TECHNICAL MEMORANDUM 4

DATE: May 22, 2023

TO: Project Team

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SUBJECT: US 20 Bend Facility Plan: Future Baseline (No-Build) Transportation System Conditions

P#22140-000

This memorandum documents future baseline (No-Build) system conditions for the US 20 Bend Facility Plan study area, including documentation of future No-Build traffic operations and walking, biking, and transit conditions. The information provided in this memorandum, in combination with *Technical Memorandum #2: Existing Transportation System Conditions,* will help provide an understanding of the "No-Build" condition and will be used to identify deficiencies and inform the development of solutions for the US 20 study corridor.

SUMMARY OF KEY FINDINGS

CORRIDOR OPERATIONS ANALYSIS

- Future traffic volumes along US 20 are expected to grow by approximately 20 percent over the next 20 years.
- All the study intersections will experience more congestion compared to existing conditions, with higher volume-to-capacity (V/C) ratios and delays:
  - None of the signalized intersections are able to meet the adopted mobility targets, with traffic demand at four of the five signalized intersection exceeding capacity, indicating significant congestion at these study intersections, including:
    - US 20 and NE 3rd Street
    - US 20 and NE 8th Street
    - US 20 and NE Purcell Boulevard
    - US 20 and NE 27th Street
  - The roundabout at Hamby Road/Ward Road fails to meet the adopted mobility target, in part due to higher northbound and southbound volumes associated with new developments in eastern Bend.
  - The only two-way stop-controlled intersections that will fail to meet mobility targets are at Dean Swift Road and NE Benson Way. However, all the other two-way stop-

controlled intersections, with the exceptions of those at NE 4th Street and NE 6th Street, will still experience long delays on the side streets (LOS F), including:

  - US 20 and Windy Knolls Drive
  - US 20 and Erickson Road
  - US 2 and Powell Butte Highway

- Significant vehicle queues occur throughout the study corridor during future design hour, including:
  - Segment 1 (NE 3rd Street to NE 15th Street):
    - Excessive queues occur at NE 3rd Street and NE 8th Street, spilling back to adjacent intersections on all approaches.
    - The southbound queue at NE 4th Street backs up beyond NE Kearney Avenue.
    - The long eastbound queue at NE 15th Street backs up to nearly 12th Street.
  - Segment 2 (NE 15th Street to NE Providence Drive/NE Benson Way):
    - Extensive queues occur on the northbound and southbound Dean Swift Road approaches.
    - The northbound queue at NE Purcell Boulevard extends beyond the next intersection at NE Twin Knolls Drive, mainly because through traffic is often blocked by left turning vehicles that cannot fit in the 80-foot left turn lane.
    - At NE 27th Street, eastbound queues spill back through Dean Swift Road, westbound queues spill back to NE Benson Way, northbound queues spill back through Bear Creek Road, and southbound queues spill back through NE Forum Drive.
    - Southbound queues at NE Benson Way spill back into the NE Bellevue Drive intersection.
  - Segment 3 (NE Providence Drive/NE Benson Way to Powell Butte Highway):
    - A large increase in demand on the north and south approaches at the intersection results in long eastbound and westbound queues at the Hamby Road/Ward Road roundabout.
    - Limited queuing occurs at Erickson Road/Torkelson Road and Powell Butte Highway, with southbound right turns occasionally backing up beyond the striped storage at Powell Butte Highway.

IMPACT OF FUTURE TECHNOLOGIES

- The introduction of connected and autonomous vehicles (CAV) for public use brings great promise for safer and more efficient transportation alternatives than is available today. A few facets of this technology that may have implications for the US 20 study corridor include:
  - Traffic signals provide opportunities for CAVs to perform Vehicle-to-Infrastructure communication but passive detections need to be installed for the transportation network to fully detect vulnerable road users and communicate with CAVs that these users are present.
    - This will be particularly important along Segment 1 and 2, where a high number of people walking and biking cross US 20 on the City's low stress network.

- ODOT is in the process of upgrading traffic signal controllers and providing smarter detection across the state. US 20 is also identified as an ITS corridor with a plan for future fiber to support future technology. This would enhance traffic signals in the area and should be considered along with any recommended alternatives.

ACTIVE TRANSPORTATION

- ODOT currently has not identified any planned improvements along US 20 and without improvements, US 20 will remain a high-stress corridor for walking and biking.
  - However, ODOT's Blueprint for Urban Design (BUD) identifies separated bicycle facilities as the optimal treatment for the land use contexts identified for the US 20 corridor. The BUD also identifies continuous and buffered sidewalks as the optimal treatment for people walking. In addition, within the Urban Mix land use context (west of 12th Street), the BUD also discusses the need for providing ample sidewalk space for other activities such as transit shelters and sidewalk cafes.
- Bend's Transportation System Plan (TSP) lists several planned projects to improve conditions for people walking and bicycling in the future crossing US 20 and along parallel routes (see TSP Figure 5-3b). Near the study area, these include:
  - Mid-term improvement project at US 20 and NE 8th Street (C-30) will enhance connectivity for people walking and biking.
  - Planned Key Walking and Biking Route project (R2-D) on Bear Creek Road (the closest Key Walking and Biking Route parallel to US 20) will close sidewalk gaps and create a connection between Coyner and Larkspur Trails.
  - Planned Key Walking and Biking Route project (R2-E) will close sidewalk gaps between Cessna Avenue and the eastern edge of the Bend urban growth boundary and create a low-stress bikeway extending to 170 new affordable housing units.
- The Cascades East Transit (CET) 2040 Transit Master Plan (TMP) identifies US 20/Greenwood Avenue and NE 3rd Street as primary transit corridors that could eventually support high-capacity transit in Bend, connecting several key mobility hubs at Central Oregon Community College, Downtown, Hawthorne Station and in East Bend near 27th Street.
- The CET TMP identifies several future transit service needs in Bend within the study area and planned improvements to address those needs, including the following route changes:
  - Extension of services for Route 7 (Greenwood) to serve downtown by travelling along Bond Street and Wall Street.
  - Elimination of Route 10 and extension of Route 7 farther along Bond Street to Colorado Avenue to serve the Oregon State University Cascades Campus.

TRAFFIC OPERATIONS

This evaluation includes the same study area as described in *Technical Memorandum #2: Existing Transportation System Conditions,* including the thirteen study intersections shown in Figure 1. The following sections discuss the process for developing future (Year 2042) traffic volumes and the results of the intersection operations analysis for future No-Build conditions.

FUTURE VOLUME DEVELOPMENT

Future traffic volumes were forecast to year 2042 at the study intersections as documented in *Technical Memorandum #3: Future Traffic Forecast.* Figure 1 shows the 2042 traffic volumes under No-Build conditions at the study intersections during the design hour (future equivalent of the 30th highest hour [30HV]). In general, future traffic volumes along US 20 are expected to grow by approximately 20 percent over the next 20 years. The following summarizes key traffic growth areas along the corridor:

- **Segment 1 (NE 3rd Street to NE 15th Street):**
  - Traffic travelling along US 20 in this segment is expected to increase by approximately 25 percent in the eastbound direction and 20 percent in the westbound direction.
  - At 3rd Street, southbound traffic is expected to increase by 40 percent, but northbound traffic growth is relatively small. Note the City is currently pursuing a pilot implementation of a road diet along Greenwood Avenue west of 3rd Street, which is not included in the modelling for this project. Implementing this project would likely result in a decrease in traffic volumes eastbound but an increase in traffic volumes northbound, as drivers use Franklin Avenue or Olney Avenue to access 3rd Street/US 20 instead of using Greenwood Avenue[1].
  - At 4th Street, traffic is expected to increase by 35 percent on the northbound approach and 70 percent on the southbound approach.
  - At 15th Street, northbound traffic is expected to increase by 30 percent.
- **Segment 2 (NE 15th Street to NE Providence Drive/NE Benson Way):**
  - Traffic travelling along US 20 in this segment is expected to increase approximately 30 percent in the eastbound direction and 20 percent in the westbound direction.
  - At Purcell Boulevard, northbound traffic is expected to increase by 40 percent, with minimal growth on the southbound approach.
  - At 27th Street, traffic is expected to increase by 80 percent on the northbound approach and 40 percent on the southbound approach.
- **Segment 3 (NE Providence Drive/NE Benson Way to Powell Butte Highway):**
  - Traffic travelling along US 20 in this segment is expected to increase approximately 30 percent in the eastbound direction, 10 percent in the westbound direction between Erickson Road/Torkelson Road and NE Providence Drive/NE Benson Way, and 25

[1] *Greenwood Avenue West Segment Alternatives Comparison Technical Memorandum*, DKS Associates, December 2021

percent in the westbound direction between Powell Butte Highway and Erickson Road/Torkelson Road.

- At Hamby Road/Ward Road, northbound and southbound traffic volumes are forecast to significantly increase (greater than 75 percent) in response to urban growth in eastern Bend and drivers diverting around congestion along 27th Street.

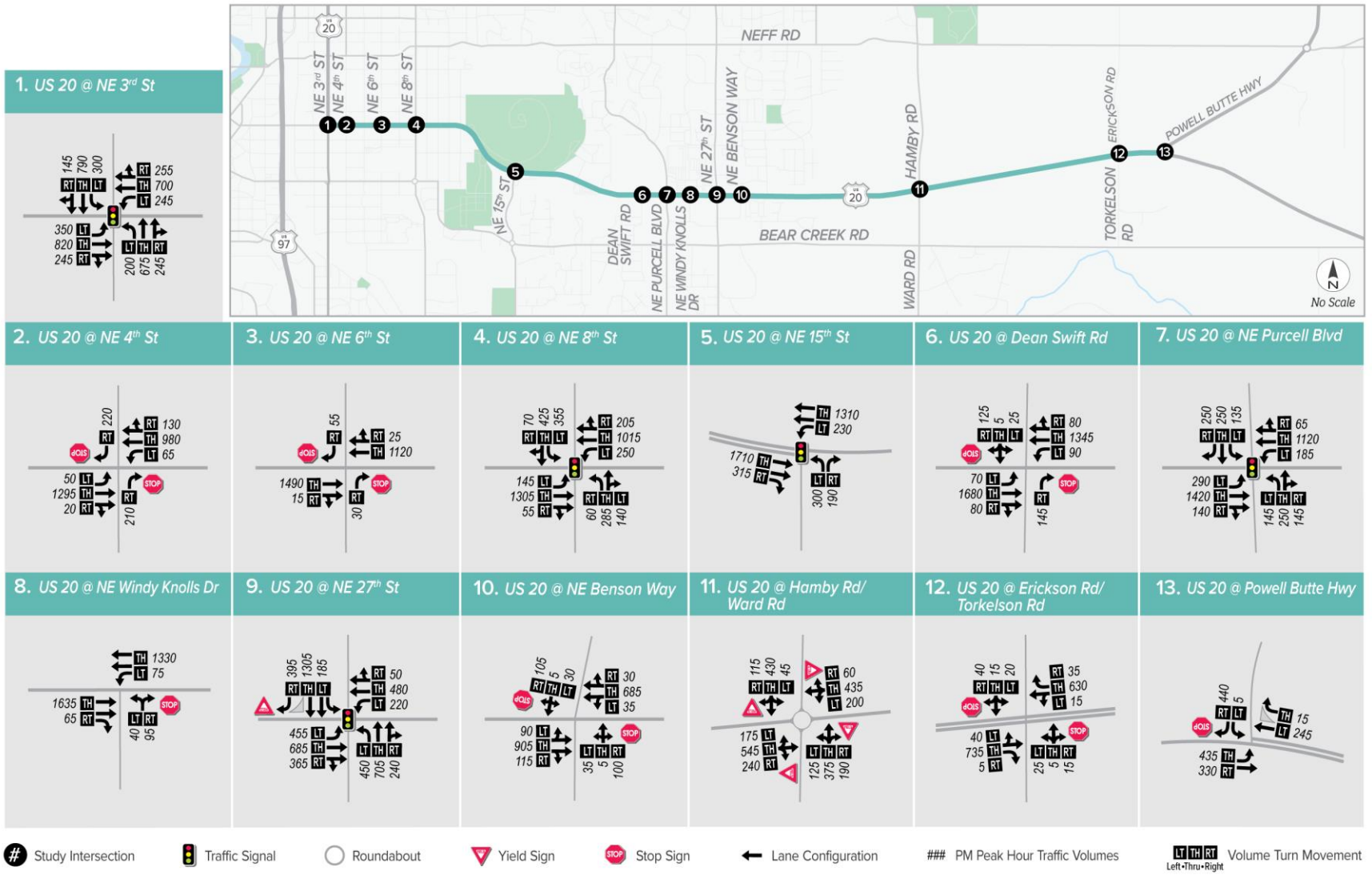

FIGURE 1. FUTURE (YEAR 2042) MOTOR VEHICLE DESIGN HOUR TRAFFIC VOLUMES

INTERSECTION OPERATIONS

Intersection operations were analyzed using Synchro and Sidra software and the Highway Capacity Manual 6th Edition (HCM 6) methodologies to assess the level of congestion experienced. Performance measures used for this analysis include volume-to-capacity (V/C) ratios, level of service (LOS), and seconds of control delay. Table 1 summarizes the results of this analysis, with each intersection's performance compared to the adopted mobility target[2]. HCM reports are included in Appendix A.

As shown in the table, all the study intersections have higher V/C ratios and delays compared to the existing conditions, indicating operational performance is expected to worsen in the future under No-Build conditions as Bend continues to grow. Under existing conditions, only the intersections of NE 3rd Street and NE 8th Street failed to meet adopted mobility targets. In the future, none of the signalized intersections are expected to meet the adopted mobility targets, and traffic demand at four of the five signalized intersections is forecast to exceed capacity, indicating there will be a significant amount of congestion.

The only two-way stop-controlled intersections that will fail to meet mobility targets are at Dean Swift Road and NE Benson Way. However, all the other two-way stop-controlled intersections, with the exception of those at NE 4th Street and NE 6th Street, will still experience long delays on the side streets (LOS F). Furthermore, the roundabout at Hamby Road/Ward Road will fail to meet the adopted mobility target, in part due to higher northbound and southbound traffic volumes associated with new developments in eastern Bend.

[2] Mobility targets for ODOT facilities obtained from the 1999 Oregon Highway Plan, as amended May 2015.

TABLE 1. FUTURE (2042) DESIGN HOUR INTERSECTION OPERATIONS ANALYSIS SUMMARY

INTERSECTION	CONTROL	MOBILITY TARGET[A] (V/C)	EXISTING (2022)			FUTURE (2042)		
			V/C	LOS	DELAY (SEC)	V/C	LOS	DELAY (SEC)
US 20 & 3RD ST	Signalized	0.85	**0.89**	E	68	**1.05**	F	114
US 20 & 4TH ST	TWSC	0.85/0.95	0.31/0.38	B/C	12/18	0.35/0.60	B/D	14/28
US 20 & 6TH ST	TWSC	0.85/0.95	0.40/0.08	A/C	0/15	0.48/0.10	A/C	0/17
US 20 & 8TH ST	Signalized	0.85	**0.98**	E	75	**1.16**	F	83
US 20 & 15TH ST	Signalized	0.85	0.71	B	16	**0.88**	C	31
US 20 & DEAN SWIFT RD	TWSC	0.85/0.95	0.38/**>2.0**	C/F	15/**>300**	0.46/**>2.0**	C/F	23/**>300**
US 20 & PURCELL BLVD	Signalized	0.85	0.82	D	45	**1.06**	F	96
US 20 & WINDY KNOLLS DR	TWSC	0.85/0.95	0.34/0.52	B/D	13/32	0.45/0.86	C/F	20/91
US 20 & 27TH ST	Signalized	0.85	0.83	D	52	**1.26**	F	158
US 20 & BENSON WAY	TWSC	0.85/0.95	0.20/0.83	B/F	10/86	0.22/**1.27**	B/F	11/244
US 20 & HAMBY RD	Roundabout	0.85	0.75 (west)	C	15	**1.21** (west)	F	103
US 20 & ERICKSON RD/ TORKELSON RD	TWSC	0.70/0.75	0.39/0.11	A/D	9/26	0.42/0.58	A/F	10/94
US 20 & POWELL BUTTE HWY	TWSC	0.70/0.75	0.27/0.57	A/D	9/34	0.37/0.63	A/F	9/64

Bold and Red indicate failure to meet mobility target (under Design Hour operations); TWSC = two-way stop-control

[A] For signalized intersection, mobility target and results reported as overall intersection; For TWSC intersections, mobility target and results reported as major street/minor street; For roundabout, mobility target and results reported as the worst leg.

In addition, the operational analysis produced different outcomes compared to previous analysis conducted for Bend's Transportation System Plan (TSP)[3] in 2020, notably at NE 3rd Street (TSP indicated an intersection V/C ratio of 1.33), NE Purcell Street (TSP V/C of 0.95), and NE 27th Street (TSP V/C of 1.04). It should be noted that these two studies used different assumptions to forecast future traffic volumes. Forecasting for the TSP used 2010 as the base year and included all improvements listed in the TSP in the future year (2040) model, while this study used 2019 as the base year and only included financially constrained improvements in the model.

Specifically, the TSP included several Transportation Demand Management (TDM) and significant transit improvements (including mobility hubs) to reduce motor vehicle travel demand, which were not included in this study. Therefore, this analysis is generally more conservative compared to the TSP. This explains the better operational results at NE Purcell Boulevard and NE 27th Street in the TSP. In addition, the TSP future model had ramp metering implemented along US 97, limiting the ability of vehicles to enter the highway and resulting in more north-south trips in Bend travelling through 3rd Street. This study did not assume ramp metering along US 97 and, therefore, resulted in fewer trips along 3rd Street and a lower V/C ratio at the US 20/ 3rd Street intersection.

VEHICLE QUEUING ANALYSIS

Vehicle queue lengths on intersection approaches in the study area were simulated using SimTraffic software. Figure 2 shows the approximate 95th percentile vehicle queues along US 20 study corridor based on the queueing results. Notable 95th percentile queues that are near or beyond the available storage capacity are summarized in Table 2. Queuing results for all study intersections within the study area are included in the SimTraffic reports in Appendix B. A summary of key queueing impacts is provided for each segment below.

[3] Bend Transportation System Plan, 2020, City of Bend

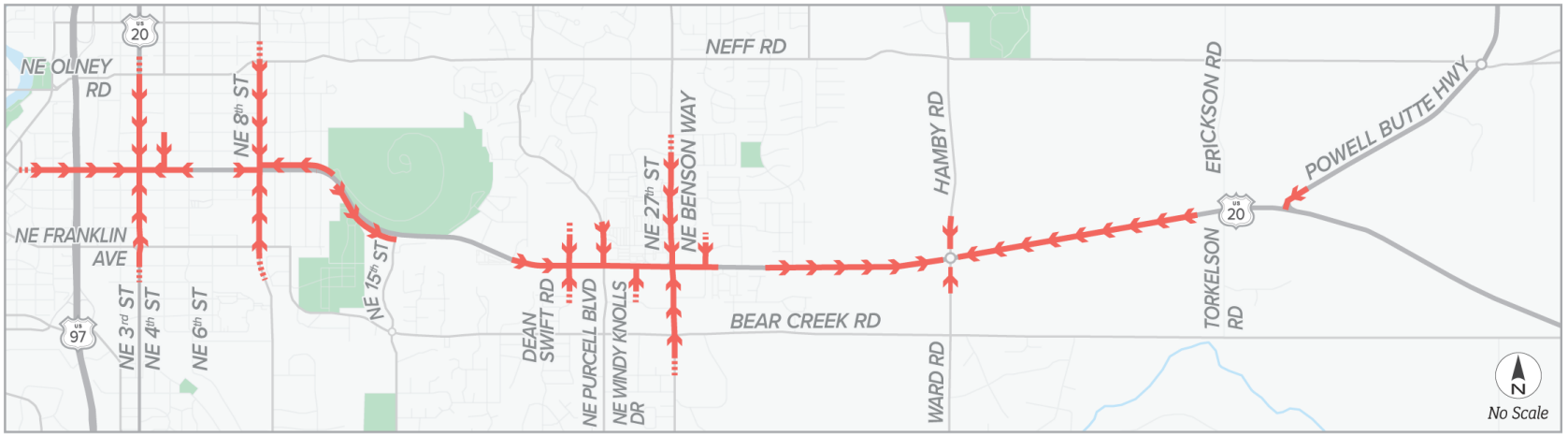

FIGURE 2. FUTURE (YEAR 2042) US 20 CORRIDOR VEHICLE QUEUES

TABLE 2. FUTURE (2042) DESIGN HOUR INTERSECTION VEHICLE QUEUEING SUMMARY

		95TH PERCENTILE QUEUE (FT)[B]	95TH PERCENTILE QUEUE (FT)	APPROXIMATE AVAILABLE STORAGE (FT)[C]
US 20 & 3RD ST	EBL	**200**	**200**	150
	EBTR	**1100**	**>2000**	300
	WBL	**375**	**400**	175 (TWLTL)
	WBTR	**750[D]**	**750[D]**	400
	NBL	**400**	**400**	125 (TWLTL)
	NBTR	**>1400**	**>1400**	325
	SBL	**350**	**350**	175 (TWLTL)
	SBTR	**550**	**>1700**	300
US 20 & 4TH ST	SBR	125	375	375
US 20 & 8TH ST	EBL	**350**	**350**	125 (TWLTL)
	EBTR	**>825**	**625**	400
	WBL	**350**	**350**	125 (TWLTL)
	WBTR	**700**	**>900**	275
	NBL	**300**	**300**	175
	NBTR	**>1400**	**>1400**	300
	SBL	**375**	**375**	150 (TWLTL)
	SBTR	**>1800**	**>1800**	325
US 20 & 15TH ST	EBT	750	1800	1975
	EBR	**300**	**300**	200
US 20 & DEAN SWIFT RD	NBR	150	**>800**	575
	SBLTR	>450	**>525**	500
US 20 & PURCELL BLVD	EBL	**375**	**375**	150 (TWLTL)
	WBL	**350**	**350**	100 (TWLTL)
	WBTR	**800[E]**	**625[E]**	550
	SBTR	325	**675**	450
US 20 & NE WINDY KNOLLS DR	NBLR	200	**>600**	625

INTERSECTION	MOVEMENT[A]	EXISTING (2022)	FUTURE (2042)	APPROXIMATE AVAILABLE STORAGE (FT)[C]
		95TH PERCENTILE QUEUE (FT)[B]	95TH PERCENTILE QUEUE (FT)	
US 20 & 27TH ST	EBL	**350**	**350**	150 (TWLTL)
	EBTR	**575[F]**	**3450[G]**	375
	WBL	**375**	**550**	150 (TWLTL)
	WBTR	450	**600**	550
	NBL	**300**	**300**	275
	NBTR	**300**	**>1500**	570
	SBL	**425**	**425**	200
	SBT	**>1400**	**>1900**	425
	SBR	**325**	**325**	200
US 20 & BENSON WAY	SBLTR	125	300	300
US 20 & HAMBY RD	EBLTR	800	3550	3875
	WBLTR	475	5200	5500
	NBLTR	75	625	3600
	SBLTR	100	425	1500
US 20 & POWELL BUTTE RD	SBR	**125**	**125**	100

Bold and red queue exceeds approximate available storage, TWLTL=Two Way Left Turn Lane

[A] EB = Eastbound, WB = Westbound, NB = Northbound, SB = Southbound, L = Left, T = Through, R = Right

[B] Notable queue within 50 feet or intersection failed in operational analysis

[C] Available storage reported as approximate turn bay length or approximate distance to the nearest intersection.

[D] Included WBTR queue at 4th Street

[E] Included WBT queue at Windy Knolls Drive

[F] Included EBT queue at Windy Knolls Drive

[G] Included EBTR queue at Dean Swift Road, EBTR queue at Purcell Boulevard, and EBT queue at Windy Knolls Drive

As shown in Figure 2 and presented in Table 2, there are significant queues throughout the study corridor during the design hour in the future, including:

- **Segment 1 (NE 3rd Street to NE 15th Street):**
  - At 3rd Street, eastbound queues extend well beyond the intersection at NW Hill Street, westbound queues spill back to NE 4th Street, southbound queues spill back beyond NE Olney Avenue, and northbound queues spill back well beyond NE Franklin Avenue. Note that the City of Bend is currently pursuing implementation of a lane reallocation on Greenwood Avenue west of NE 3rd Street as a pilot program, which is not included in this analysis.
  - Side streets at NE 4th Street only allow right-in and right-out movements but some southbound queues occur due to queue spillback from the signal at NE 3rd Street during the design hour.
  - At NE 8th Street, eastbound queues spill back to NE 7th Street, westbound queues extend well beyond NE 12th Street, southbound queues spill beyond NE Olney Avenue, and northbound queues extend well beyond NE Franklin Avenue.
  - At NE 15th Street, although the queue does not extend to the next intersection at NE 12th Street, the eastbound queue is greater than 1,500 feet and queues back within 200 feet of 12th Street.
- **Segment 2 (NE 15th Street to NE Providence Drive/NE Benson Way):**
  - Significant eastbound queues occur in this segment, with the eastbound queue at NE 27th Street spilling back beyond Dean Swift Road.
  - At NE 27th Street, westbound queues spill back to NE Benson Way, northbound queues spill back through Bear Creek Road, and southbound queues extend beyond NE Forum Drive.
  - At NE Benson Way, the intersection operates over capacity with long side street delays and queues. This could result in drivers accepting less safe gaps in traffic to turn onto US 20.
  - At Dean Swift Road, extensive queues occur on the northbound and southbound approaches. The side street approaches are significantly over capacity and there are limited opportunities to turn onto US 20 given the high eastbound and westbound volumes and queue spillback from nearby traffic signals.
  - At NE Purcell Boulevard, northbound queues extend beyond NE Twin Knolls Drive, as the northbound left turn is significantly over capacity and spills back into the through lane.
- **Segment 3 (NE Providence Drive/NE Benson Way to Powell Butte Highway):**
  - The queues that occur at the Hamby Road/Ward Road roundabout do not spill back to the next intersection, but multiple legs of the intersection are expected to operate well over capacity, resulting in long eastbound and westbound queues (greater than 3,500 feet).
  - Limited queuing occurs at Erickson Road/Torkelson Road and Powell Butte Highway, with southbound right turns occasionally backing up beyond the striped storage at Powell Butte Highway.

Note that future queues for the eastbound through movement at NE 8th Street and westbound through movement at Purcell Boulevard were slightly shorter compared to the existing queues. This is due in large part to the congestion at NE 3rd Street and NE 27th Street in the future, which meters the ability of vehicles to proceed to NE 8th Street and NE Purcell Boulevard.

CORRIDOR TRAVEL TIMES

In addition to queueing results, travel times along the US 20 corridor were obtained from SimTraffic and compared to the travel times modeled in SimTraffic under existing conditions. As shown in Table 3, travel times under future conditions are higher compared to the existing conditions, especially in Segments 2 and 3. In Segment 2, the eastbound travel time nearly doubles, which is primarily a result of congestion at NE 27th Street. In Segment 3, travel time increases in both directions are even worse because of congestion at the Hamby Road/Ward Road roundabout, with a trip taking five to six minutes longer than under existing conditions.

TABLE 3. US 20 TRAVEL TIME COMPARISONS

SEGMENT	TRAVEL TIME (MINUTES)					
	EASTBOUND			WESTBOUND		
	EXISTING	FUTURE	DIFFERENCE (SEC/%)	EXISTING	FUTURE	DIFFERENCE (SEC/%)
1	3.4	4.3	55 /27	3.3	3.6	16 /8
2	3.3	6.3	183 /92	3.3	4.2	54 /28
3	3.5	9.5	358 /170	3.0	8.1	304 /169

Note that this level of congestion will likely cause additional diversion to parallel local routes such as Bear Creek Road, which is a Key Walking and Biking Route. Based on outputs from the regional travel demand model, traffic volumes on Bear Creek Road are expected to more than double over the next 20 years between NE 8th Street and NE 27th Street as congestion on US 20 increases and as more development occurs in eastern Bend.

IMPACT OF FUTURE TECHNOLOGIES

The introduction of connected and autonomous vehicles (CAVs) for public use brings great promise for safer and more efficient transportation alternatives than is available today. There are a few interesting facets of this technology that may have implications for the US 20 study corridor, including:

- The impact of a mixed CAV and non-CAV environment on congestion and safety as CAVs are gradually introduced into the fleet.
- How established use of CAVs could influence changes in travel choices.
- Technology needs to support safe interaction between CAVs and vulnerable road users (e.g., people walking, biking, and using micromobility) and to address challenges created by inclement weather.
- Each of these issues are discussed in further detail below.

CAV TO NON-CAV INTERACTION

The intersection of new CAV technology with human driving behavior is a complex area of study. There remain many questions about how the general public will respond to technology-based information in their own vehicles and how they might interact with non-CAV drivers in the adjacent travel lanes. Early theoretical predictions claimed major upgrades in throughput with CAV technology, as much as double existing capacity. A recent study[4] by Texas Transportation Institute (TTI) of the I-35 Corridor in Austin, however, showed much different results. TTI's model simulations of that 12-mile highly congested urban freeway corridor evaluated freeway throughput per lane, volumes, and overall travel speeds related to increasing proportions of CAVs in the vehicle mix. The authors demonstrated a major degradation of mobility, in terms of throughput, speeds, and safety as CAVs were added to the vehicle mix due to interactions between CAVs and non-CAVs. In fact, the higher the CAV share, the lower the travel speeds and freeway throughput, and greater the travel times became, which is a counter-intuitive outcome.

One of the major performance factors in the mixed vehicle environment is associated with the friction created between CAVs and non-CAVs in the pursuit of traffic harmonization. When a CAV communicates to other CAVs of upcoming traffic, the CAVs respond accordingly but the non-CAVs may or may not. This tends to exacerbate the existing bottlenecks and be more problematic because of increased lane changing as non CAVs navigate around CAVs that are obeying the rules of the road. These types of behaviors not only impact congestion but tend to degrade the expected safety benefits of traffic harmonization.

LONGER TERM IMPLICATIONS TO TRAVEL CHOICES

Another aspect of CAV evolution that is relevant to the US 20 corridor is a broader effect on community travel choices and auto ownership, which is based on not just CAV technologies, but more about the convergence of CAVs with Shared and Electric vehicle adoption. This convergence is often referred to as Autonomous, Connected, Electric, and Shared (ACES) vehicle evolution. As the CAV market penetration rises, the availability of Transport as a Service (TaaS) may introduce a fundamental shift in how current transport choices are made. As the cost of drivers is removed from the business equation, the concept is that Transportation Network Carrier (TNC) type activities, like Uber and Lyft, will grow exponentially by offering transportation at a fraction of the current cost per trip. Early estimates by the ReThinkX research group[5] are that TaaS will offer vastly lower cost transport alternatives, as much as four to ten times cheaper per mile than buying a new car and two to four times cheaper than operating an existing vehicle. In addition, they predicted that switching from internal combustion engine vehicles to all electric powered for TaaS

[4] Impacts Of Connected Vehicles In A Complex, Congested Urban Freeway Setting Using Multi-Resolution Modeling Methods, International Journal of Transportation Science and Technology, Volume 8, Issue 1, March 2019,

[5] RethinkX, Rethinking Transportation Choices 2020-2030, 2017. https://bit.ly/2AeAxJR

could dramatically increase vehicle-utilization rates, which could reduce the total number of vehicles on the system.

If these predictions are realized in the greater Bend area, this will fundamentally change how people travel around the city, including how they use the US 20 corridor. Behavioral issues such as love of driving, fear of new technology, or habit may pose initial barriers to consumer uptake. The side effects of this type of change are much higher vehicle-miles traveled (VMT) per vehicle (at least 10 times more than individually owned cars), lower auto ownership, and lower travel costs. Reductions in auto ownership and usage will drive down gas tax revenues for state and local agencies (a problem that is already being exacerbated by the migration to Electric Vehicles that is happening at a much faster rate than CAVs).

The same ReThinkX study cited above estimated that TaaS will provide 95 percent of passenger miles traveled within 10 years of widespread regulatory approval of CAVs. Overall, the travel behavior trends for CAV fleet penetration vary widely across different studies, and for the purposes of US 20, are not well enough understood to provide input into future performance measures or suggest significant recommended design modifications, other than the technology enhancements described in the following section.

CAV INTERACTION WITH INTERSECTION CONTROL, VULNERABLE ROAD USERS, WEATHER IMPACTS, AND TECHNOLOGY ENHANCEMENTS

A few aspects regarding the transportation system and network within the study area need to be considered to implement the technology: intersection control, vulnerable road users (VRUs), and weather. Traffic signals provide opportunities for CAVs to perform Vehicle-to-Infrastructure communication and support the CAV movement. Depending on the volume of VRUs, passive detections need to be installed for the transportation network to fully detect VRUs and communicate with CAVs that these users are present.

There are five signalized intersections and one Rectangular Rapid-Flashing Beacon (RRFB) along the US 20 study corridor, which help provide communication opportunities. According to the turning movement counts, 75 people walking were reported crossing along Segment 1 (from 3rd Street to 15th Street), 76 people walking were reported crossing along Segment 2 (from 15th Street to Providence Drive), and none were reported crossing east of Providence Drive (Segment 3). A passive detection system is needed along Segments 1 and 2 given the high volume of people walking and should be considered in Segment 3 as more safe crossing opportunities are provided and pedestrian volumes increase. Winters in the City of Bend are very cold, snowy, and partly cloudy. Snow will potentially cover the ground and affect the ability of CAVs to detect pavement markings.

Weather conditions, particularly, rain, snow, and ice, bring negative impacts to the CAV system as detection will be obstructed and the reliance on video camera technology in the CAVs is a limiting factor on the safety of these systems. More robust Infrastructure-to-Vehicle systems, connected with other detection technologies, digital information about lane striping, signage, and other traditional infrastructure, can all help mitigate some of these issues.

ODOT is working towards providing infrastructure to support this type of technology with upgraded traffic signal controllers and smarter detection. Region 4 currently has the fewest upgraded intersections to support this technology. The cost to begin implementing this is approximately:

- Upgraded Controller = $2,500 per intersection
- Upgraded Detection = $30,000 per intersection
- Where needed, Communication Upgrades = $10,000 per intersection

This effort would go with improving signal operations which may be a recommended alternative.

CONDITIONS FOR PEOPLE WALKING, BIKING, AND TAKING TRANSIT

Technical Memorandum #2: Existing Transportation System Conditions documents in detail the existing conditions for people walking, biking and taking transit. That memorandum includes a discussion of Key Walking and Biking Routes in the area as well as bicycle low stress network crossing locations of US 20, a Level of Traffic Stress (LTS) analysis, a discussion of pedestrian crossing needs and discussion of current transit. Given that, this memorandum discusses any planned future changes in the area that might influence conditions for people walking, biking and taking transit.

PLANNED WALKING AND BIKING IMPROVEMENTS

As discussed in *Technical Memorandum #2: Existing Transportation System Conditions*, there are nine marked pedestrian crossing opportunities in the study area, eight of which are within the urban area of Bend. The average distance between a transit stop and the nearest marked pedestrian crossings is 112 feet and bus stop pairs are predominately associated with marked crossings except between NE 15th Street and NE Purcell Boulevard. While the City of Bend maintains an extensive bicycle network throughout the urbanized area, including parallel low stress bicycle routes along portions of the local streets, facilities along US 20 are high stress, with a level of traffic stress (LTS) of 3 or 4. US 20 is identified as part of the low stress bicycle network between NE 11th Street and Larkspur Trail, however, improvements will be needed within the study area to reduce the LTS and address the project's goals.

The first goal in the City's TSP is to increase system capacity, quality, and connectivity for all users. In particular, policies are included in the TSP to improve safety and usability of facilities for people walking and biking and for micromobility. Policy 40 from the City's TSP mentions all streets should be "complete streets" to allow everyone to travel safely and comfortably along and across the street by all travel modes. The transportation system is intended to increase connectivity, safety, and travel time reliability while encouraging walking, biking, and opportunities for using transit and other transportation options. In addition, Policy 59 states the City will consider the environmental impacts of the overall transportation system and act to mitigate negative effects and enhance positive features. The intention of the policy is to reduce greenhouse gases and VMT by encouraging bicycling, walking, transit, and electric or other alternatively fueled vehicles. The City's TSP focuses on improving multimodal facilities and adding micromobility options to encourage more people to walk and bike. The increase in congestion and the reductions in parking for new

development are likely to further increase the number of people walking and biking. To implement these goals and policies within the study area, improvements will be needed to the active transportation facilities along US 20 and will be identified as part of this Facility Plan, including opportunities for micro-mobility.

Bend's TSP lists several planned projects to improve conditions for people walking and bicycling in the future across US 20 and along parallel routes. Specifically, within the study area, the mid-term improvement project at US 20 and NE 8th Street (C-30) will enhance connectivity for people walking and biking. Parallel to US 20, there are several projects along the planned Key Walking and Biking Route on Bear Creek Road. These projects will close sidewalk gaps and create a connection between Coyner and Larkspur Trails (R2-D), close sidewalk gaps between Cessna Avenue and the east Bend urban growth boundary and create a low stress bikeway extending to 170 new affordable housing units (R2-E). While there are several planned improvements in the area (as listed above), the improvements are primarily focused on parallel routes to US 20 or at a singular intersection. In general, LTS will still be high along the US 20 study corridor without additional improvements (to be identified through this Facility Plan).

PLANNED TRANSIT IMPROVEMENTS

Regarding transit conditions, there is one route (Route 7: Greenwood) currently operating within the study area. The Cascades East Transit (CET) 2040 Transit Master Plan (TMP)[6] identifies several future transit service needs in Bend, including increasing route frequency and service coverage, improving bus on-time arrival and reliability, enhancing services to transit-underserved areas, expanding connections to other transportation modes, and expanding accessibility. US 20/Greenwood Avenue and NE 3rd Street are both identified as primary transit corridors that could eventually support high-capacity transit in Bend, connecting several key mobility hubs at Central Oregon Community College, Downtown, Hawthorne Station and in East Bend near 27th Street. Future mobility hubs could also be located near Forum Shopping Center which is bordered by US 20 and 27th Street.

The TMP also identifies the following routes changes within the study area:

- Extension of Route 7 services to serve downtown by travelling along Bond Street and Wall Street.
- Elimination of Route 10 and extend Route 7 farther along Bond Street to Colorado Avenue to serve the Oregon State University Cascades Campus.

While there are not currently transit stops east of 27th Street, there is a desire to connect people taking transit to key destinations on the east side of 27th Street, such as Walgreens. A planned housing development in that area has also reserved space for a future transit stop along US 20 east of 27th Street. Options for enhanced transit stops or micromobility enhancements along US 20 will be identified in the Facility Plan.

[6] Cascades East Transit 2040 Transit Master Plan, Cascades East Transit, August 2020.

APPENDIX A: HCM REPORT

Intersection	
Int Delay, s/veh	4.1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	50	1295	20	65	980	130	0	0	210	0	0	220
Future Vol, veh/h	50	1295	20	65	980	130	0	0	210	0	0	220
Conflicting Peds, #/hr	1	0	1	1	0	1	2	0	0	0	0	2
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	50	-	-	100	-	-	-	-	0	-	-	0
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	93	93	93	93	93	93	93	93	93	93	93	93
Heavy Vehicles, %	0	1	5	2	1	0	0	0	1	0	0	0
Mvmt Flow	54	1392	22	70	1054	140	0	0	226	0	0	237

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	1195	0	0	1415	0	0	-	-	708	-	-	600
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy	4.1	-	-	4.14	-	-	-	-	6.92	-	-	6.9
Critical Hdwy Stg 1	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy Stg 2	-	-	-	-	-	-	-	-	-	-	-	-
Follow-up Hdwy	2.2	-	-	2.22	-	-	-	-	3.31	-	-	3.3
Pot Cap-1 Maneuver	591	-	-	478	-	-	0	0	379	0	0	449
Stage 1	-	-	-	-	-	-	0	0	-	0	0	-
Stage 2	-	-	-	-	-	-	0	0	-	0	0	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	590	-	-	478	-	-	-	-	379	-	-	448
Mov Cap-2 Maneuver	-	-	-	-	-	-	-	-	-	-	-	-
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0.4	0.8	27.6	21.7
HCM LOS			D	C

Minor Lane/Major Mvmt	NBLn1	EBL	EBT	EBR	WBL	WBT	WBR	SBLn1
Capacity (veh/h)	379	590	-	-	478	-	-	448
HCM Lane V/C Ratio	0.596	0.091	-	-	0.146	-	-	0.528
HCM Control Delay (s)	27.6	11.7	-	-	13.8	-	-	21.7
HCM Lane LOS	D	B	-	-	B	-	-	C
HCM 95th %tile Q(veh)	3.7	0.3	-	-	0.5	-	-	3

Intersection	
Int Delay, s/veh	0.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	1490	15	0	1120	25	0	0	30	0	0	55
Future Vol, veh/h	0	1490	15	0	1120	25	0	0	30	0	0	55
Conflicting Peds, #/hr	1	0	5	5	0	1	4	0	0	0	0	4
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	-	-	0	-	-	0
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	93	93	93	93	93	93	93	93	93	93	93	93
Heavy Vehicles, %	0	1	0	0	1	0	0	0	0	0	0	0
Mvmt Flow	0	1602	16	0	1204	27	0	0	32	0	0	59

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	-	0	0	-	-	0	-	-	814	-	-	621
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy	-	-	-	-	-	-	-	-	6.9	-	-	6.9
Critical Hdwy Stg 1	-	-	-	-	-	-	-	-	-	-	-	-
Critical Hdwy Stg 2	-	-	-	-	-	-	-	-	-	-	-	-
Follow-up Hdwy	-	-	-	-	-	-	-	-	3.3	-	-	3.3
Pot Cap-1 Maneuver	0	-	-	0	-	-	0	0	325	0	0	435
Stage 1	0	-	-	0	-	-	0	0	-	0	0	-
Stage 2	0	-	-	0	-	-	0	0	-	0	0	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	-	-	-	-	-	-	-	-	323	-	-	433
Mov Cap-2 Maneuver	-	-	-	-	-	-	-	-	-	-	-	-
Stage 1	-	-	-	-	-	-	-	-	-	-	-	-
Stage 2	-	-	-	-	-	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0	0	17.4	14.6
HCM LOS			C	B

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBT	WBR	SBLn1
Capacity (veh/h)	323	-	-	-	-	433
HCM Lane V/C Ratio	0.1	-	-	-	-	0.137
HCM Control Delay (s)	17.4	-	-	-	-	14.6
HCM Lane LOS	C	-	-	-	-	B
HCM 95th %tile Q(veh)	0.3	-	-	-	-	0.5

Intersection	
Int Delay, s/veh	334

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	70	1680	80	105	1345	95	0	0	145	25	5	125
Future Vol, veh/h	70	1680	80	105	1345	95	0	0	145	25	5	125
Conflicting Peds, #/hr	4	0	4	4	0	4	1	0	2	2	0	1
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	100	-	-	-	-	0	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	1	0	0	1	0	0	0	0	0	0	0
Mvmt Flow	76	1826	87	114	1462	103	0	0	158	27	5	136

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	1569	0	0	1917	0	0	-	-	963	2813	3815	788
Stage 1	-	-	-	-	-	-	-	-	-	1746	1746	-
Stage 2	-	-	-	-	-	-	-	-	-	1067	2069	-
Critical Hdwy	4.14	-	-	4.1	-	-	-	-	6.9	7.5	6.5	6.9
Critical Hdwy Stg 1	-	-	-	-	-	-	-	-	-	6.5	5.5	-
Critical Hdwy Stg 2	-	-	-	-	-	-	-	-	-	6.5	5.5	-
Follow-up Hdwy	2.22	-	-	2.2	-	-	-	-	3.3	3.5	4	3.3
Pot Cap-1 Maneuver	417	-	-	313	-	-	0	0	259	~ 9	~ 4	338
Stage 1	-	-	-	-	-	-	0	0	-	91	142	-
Stage 2	-	-	-	-	-	-	0	0	-	241	97	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	415	-	-	312	-	-	-	-	258	~ 2	~ 2	336
Mov Cap-2 Maneuver	-	-	-	-	-	-	-	-	-	~ 2	~ 2	-
Stage 1	-	-	-	-	-	-	-	-	-	74	90	-
Stage 2	-	-	-	-	-	-	-	-	-	76	79	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0.6	1.6	38.6	$ 7860.6
HCM LOS			E	F

Minor Lane/Major Mvmt	NBLn1	EBL	EBT	EBR	WBL	WBT	WBR	SBLn1
Capacity (veh/h)	258	415	-	-	312	-	-	10
HCM Lane V/C Ratio	0.611	0.183	-	-	0.366	-	-	16.848
HCM Control Delay (s)	38.6	15.6	-	-	23	-	-	$ 7860.6
HCM Lane LOS	E	C	-	-	C	-	-	F
HCM 95th %tile Q(veh)	3.6	0.7	-	-	1.6	-	-	22.6

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Intersection	
Int Delay, s/veh	4.3

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	1635	65	105	1440	40	95
Future Vol, veh/h	1635	65	105	1440	40	95
Conflicting Peds, #/hr	0	5	5	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	100	100	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	95	95	95	95	95	95
Heavy Vehicles, %	1	0	0	1	0	1
Mvmt Flow	1721	68	111	1516	42	100

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	1794	0	2706	866
Stage 1	-	-	-	-	1726	-
Stage 2	-	-	-	-	980	-
Critical Hdwy	-	-	4.1	-	6.8	6.92
Critical Hdwy Stg 1	-	-	-	-	5.8	-
Critical Hdwy Stg 2	-	-	-	-	5.8	-
Follow-up Hdwy	-	-	2.2	-	3.5	3.31
Pot Cap-1 Maneuver	-	-	349	-	~ 18	299
Stage 1	-	-	-	-	132	-
Stage 2	-	-	-	-	329	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	347	-	~ 12	298
Mov Cap-2 Maneuver	-	-	-	-	81	-
Stage 1	-	-	-	-	131	-
Stage 2	-	-	-	-	224	-

Approach	EB	WB	NB
HCM Control Delay, s	0	1.4	91.3
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	166	-	-	347	-
HCM Lane V/C Ratio	0.856	-	-	0.319	-
HCM Control Delay (s)	91.3	-	-	20.1	-
HCM Lane LOS	F	-	-	C	-
HCM 95th %tile Q(veh)	6	-	-	1.3	-

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Intersection	
Int Delay, s/veh	23.2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	90	915	115	35	685	30	35	5	100	30	5	105
Future Vol, veh/h	90	915	115	35	685	30	35	5	100	30	5	105
Conflicting Peds, #/hr	1	0	12	12	0	1	1	0	1	1	0	1
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	50	-	-	75	-	-	-	-	-	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	94	94	94	94	94	94	94	94	94	94	94	94
Heavy Vehicles, %	0	1	0	0	2	0	0	0	0	0	0	0
Mvmt Flow	96	973	122	37	729	32	37	5	106	32	5	112

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	762	0	0	1107	0	0	1680	2074	561	1502	2119	383
Stage 1	-	-	-	-	-	-	1238	1238	-	820	820	-
Stage 2	-	-	-	-	-	-	442	836	-	682	1299	-
Critical Hdwy	4.1	-	-	4.1	-	-	7.5	6.5	6.9	7.5	6.5	6.9
Critical Hdwy Stg 1	-	-	-	-	-	-	6.5	5.5	-	6.5	5.5	-
Critical Hdwy Stg 2	-	-	-	-	-	-	6.5	5.5	-	6.5	5.5	-
Follow-up Hdwy	2.2	-	-	2.2	-	-	3.5	4	3.3	3.5	4	3.3
Pot Cap-1 Maneuver	859	-	-	638	-	-	63	54	476	86	51	621
Stage 1	-	-	-	-	-	-	189	250	-	340	392	-
Stage 2	-	-	-	-	-	-	570	385	-	411	234	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	858	-	-	631	-	-	40	45	470	53	42	620
Mov Cap-2 Maneuver	-	-	-	-	-	-	40	45	-	53	42	-
Stage 1	-	-	-	-	-	-	166	220	-	302	368	-
Stage 2	-	-	-	-	-	-	433	362	-	275	205	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0.8	0.5	243.5	103.2
HCM LOS			F	F

Minor Lane/Major Mvmt	NBLn1	EBL	EBT	EBR	WBL	WBT	WBR	SBLn1
Capacity (veh/h)	117	858	-	-	631	-	-	164
HCM Lane V/C Ratio	1.273	0.112	-	-	0.059	-	-	0.908
HCM Control Delay (s)	243.5	9.7	-	-	11.1	-	-	103.2
HCM Lane LOS	F	A	-	-	B	-	-	F
HCM 95th %tile Q(veh)	9.7	0.4	-	-	0.2	-	-	6.6

Intersection	
Int Delay, s/veh	5.9

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	40	730	5	15	630	35	25	5	15	20	15	40
Future Vol, veh/h	40	730	5	15	630	35	25	5	15	20	15	40
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	68	-	-	93	-	-	-	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	0	2	0	12	3	0	0	0	0	0	0	0
Mvmt Flow	43	793	5	16	685	38	27	5	16	22	16	43

Major/Minor	Major1			Major2			Minor1			Minor2		
Conflicting Flow All	723	0	0	798	0	0	1645	1634	793	1609	1601	685
Stage 1	-	-	-	-	-	-	879	879	-	717	717	-
Stage 2	-	-	-	-	-	-	766	755	-	892	884	-
Critical Hdwy	4.1	-	-	4.22	-	-	7.1	6.5	6.2	7.1	6.5	6.2
Critical Hdwy Stg 1	-	-	-	-	-	-	6.1	5.5	-	6.1	5.5	-
Critical Hdwy Stg 2	-	-	-	-	-	-	6.1	5.5	-	6.1	5.5	-
Follow-up Hdwy	2.2	-	-	2.308	-	-	3.5	4	3.3	3.5	4	3.3
Pot Cap-1 Maneuver	889	-	-	782	-	-	80	102	392	85	107	452
Stage 1	-	-	-	-	-	-	345	368	-	424	437	-
Stage 2	-	-	-	-	-	-	398	420	-	339	366	-
Platoon blocked, %		-	-		-	-						
Mov Cap-1 Maneuver	889	-	-	782	-	-	57	90	392	71	94	452
Mov Cap-2 Maneuver	-	-	-	-	-	-	57	90	-	71	94	-
Stage 1	-	-	-	-	-	-	315	336	-	387	422	-
Stage 2	-	-	-	-	-	-	334	406	-	292	334	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	0.5	0.2	93.6	60
HCM LOS			F	F

Minor Lane/Major Mvmt	NBLn1	EBL	EBT	EBR	WBL	WBT	WBR	SBLn1
Capacity (veh/h)	85	889	-	-	782	-	-	142
HCM Lane V/C Ratio	0.575	0.049	-	-	0.021	-	-	0.574
HCM Control Delay (s)	93.6	9.3	0	-	9.7	0	-	60
HCM Lane LOS	F	A	A	-	A	A	-	F
HCM 95th %tile Q(veh)	2.6	0.2	-	-	0.1	-	-	2.9

Intersection	
Int Delay, s/veh	8.2

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Vol, veh/h	435	330	245	15	5	440
Future Vol, veh/h	435	330	245	15	5	440
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	Free	-	None
Storage Length	220	-	-	140	0	80
Veh in Median Storage, #	-	0	0	-	0	-
Grade, %	-	0	0	-	0	-
Peak Hour Factor	91	91	91	91	91	91
Heavy Vehicles, %	0	3	9	11	25	1
Mvmt Flow	478	363	269	16	5	484

Major/Minor	Major1		Major2		Minor2	
Conflicting Flow All	269	0	-	0	1588	269
Stage 1	-	-	-	-	269	-
Stage 2	-	-	-	-	1319	-
Critical Hdwy	4.1	-	-	-	6.65	6.21
Critical Hdwy Stg 1	-	-	-	-	5.65	-
Critical Hdwy Stg 2	-	-	-	-	5.65	-
Follow-up Hdwy	2.2	-	-	-	3.725	3.309
Pot Cap-1 Maneuver	1306	-	-	0	105	772
Stage 1	-	-	-	0	726	-
Stage 2	-	-	-	0	224	-
Platoon blocked, %			-	-		
Mov Cap-1 Maneuver	1306	-	-	-	67	772
Mov Cap-2 Maneuver	-	-	-	-	67	-
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	224	-

Approach	EB	WB	SB
HCM Control Delay, s	5.3	0	17.6
HCM LOS			C

Minor Lane/Major Mvmt	EBL	EBT	WBT	SBLn1	SBLn2
Capacity (veh/h)	1306	-	-	67	772
HCM Lane V/C Ratio	0.366	-	-	0.082	0.626
HCM Control Delay (s)	9.3	-	-	63.5	17.1
HCM Lane LOS	A	-	-	F	C
HCM 95th %tile Q(veh)	1.7	-	-	0.3	4.5

APPENDIX B: SIMTRAFFIC REPORT

Summary of All Intervals

Run Number	1	2	4	5	6	8	9
Start Time	4:15	4:15	4:15	4:15	4:15	4:15	4:15
End Time	5:25	5:25	5:25	5:25	5:25	5:25	5:25
Total Time (min)	70	70	70	70	70	70	70
Time Recorded (min)	60	60	60	60	60	60	60
# of Intervals	3	3	3	3	3	3	3
# of Recorded Intervals	2	2	2	2	2	2	2
Vehs Entered	12427	12336	12353	12212	12172	12119	12137
Vehs Exited	11533	11608	11560	11558	11376	11398	11429
Starting Vehs	1061	1047	1150	1097	1199	1167	1158
Ending Vehs	1955	1775	1943	1751	1995	1888	1866
Travel Distance (mi)	13646	13689	13669	13578	13483	13493	13411
Travel Time (hr)	2588.0	2584.5	2759.5	2697.9	2772.0	2689.3	2669.8
Total Delay (hr)	2169.5	2166.3	2339.7	2281.2	2356.6	2274.7	2258.3
Total Stops	38313	36654	35412	35212	37416	36180	35979
Fuel Used (gal)	939.6	941.8	979.1	964.9	975.2	958.0	953.4

Summary of All Intervals

Run Number	10	Avg
Start Time	4:15	4:15
End Time	5:25	5:25
Total Time (min)	70	70
Time Recorded (min)	60	60
# of Intervals	3	3
# of Recorded Intervals	2	2
Vehs Entered	12208	12243
Vehs Exited	11511	11498
Starting Vehs	1037	1106
Ending Vehs	1734	1858
Travel Distance (mi)	13484	13556
Travel Time (hr)	2573.0	2666.8
Total Delay (hr)	2158.9	2250.6
Total Stops	33814	36124
Fuel Used (gal)	936.5	956.1

Interval #0 Information Seeding

Start Time	4:15
End Time	4:25
Total Time (min)	10

Volumes adjusted by PHF, Growth Factors.

No data recorded this interval.

Interval #1 Information Recording1

Start Time	4:25
End Time	4:40
Total Time (min)	15

Volumes adjusted by PHF, Growth Factors.

Run Number	1	2	4	5	6	8	9
Vehs Entered	3492	3535	3481	3467	3368	3435	3351
Vehs Exited	2941	2970	2965	2963	2904	2945	2927
Starting Vehs	1061	1047	1150	1097	1199	1167	1158
Ending Vehs	1612	1612	1666	1601	1663	1657	1582
Travel Distance (mi)	3599	3615	3554	3553	3526	3588	3456
Travel Time (hr)	378.9	380.2	428.0	392.7	409.7	396.8	399.9
Total Delay (hr)	268.5	270.2	319.1	283.7	301.8	287.0	294.1
Total Stops	9130	9527	9046	8667	9394	9189	8389
Fuel Used (gal)	178.4	180.1	190.1	181.2	183.7	183.0	180.5

Interval #1 Information Recording1

Start Time	4:25
End Time	4:40
Total Time (min)	15

Volumes adjusted by PHF, Growth Factors.

Run Number	10	Avg
Vehs Entered	3460	3446
Vehs Exited	2983	2947
Starting Vehs	1037	1106
Ending Vehs	1514	1603
Travel Distance (mi)	3575	3558
Travel Time (hr)	361.3	393.4
Total Delay (hr)	251.8	284.5
Total Stops	8282	8946
Fuel Used (gal)	175.2	181.5

Interval #2 Information Recording2

Start Time	4:40
End Time	5:25
Total Time (min)	45

Volumes adjusted by Growth Factors, Anti PHF.

Run Number	1	2	4	5	6	8	9
Vehs Entered	8935	8801	8872	8745	8804	8684	8786
Vehs Exited	8592	8638	8595	8595	8472	8453	8502
Starting Vehs	1612	1612	1666	1601	1663	1657	1582
Ending Vehs	1955	1775	1943	1751	1995	1888	1866
Travel Distance (mi)	10047	10074	10114	10025	9957	9904	9954
Travel Time (hr)	2209.1	2204.3	2331.6	2305.2	2362.3	2292.5	2269.9
Total Delay (hr)	1901.0	1896.1	2020.6	1997.6	2054.8	1987.7	1964.2
Total Stops	29183	27127	26366	26545	28022	26991	27590
Fuel Used (gal)	761.2	761.8	789.0	783.7	791.5	775.0	772.9

Interval #2 Information Recording2

Start Time	4:40
End Time	5:25
Total Time (min)	45

Volumes adjusted by Growth Factors, Anti PHF.

Run Number	10	Avg
Vehs Entered	8748	8788
Vehs Exited	8528	8544
Starting Vehs	1514	1603
Ending Vehs	1734	1858
Travel Distance (mi)	9908	9998
Travel Time (hr)	2211.8	2273.3
Total Delay (hr)	1907.1	1966.1
Total Stops	25532	27176
Fuel Used (gal)	761.3	774.5

Arterial Level of Service: EB US 20

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
NE 3rd St	1	358.6	976.8	0.4	3
NE 4th Street	2	2.2	15.9	0.1	21
NE 6th Street	3	2.1	21.1	0.2	30
NE 8th St	4	45.9	63.2	0.2	10
	21	6.6	23.8	0.2	25
	109	1.0	5.1	0.0	28
SE 15th St	5	96.1	140.1	0.4	10
	111	10.5	34.7	0.2	24
Dean Swift Road	6	101.6	143.7	0.4	10
Purcell Blvd	7	83.9	96.7	0.1	5
NE Windy Knolls Dr	8	35.3	47.3	0.1	9
	16	25.3	31.5	0.1	6
SE 27th St	9	66.5	76.3	0.1	4
NE Bellevue Dr	10	6.0	18.4	0.1	23
	24	3.9	15.6	0.1	32
	119	3.5	10.1	0.1	29
Hamby Rd	11	416.6	461.7	0.7	5
Torkelson Rd	12	13.2	84.4	1.0	43
Powell Butte Rd	13	4.8	19.3	0.2	41
Total		1283.7	2285.7	4.7	10

Arterial Level of Service: WB US 20

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Powell Butte Rd	13	4.2	16.8	0.2	42
Erickson Road	12	9.2	23.8	0.2	34
Hamby Rd	11	488.3	551.3	1.0	7
	119	8.4	62.4	0.7	38
	24	1.0	7.5	0.1	39
NE Benson Way	10	4.9	19.2	0.1	26
NE 27th St	9	120.8	136.4	0.1	3
	16	5.4	14.2	0.1	22
NE Windy Knolls Dr	8	2.1	7.4	0.1	25
Purcell Blvd	7	35.7	47.5	0.1	9
Dean Swift Road	6	4.9	17.6	0.1	25
	111	5.4	47.5	0.4	31
	5	19.9	44.6	0.2	19
	109	15.2	54.8	0.4	25
	21	8.8	13.6	0.0	11
NE 8th St	4	55.7	73.6	0.2	8
NE 6th Street	3	4.4	22.3	0.2	27
NE 4th Street	2	14.3	32.3	0.2	19
NE 3rd St	1	67.0	79.5	0.1	4
Total		875.5	1272.2	4.5	13

Intersection: 1: NE 3rd St & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	185	2022	2021	325	454	462	325	1455	1460	325	1539	1510
Average Queue (ft)	183	1995	1991	285	388	418	298	1352	1348	323	1275	1241
95th Queue (ft)	191	2163	2172	389	484	508	389	1667	1665	335	1899	1876
Link Distance (ft)		1999	1999		406	406		1413	1413		1780	1780
Upstream Blk Time (%)		86	73		14	22		59	57		19	15
Queuing Penalty (veh)		0	0		85	135		0	0		0	0
Storage Bay Dist (ft)	160			300			300			300		
Storage Blk Time (%)	72	20		14	23		21	60		69	13	
Queuing Penalty (veh)	293	70		49	57		69	120		274	38	

Intersection: 2: NE 4th Street & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	SB
Directions Served	L	T	TR	L	T	TR	R	R
Maximum Queue (ft)	70	106	89	123	416	433	205	410
Average Queue (ft)	29	6	5	39	107	135	90	161
95th Queue (ft)	67	46	38	96	314	355	161	367
Link Distance (ft)		406	406		857	857	562	475
Upstream Blk Time (%)								3
Queuing Penalty (veh)								0
Storage Bay Dist (ft)	50			100				
Storage Blk Time (%)	7	0		0	9			
Queuing Penalty (veh)	44	0		0	6			

Intersection: 3: NE 6th Street & US 20

Movement	EB	EB	WB	WB	NB	SB
Directions Served	T	TR	T	TR	R	R
Maximum Queue (ft)	51	61	58	76	66	70
Average Queue (ft)	5	5	3	4	24	35
95th Queue (ft)	32	33	30	36	57	63
Link Distance (ft)	857	857	833	833	555	452
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 4: NE 8th St & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	NB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	TR	L	TR
Maximum Queue (ft)	325	604	614	325	810	825	250	1462	375	1940
Average Queue (ft)	152	385	409	303	596	586	129	1389	371	1796
95th Queue (ft)	331	606	626	383	981	979	305	1613	410	2300
Link Distance (ft)		833	833		816	816		1414		1885
Upstream Blk Time (%)		0	0		13	7		85		69
Queuing Penalty (veh)		1	2		97	53		0		0
Storage Bay Dist (ft)	300			300			225		350	
Storage Blk Time (%)	1	17		67	3		0	83	56	16
Queuing Penalty (veh)	4	25		335	8		0	50	278	55

Intersection: 5: SE 15th St & US 20

Movement	EB	EB	EB	B109	B109	WB	WB	WB	NB	NB
Directions Served	T	T	R	T	T	L	T	T	L	R
Maximum Queue (ft)	1430	1481	225	19	35	366	649	619	310	362
Average Queue (ft)	903	933	181	3	5	240	318	306	205	110
95th Queue (ft)	1770	1807	302	31	46	427	817	789	314	283
Link Distance (ft)	1972	1972		150	150		1183	1183		933
Upstream Blk Time (%)	1	2		0	0					
Queuing Penalty (veh)	13	22		0	1					
Storage Bay Dist (ft)			200			350			300	
Storage Blk Time (%)		43	1			26	0		3	
Queuing Penalty (veh)		135	5			172	0		6	

Intersection: 6: Dean Swift Road & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	SB
Directions Served	L	T	TR	L	T	TR	R	LTR
Maximum Queue (ft)	125	1615	1602	120	184	157	618	434
Average Queue (ft)	60	799	783	57	8	8	455	390
95th Queue (ft)	139	1982	1969	107	66	58	808	531
Link Distance (ft)		2099	2099		570	570	602	417
Upstream Blk Time (%)		1	1				59	79
Queuing Penalty (veh)		6	5				0	0
Storage Bay Dist (ft)	100			100				
Storage Blk Time (%)	0	41		4	0			
Queuing Penalty (veh)	3	28		24	0			

Intersection: 7: Purcell Blvd & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	TR	L	T	R
Maximum Queue (ft)	325	610	610	324	493	486	200	525	311	512	298
Average Queue (ft)	294	552	546	240	292	286	177	524	217	317	106
95th Queue (ft)	405	681	676	376	478	444	248	529	361	678	245
Link Distance (ft)		570	570		541	541		506		644	
Upstream Blk Time (%)		29	27		3	0		80		17	
Queuing Penalty (veh)		266	244		20	3		0		0	
Storage Bay Dist (ft)	300			300			175		290		290
Storage Blk Time (%)	8	49		18	4		25	63	23	4	0
Queuing Penalty (veh)	56	142		103	8		100	92	115	16	0

Intersection: 8: NE Windy Knolls Dr & US 20

Movement	EB	EB	EB	WB	WB	WB	NB
Directions Served	T	T	R	L	T	T	LR
Maximum Queue (ft)	568	584	125	123	176	146	552
Average Queue (ft)	421	355	11	61	30	15	366
95th Queue (ft)	719	695	68	118	138	97	705
Link Distance (ft)	541	541			213	213	600
Upstream Blk Time (%)	5	2			1	0	22
Queuing Penalty (veh)	42	17			10	2	0
Storage Bay Dist (ft)			100	100			
Storage Blk Time (%)		15	0	4	3		
Queuing Penalty (veh)		10	0	31	3		

Intersection: 9: SE 27th St/NE 27th St & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	T
Maximum Queue (ft)	305	429	400	474	565	544	300	1636	1628	335	1951	1953
Average Queue (ft)	301	394	352	377	426	385	299	1558	1545	267	1923	1922
95th Queue (ft)	331	420	434	560	606	525	300	1840	1860	432	2094	2101
Link Distance (ft)		368	368		547	547		1598	1598		1922	1922
Upstream Blk Time (%)		56	22		13	1		81	35		64	77
Queuing Penalty (veh)		416	164		54	3		0	0		0	0
Storage Bay Dist (ft)	280			450			275			310		
Storage Blk Time (%)	60	17		27	2		89	1		0	58	59
Queuing Penalty (veh)	206	79		69	4		315	4		2	112	233

Intersection: 9: SE 27th St/NE 27th St & US 20

Movement	SB
Directions Served	R
Maximum Queue (ft)	250
Average Queue (ft)	228
95th Queue (ft)	336
Link Distance (ft)	
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	225
Storage Blk Time (%)	3
Queuing Penalty (veh)	18

Intersection: 10: NE Bellevue Dr/NE Benson Way & US 20

Movement	EB	EB	EB	WB	WB	WB	NB	SB
Directions Served	L	T	TR	L	T	TR	LTR	LTR
Maximum Queue (ft)	60	36	30	80	161	109	293	229
Average Queue (ft)	24	2	1	19	36	16	138	112
95th Queue (ft)	54	22	13	60	164	101	377	304
Link Distance (ft)		547	547		674	674	476	472
Upstream Blk Time (%)							10	5
Queuing Penalty (veh)							0	0
Storage Bay Dist (ft)	50			75				
Storage Blk Time (%)	1	0		0	8			
Queuing Penalty (veh)	4	0		0	3			

Intersection: 11: Hamby Rd & US 20

Movement	EB	B119	WB	NB	SB
Directions Served	LTR	T	LTR	LTR	LTR
Maximum Queue (ft)	3046	124	4596	583	369
Average Queue (ft)	2166	15	3051	308	229
95th Queue (ft)	3553	128	5204	635	415
Link Distance (ft)	3396	372	5206	571	337
Upstream Blk Time (%)	6	0	1	13	25
Queuing Penalty (veh)	45	2	5	0	0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 12: Torkelson Rd/Erickson Road & US 20

Movement	EB	WB	WB	NB	SB
Directions Served	LT	LT	R	LTR	LTR
Maximum Queue (ft)	186	250	21	89	123
Average Queue (ft)	32	36	2	33	41
95th Queue (ft)	112	258	28	73	99
Link Distance (ft)	5206	1102		732	727
Upstream Blk Time (%)		0			
Queuing Penalty (veh)		1			
Storage Bay Dist (ft)			93		
Storage Blk Time (%)	2	3	0		
Queuing Penalty (veh)	0	1	0		

Intersection: 13: US 20 & Powell Butte Rd

Movement	EB	WB	SB	SB
Directions Served	L	T	L	R
Maximum Queue (ft)	144	26	313	105
Average Queue (ft)	62	1	82	91
95th Queue (ft)	114	12	243	120
Link Distance (ft)		973	1370	
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)	220			80
Storage Blk Time (%)	0		0	25
Queuing Penalty (veh)	0		0	1

Intersection: 16: US 20

Movement	EB	EB	EB	WB	WB	WB	NB	SB
Directions Served	L	T	TR	L	T	TR	LTR	R
Maximum Queue (ft)	124	278	273	71	187	129	458	317
Average Queue (ft)	86	231	170	25	13	7	428	119
95th Queue (ft)	154	296	317	60	88	75	499	267
Link Distance (ft)		213	213		368	368	430	733
Upstream Blk Time (%)		43	13			0	93	1
Queuing Penalty (veh)		373	112			1	0	0
Storage Bay Dist (ft)	100			50				
Storage Blk Time (%)	2	56		5	1			
Queuing Penalty (veh)	13	94		34	1			

Intersection: 21: US 20

Movement	EB	EB	WB	WB	B109	B109	NB	SB
Directions Served	T	TR	T	TR	T	T	LTR	LTR
Maximum Queue (ft)	6	23	219	208	347	347	200	196
Average Queue (ft)	0	1	72	68	66	66	128	98
95th Queue (ft)	4	9	233	230	328	334	207	214
Link Distance (ft)	816	816	150	150	1972	1972	166	200
Upstream Blk Time (%)			16	11			19	17
Queuing Penalty (veh)			131	85			0	0
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Intersection: 24: US 20

Movement	EB	EB	EB	WB	NB	SB
Directions Served	L	T	TR	TR	LTR	LTR
Maximum Queue (ft)	90	68	6	3	105	115
Average Queue (ft)	32	2	0	0	42	47
95th Queue (ft)	66	30	5	3	87	87
Link Distance (ft)		674	674	372	235	227
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	100					
Storage Blk Time (%)	0	1				
Queuing Penalty (veh)	0	1				

Intersection: 111: US 20

Movement	EB	EB	NB	SB
Directions Served	T	TR	LTR	LTR
Maximum Queue (ft)	113	113	68	92
Average Queue (ft)	15	16	23	35
95th Queue (ft)	105	115	58	70
Link Distance (ft)	1183	1183	341	314
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Network Summary

Network wide Queuing Penalty: 6439