result of how the 2015 volumes were developed. The traffic counts taken in 2015, based on the project schedule, were taken in June when Colorado School of Mines was not in session. Historic turning movement counts taken during the school year were used to adjust the June 2015 counts. The adjustment process resulted in a conservative estimate of traffic volumes, which was confirmed by the November 2017 counts.

ORIGINAL CONDITIONS

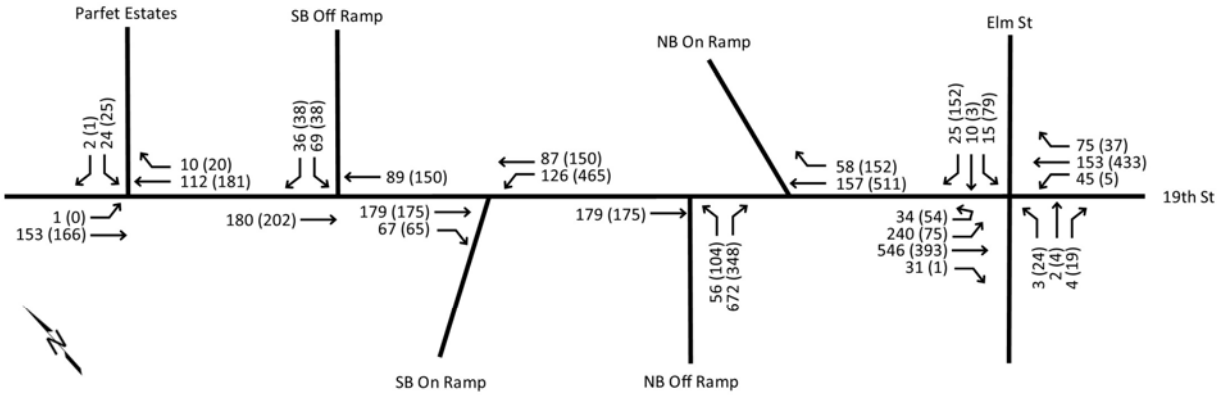
Prior to the construction of the interchange and roundabout on 19th Street, the corridor consisted of a signalized at-grade intersection at US 6 and a side-street stop-controlled intersection at Elm Street. Existing (2015) conditions were analyzed at both intersections as part of the System Level Feasibility Study. **Table 1** presents the peak hour average delay and average and 95th percentile queues for each movement at the original US 6 / 19th Street intersection. **Table 2** presents the same information for the Elm Street

Figure 1 – 2015, 2017 and 2035 Turning Movement Volumes

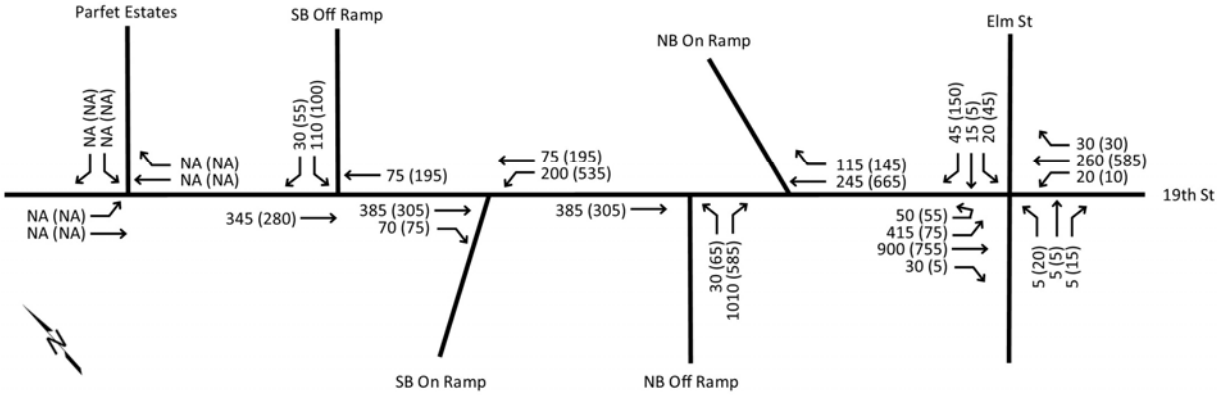
1601 Report—Existing (2015) Peak Hour Volumes



November 2017 Peak Hour Counts



1601 Report—Future (2035) Peak Hour Volumes



intersection. For the purpose of this study, 19th Street is referred to as an east-west road, and Elm Street, Parfet Estates, and all US 6 ramps are referred to as north-south roads.

Based on the average delays and the peak hour volumes, the original intersection at US 6 / 19th Street experienced 20.2 vehicle-hours of delay during the AM peak hour and 56.4 vehicle-hours of delay during the PM peak hour. The Elm Street intersection experienced 2.2 vehicle-hours of delay during the AM peak hour and 1.9 vehicle-hours of delay during the PM peak hour. The above vehicle delay data was determined using Trafficware's Synchro© traffic modeling software for US 6 / 19th Street and Rodel© roundabout analysis software for 19th Street / Elm Street.

Table 1 – US 6 / 19th Street Average Delay and Queues (2015)

	AM Peak Hour				PM Peak Hour			
Movement	Delay (sec)	LOS	Ave. Queue (ft)	95th % Queue (ft)	Delay (sec)	LOS	Ave. Queue (ft)	95th % Queue (ft)
Eastbound Left	19	B	21	37	20	B	19	38
Eastbound Through	31	C	111	144	30	C	57	91
Eastbound Right	0	A	0	0	0	A	0	0
Westbound Left	20	B	39	62	26	C	120	163
Westbound Through	12	B	10	46	28	C	98	173
Westbound Right	12	B	10	46	28	C	98	173
Northbound Left	69	E	22	26	79	E	48	62
Northbound Through	18	B	168	152	85	F	616	735
Northbound Right	22	C	112	79	3	A	3	21
Southbound Left	95	F	44	120	95	F	51	92
Southbound Through	30	C	405	533	40	D	496	633
Southbound Right	0	A	0	0	0	A	1	1
Full Intersection	25	C	NA	NA	49	D	NA	NA

Note: LOS, Delay and queue estimates were determined using Synchro 9 analysis software.

Table 2 – Elm Street / 19th Street Average Delay and Queues (2015)

	AM Peak Hour				PM Peak Hour			
Movement	Delay (sec)	LOS	Ave. Queue (ft)	95th % Queue (ft)	Delay (sec)	LOS	Ave. Queue (ft)	95th % Queue (ft)
Eastbound Left	9	A	NA	28	9	A	NA	5
Eastbound Through	0	A	NA	0	0	A	NA	0
Eastbound Right	0	A	NA	0	0	A	NA	0
Westbound Left	9	A	NA	2	9	A	NA	0
Westbound Through	0	A	NA	0	0	A	NA	0
Westbound Right	0	A	NA	0	0	A	NA	0
Northbound Left	116	F	NA	4	79	F	NA	30
Northbound Through	26	D	NA	4	12	B	NA	2
Northbound Right	26	D	NA	4	12	B	NA	2
Southbound Left	128	F	NA	38	52	F	NA	41
Southbound Through	35	D	NA	36	16	C	NA	35
Southbound Right	35	D	NA	36	16	C	NA	35

Note: LOS, Delay and queue estimates were determined using Synchro 9 software. Average queue is not calculated by synchro for stop controlled intersections.

INTERCHANGE CONDITIONS

With the construction of the interchange complete and open to traffic, volume, queuing, and delay data were field-collected at the interchange ramp intersections and the Elm Street roundabout on November

14, 2017 by IDAX Data Solutions. The collected data was then compared to the calculated and forecast operations conditions presented in the System Level Feasibility Study.

ELM STREET INTERSECTION

Table 3 documents the AM and PM peak hour queues for the Elm Street roundabout just east of the interchange. During the AM peak hour, the 2017 field measured queues were found to be lower than either the 2015 estimates and the 2035 forecasts in the feasibility study, except for the westbound entry into the roundabout. The 95th percentile queue for the westbound entry is approximately two vehicles longer than the calculated queues. However, the eastbound queues were observed to be shorter than the calculated queues for both entry lanes. In fact, during much of the AM peak hour, there are no eastbound entry queues into the roundabout. The PM peak hour queues were found to be less than the calculated queues for all approaches of the roundabout. The southbound queues are slightly longer than calculated, but still equivalent in magnitude.

Table 3: 19th Street / Elm Street Peak Hour 95th Percentile Queues

Time Period	EBL/EB U-Turn (ft)	EBT/EBR (ft)	WBL/WBT/WBR (ft)	NBL/NBT/NBR (ft)	SBL/SBT/SBR (ft)
2015 AM Peak Hour	40	155	43	3	8
2017 AM Peak Hour	0	0	100	0	0
2035 AM Peak Hour	123	173	63	3	8
2015 PM Peak Hour	8	78	105	5	35
2017 PM Peak Hour	0	0	75	0	50
2035 PM Peak Hour	50	63	140	5	43

Note: Queue lengths noted as Average Queue / 95th Percentile Queue

Table 4 documents the intersection level of service and average delay based on the recorded volumes in Figure 1. Rodel software was used to estimate the HCM 2010 peak hour level of service and average delay for the 2015 and 2035 analysis years. Queue counts taken every 15 seconds during the peak hours were used to calculate the average delay for 2017 conditions. During the AM peak hour, the roundabout was calculated to operate with approximately 2 seconds of overall average delay at LOS A under 2017 conditions. The 2017 conditions are better than both the 2015 and 2035 conditions documented in the System Level Feasibility Study. During the 2017 PM peak hour, the roundabout was calculated to operate at LOS A with approximately 3 seconds of average delay. Again, the 2017 conditions are better than both the 2015 and 2035 documented conditions. Based on the 2017 data, the roundabout is operating slightly better than what was predicted in the System Level Feasibility Study.

Table 4: 19th Street / Elm Street Peak Hour Level of Service and Delay

Time Period	EB Approach		WB Approach		NB Approach		SB Approach		Full Intersection	
	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
2015 AM Peak Hour	9	A	7	A	7	A	5	A	8	A
2017 AM Peak Hour	1	A	7	A	8	A	2	A	2	A
2035 AM Peak Hour	10	B	10	A	9	A	5	A	10	B
2015 PM Peak Hour	7	A	9	A	6	A	9	A	8	A
2017 PM Peak Hour	1	A	3	A	5	A	7	A	3	A
2035 PM Peak Hour	6	A	11	B	7	A	10	B	8	B

Note: EB approach includes EB U-Turns.

RAMP TERMINAL INTERSECTIONS

Table 5 documents the AM and PM peak hour queues for the movements at the ramp terminals within the interchange. During the AM peak hour, the 2017 queues were found to be slightly longer for the northbound left on the northbound off-ramp and the shared left / right lane on the southbound off-ramp. However, the additional queue length calculates to less than two additional vehicles in the 95th percentile queue. All recorded queues for 2017 conditions were less than 100 feet in length. The 2017 PM peak hour queues were found to be of similar length to the queues predicted in the System Level Feasibility Study. Based on the 2017 data, none of the ramps appear to be experiencing an unexpected level of queuing.

Table 5: 19th Street / Interchange Peak Hour 95th Percentile Queues

Time Period	NB Off-Ramp		SB Off-Ramp	SB On-Ramp
	NBL (ft)	NBR (ft)	SBL & SBR (ft)	EB Thru & EB Right (ft)
2015 AM Peak Hour	5	0	14	67
2017 AM Peak Hour	25	0	50	50
2035 AM Peak Hour	10	550	25	90
2015 PM Peak Hour	20	0	18	106
2017 PM Peak Hour	25	0	25	75
2035 PM Peak Hour	30	0	30	175

Table 6 documents the level of service and average delay at the interchange intersections based on the recorded volumes in Figure 1. Synchro 9 software was used to estimate the level of service and average delay for the 2015 and 2035 analysis years. The queue counts taken in 2017 were used to calculate an average delay per vehicle, assuming each queued vehicle was stopped for the full 15 seconds of the recorded queue measurement interval. During the AM peak hour, each recorded ramp movement was calculated to operate with less average delay per vehicle compared to the delays documented in the System Level Feasibility Study. Each movement was found to operate at LOS A with less than 10 seconds in average delay. During the PM peak hour, each ramp movement was calculated to operate with less average delay per vehicle compared to the delays documented in the System Level Feasibility Study. The southbound on-ramp intersection currently operates at LOS B. Based on the 2017 data, all of the ramps are operating better than expected based on the analysis in the System Level Feasibility Study.

Table 6: 19th Street / Interchange Peak Hour Level of Service and Delay

Time Period	NBL Off-Ramp		NBR Off-Ramp		SB Off-Ramp		SB On-Ramp	
	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
2015 AM Peak Hour	13	B	0	A	11	B	14	B
2017 AM Peak Hour	7	A	1	A	10	A	7	A
2035 AM Peak Hour	14	B	26	C	13	B	19	C
2015 PM Peak Hour	20	C	0	A	12	B	26	D
2017 PM Peak Hour	9	A	0	A	9	A	15	B
2035 PM Peak Hour	25	C	2	A	13	B	73	F

Note: Interchange LOS and delay does not account for traffic platooning from the 19th Street/Illinois Street traffic signal.

COMPARISON TO ORIGINAL CONDITIONS

Two comparisons were made between the original geometric conditions along 19th Street and the completed interchange configuration. Since the eastbound left-turn from 19th Street to US 6 was eliminated at the interchange and now requires drivers to conduct a U-turn at the Elm Street roundabout, a comparison of the previous delay at the traffic signal to the new travel pattern was completed. In addition, a comparison of the total vehicle hours of delay of the original and interchange conditions was completed.

As shown previously in **Table 1**, the eastbound left-turn experienced 19 seconds of average delay during the AM peak hour and 20 seconds of average delay during the PM peak hour under 2015 conditions. The new travel pattern requires drivers to drive approximately 1600 feet to conduct a U-turn at the roundabout. At 25 miles per hour, this distance requires 43 seconds of travel time, plus any delays at the roundabout entry. During both the AM and PM peak hours, the average eastbound entry delay at the roundabout is 1 second. The stop-controlled delay for eastbound 19th Street at the southbound on-ramp is 7 seconds during the AM peak hour and 15 seconds during the PM peak hour. As a result, the total travel time during the AM peak hour is 51 seconds and 59 seconds during the PM peak hour, an increase of 32 seconds in the AM peak hour and 39 seconds in the PM peak hour when compared to 2015 conditions.

The total vehicle-hours of delay were also compared between the original signalized intersection and the new interchange. **Table 7** presents the comparison of vehicle-hours of delay between the original condition (signalized intersection) and the new configuration (grade-separated interchange). As presented previously, the original intersection configuration experienced 20.5 vehicle-hours of delay at the US 6 intersection and 2.2 vehicle-hours of delay at the Elm Street intersection during the AM peak hour. During the PM peak hour, the US 6 intersection experienced 56.4 vehicle-hours of delay with 1.9 vehicle hours of delay at the Elm Street intersection.

The construction of the interchange was expected to decrease the vehicle-hours of delay by removing all delay from the traffic on US 6 and by reducing delay along 19th Street. Based on the 2017 data collected along 19th Street, the vehicle-hours of delay at the Elm Street roundabout reduced to 0.73 hours during the AM peak hour and 0.99 hours during the PM peak hour. The delays at the interchange ramps result in

0.90 vehicle-hours of delay during the AM peak hour and 1.43 vehicle-hours of delay during the PM peak hour.

Table 7 – Interchange Vehicle-Hours of Delay

Scenario	AM Peak Hour			PM Peak Hour		
	Interchange / Intersection	Elm Street	Total	Interchange / Intersection	Elm Street	Total
2015 Original	20.50	2.20	22.70	56.40	1.90	58.30
2017 Interchange	0.90	0.73	1.63	1.43	0.99	2.42
Change	-19.6	-1.47	-21.07	-54.97	-0.91	-55.88

Source: Muller Engineering Company, 2017.

The interchange reduced the total vehicle-hours of delay by 21.07 hours during the AM peak hour and 55.88 hours during the PM peak hour. Those reductions equate to a 92 percent reduction in system delay during the AM peak hour and a 95 percent reduction during the PM peak hour.

CONCLUSIONS

The data collected in November 2017 consistently demonstrates that the new interchange and roundabout are operating equal to, or better than, the conditions documented in the System Level Feasibility Study. Both delays and queues were found to be equal to or shorter in most locations. Both the Elm Street roundabout and the intersection ramp terminals are operating at LOS A during peak hours.

In addition, while eastbound left-turning drivers experience longer travel times with the new interchange configuration, the overall total of vehicle-hours of delay within the interchange complex has been reduced by over 90 percent during both peak hours.

It is also recommended that the City of Golden conduct a safety study approximately one year after the opening of the new interchange to compare before and after crash conditions. With that crash data, the City will be able to conduct a full assessment of the benefits of the interchange compared to the original at-grade intersection.