Underpass Avenue Improvements – Billings
Project Number: CM 1025(8)
Control Number: UPN 8669000

Preliminary Conceptual Design Report
MDT Activity 118

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1.0 Introduction

The intended scope of work for this initial phase (Phase I) of the Underpass Avenue Improvements project is to review and analyze the existing site conditions and traffic needs to prepare possible improvement options. This report serves to identify and summarize conceptual options to consider for further development. Detailed reporting, design of site improvements, and right-of-way will not be included in this project phase, and will be addressed under the subsequent design phase (Phase II). Phase II of the project will include detailed reporting and design of improvements for the Underpass Avenue intersection and surrounding areas.

The purpose of this conceptual design report is to serve as the documentation for Activity 118 "Roadway Alignment Plan", as defined in the Scope of Services identified for Phase I. The analysis contained herein focuses on concepts based on available data including traffic volumes, site conditions, physical survey and input from MDT staff. Planning level opinions of probable construction costs have been calculated for each feasible option, and are presented herein. A complete summary of the information collected under this planning process will be detailed within a final technical memorandum under Activity 124 "Finalize Alignment and Grade."

The existing site configuration experiences operational, geometric, safety, and drainage issues. The site also lacks pedestrian and bicycle facilities. The project limits are generally bounded by the 6th Street West and Central Avenue intersection to the north and the Underpass Avenue and Calhoun Lane intersection to the south. The west boundary for the project is the intersection of Laurel Road and Moore Lane and the east boundary is just east of the Underpass Avenue and State Avenue intersection. While precise project limits will be determined during the design phase of the project, Phase I will focus on improvement recommendations for the 6th Street West and Central Avenue intersection, the Underpass Avenue and State Avenue intersection, the Underpass Avenue and Calhoun Lane intersection, and the Laurel Road on-ramp extension. A location map of the study area is shown in Figure 1 and the Laurel Road on-ramp extension is shown in Figure 2.

Figure 1: Study Area

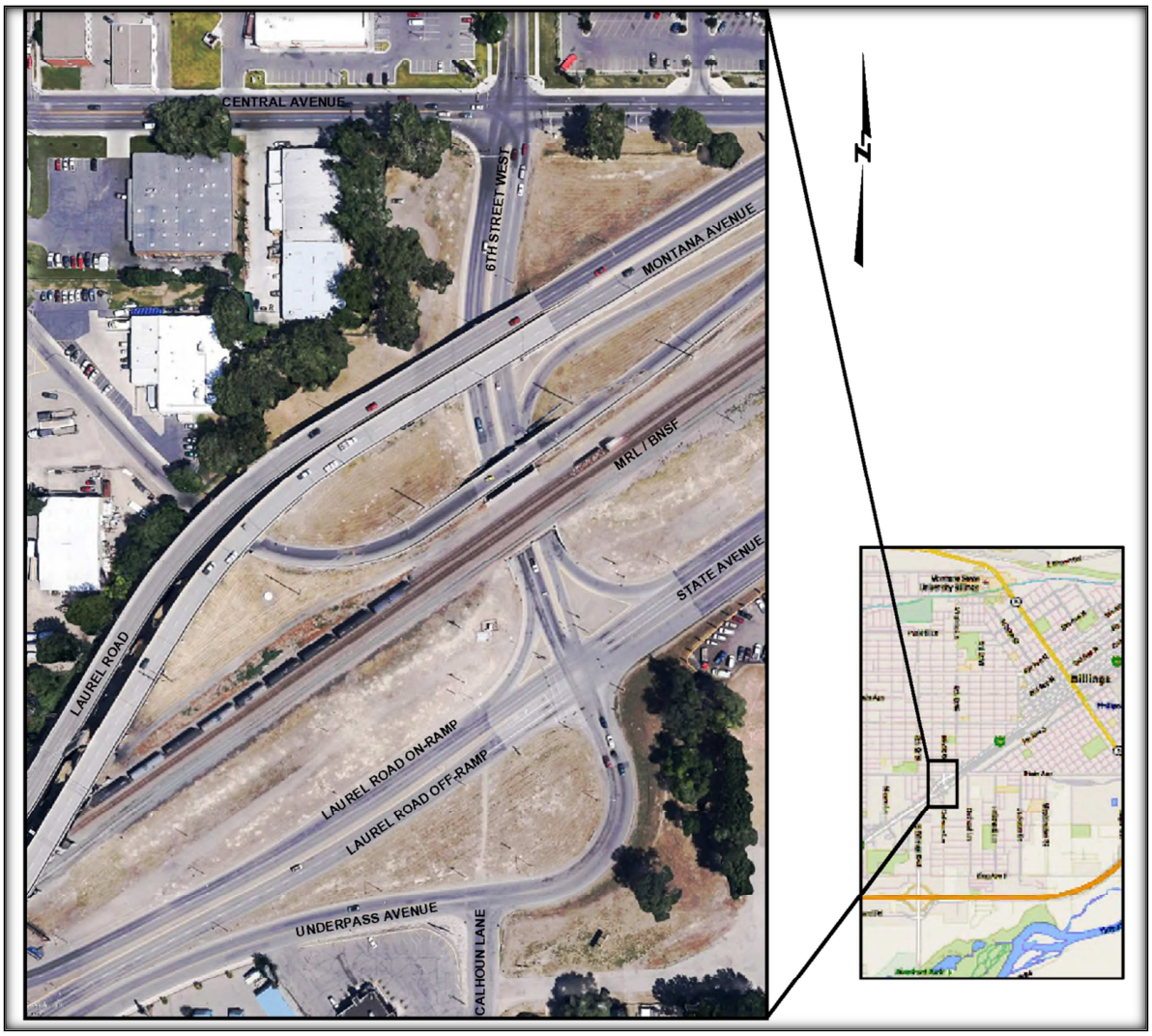


Figure 2: Westbound Laurel Road On-Ramp

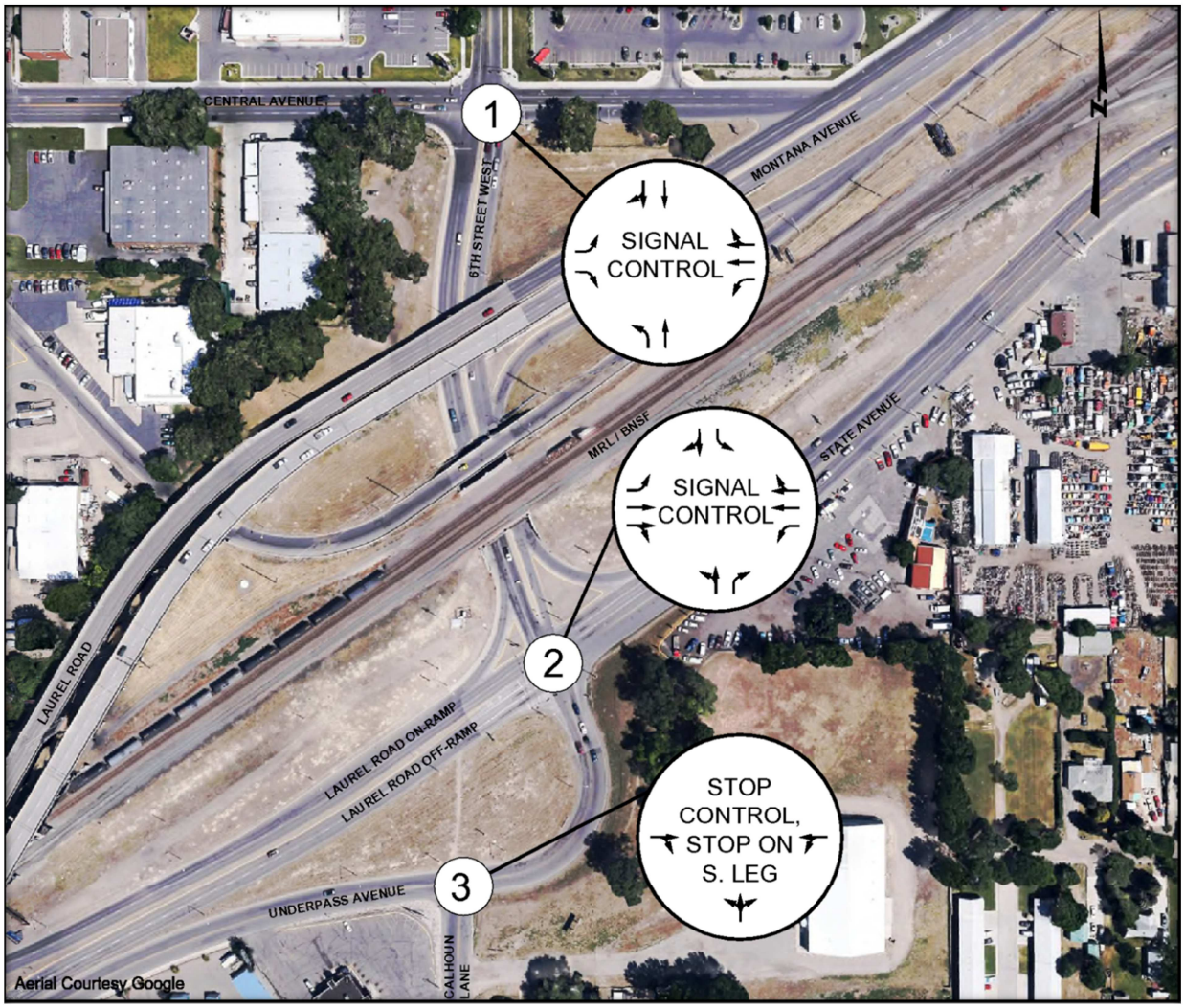
2.0 Existing Conditions

The Underpass Avenue Improvements project includes a pre-design level scan and summary of the transportation system features and physical characteristics to help identify issues, constraints, and opportunities within the project limits. The following sections summarize key information regarding the existing conditions

2.1 Transportation System

The study area includes the intersections of Underpass Avenue and Central Avenue, Underpass Avenue and State Avenue, Underpass Avenue and Calhoun Lane, and the Laurel Road on-ramp extension to Moore Lane in Billings, MT.

Figure 3: Existing Lane Configurations



Underpass Avenue/6th Street West
Underpass Avenue (U-1025) is classified by MDT as an *Urban Route* and is unclassified by the City of Billings. There is one travel lane for each direction south of State Avenue to Foote Street. The roadway extends south from State Avenue to Calhoun Lane and curves to the west past Calhoun Lane. The posted speed limit for Underpass Avenue is 25 mph.

Underpass Avenue transitions to 6th Street West at the intersection of Underpass Avenue and State Avenue. 6th Street West (U-1025) is classified by MDT as an *Urban Route* and is unclassified by the City of Billings. The road provides two travel lanes for northbound traffic and two travel lanes for southbound traffic between Central Avenue and State Avenue. There is one travel lane for each direction north of Central Avenue. A raised median separates northbound and southbound traffic from Central Avenue to State Avenue. A channelized right turn lane exists for the southbound right movement at State Avenue. The posted speed limit for 6th Street West is 25 mph.

Central Avenue
Central Avenue (U-1008) is classified by MDT as an *Urban Route* and is classified as a *Principal Arterial* by the City of Billings. The west leg of Central Avenue provides two travel lanes for eastbound traffic and two travel lanes for westbound traffic. The east leg of Central Avenue is a one-way road providing westbound travel and includes three individual lanes. One lane proceeds west to access Central Avenue westbound, one for 6th Street West southbound, and one for 6th Street West northbound. The posted speed limit is 35 MPH.

State Avenue
State Avenue (U-1024) is classified by MDT as an *Urban Route* and is classified as a *Minor Arterial* by the City of Billings. State Avenue provides two travel lanes for eastbound traffic and two travel lanes for westbound traffic within the study area. There is a channelized right turn lane for the westbound right movement at Underpass Avenue. The posted speed limit is 35 MPH.

Calhoun Lane
Calhoun Lane is unclassified by MDT, and is classified as a *Collector* by the City of Billings. The City of Billings is scheduled to complete construction to widen Calhoun to this three-lane typical section from Underpass Avenue to King Avenue East by the end of 2015. The reconstructed road provides one travel lane for northbound traffic, one travel lane for southbound traffic, and a two-way left turn lane and generally serves a residential area. The new roadway will also incorporate bike lanes and sidewalk to the intersection of Underpass Avenue and Calhoun Lane. The current posted speed limit is 25 MPH.

Montana Avenue/Laurel Road
Montana Avenue (N-113) is classified by MDT as a *NHS Non-Interstate* route and as a *Principal Arterial* by the City of Billings. The roadway provides direct access to and from the Billings central business district to the east. The Montana Avenue/Laurel Road transition is grade separated over Underpass Avenue. The current posted speed limit is 35 MPH.

Laurel Road (N-113) is classified by MDT as a *NHS Non-Interstate route* and as a *Principal Arterial* by the City of Billings. The roadway provides direct access to the West End Interchange with Interstate 90 (Exit 446) and to the commercial area surrounding King Avenue West. Laurel

Road adjacent to Underpass Avenue turns into Montana Avenue at the overpass. The current posted speed limit is 45 MPH.

An on-ramp for eastbound Montana Avenue is provided for northbound traffic on 6th Street West. The traffic from 6th Street West along with traffic from Cline Avenue/Central Avenue merges at the Montana Avenue on-ramp prior to merging with eastbound Montana Avenue traffic. Instead of continuing along the Laurel Road/Montana Avenue overpass, eastbound traffic on Laurel Road can utilize the Laurel Road off-ramp to access the intersection of Underpass Avenue and State Avenue. A westbound ramp from the Underpass Avenue and State Avenue intersection provides access to westbound Laurel Road.

2.2 Structures

Underpass Avenue/6th Street West crosses under four bridge structures, the Montana Avenue/Laurel Road overpass (2), the Montana Avenue on-ramp, and the Montana Rail Link (MRL)/Burlington Northern Santa Fe (BNSF) railroad between Central Avenue and State Avenue.

The structure over 6th Street West near the State Avenue intersection is owned by Burlington Northern Santa Fe Railway (BNSF) and used/leased by Montana Rail Link (MRL). Considering the cost, coordination and schedule implications of modifying or replacing the structure, it is assumed the railroad structure will not be disturbed in any design option. This structure confines the roadway width to approximately 64 feet, which includes a 6-foot median, four 12-foot travel lanes, minimal shoulders, and curb and gutter. The minimum vertical clearance for the underpass is approximately 14 feet, 10 inches.

Immediately north of the MRL structure is the on-ramp structure to Montana Avenue. North of the Montana Avenue ramp structure are the Montana Avenue and Laurel Road structures. These structures will not be disturbed with any design option. The roadway width is approximately 64 feet under these structures as well. The minimum vertical clearance of all three structures is approximately 15 feet, 6 inches. None of the structures in the vicinity of the project meet current vertical clearance criteria of 17 feet. However, improvement or replacement of these structures is neither feasible nor recommended.

2.3 Topography

The existing topography of the site is shown on the existing site map found in Appendix A. The site generally loses elevation from the north and south edges of the study area towards the MRL/BNSF underpass which contains the low point in the study vicinity, which collects and contributes the majority of the runoff to the existing pump house. There are steep, un-vegetated embankments adjacent to the railroad bridge crossing at Underpass Avenue. These embankments also contribute runoff to the storm drain located in the sag under the railroad crossing. All the areas north of Calhoun Lane contribute runoff to the pump house at the northwest corner of the State Avenue and Underpass Avenue intersection. This runoff is conveyed from the pump station through a 20” steel force main to the storm drain system located in Calhoun Lane. Areas adjacent to the intersections are typically a mix of native vegetation and manicured landscaping.

2.4 Right-of-Way

Ownership within the study area was determined through an examination of ownership and parcel data available on the State of Montana Cadastral website for Yellowstone County and Billings. Land ownership was confirmed through letters to the owner of record. Parcel delineation was developed based on parcel data provided by the website. An ownership report was completed that identified eight parcels as being potentially impacted as part of the Underpass Avenue Improvements project.

Sufficient right-of-way generally exists in most locations within the study area. Additional acquisition of right-of-way may be required at the intersection of Underpass Avenue and Calhoun Lane. Additional survey will be required during Phase II to document the as-built conditions of the Calhoun Lane project and to retrace the right-of-way.

2.5 Driveways and Approaches

There are no driveways or approaches on Underpass Avenue/6th Street West between Central Avenue and Calhoun Lane. Several commercial approaches exist along the south side of Underpass Avenue west of Calhoun Lane. Several approaches exist on Central Avenue, 6th Street West, and State Avenue. These approaches are generally well separated from the study intersections.

2.6 Pedestrian and Bicycle Facilities

Sidewalks and pedestrian ramps are located on the northeast, northwest, and southwest corners of the 6th Street West and Central Avenue intersection. Crosswalks with pedestrian signals are located on the north and west legs of the intersection. There are no pedestrian ramps on the southeast corner or sidewalk on the east side of 6th Street West or on the south side of Central Avenue west of 6th Street West, although pedestrians appear to be using a dirt path located behind the curb.

There is a five-foot wide sidewalk along the west side of 6th Street West from Central Avenue to State Avenue. The sidewalk crosses under the MRL/BNSF railroad bridge in a protected walkway. The walkway does not have a continuous handrail for pedestrian use and does not comply with current ADA standards. Marked crosswalks with pedestrian signals are located on the south and west legs of the Underpass Avenue and State Avenue intersection, however, no ADA compliant curb ramps are present at the existing crosswalks. There is no sidewalk on the northeast, southeast, or southwest corners of the intersection, although pedestrians appear to be using dirt trails behind the curb.

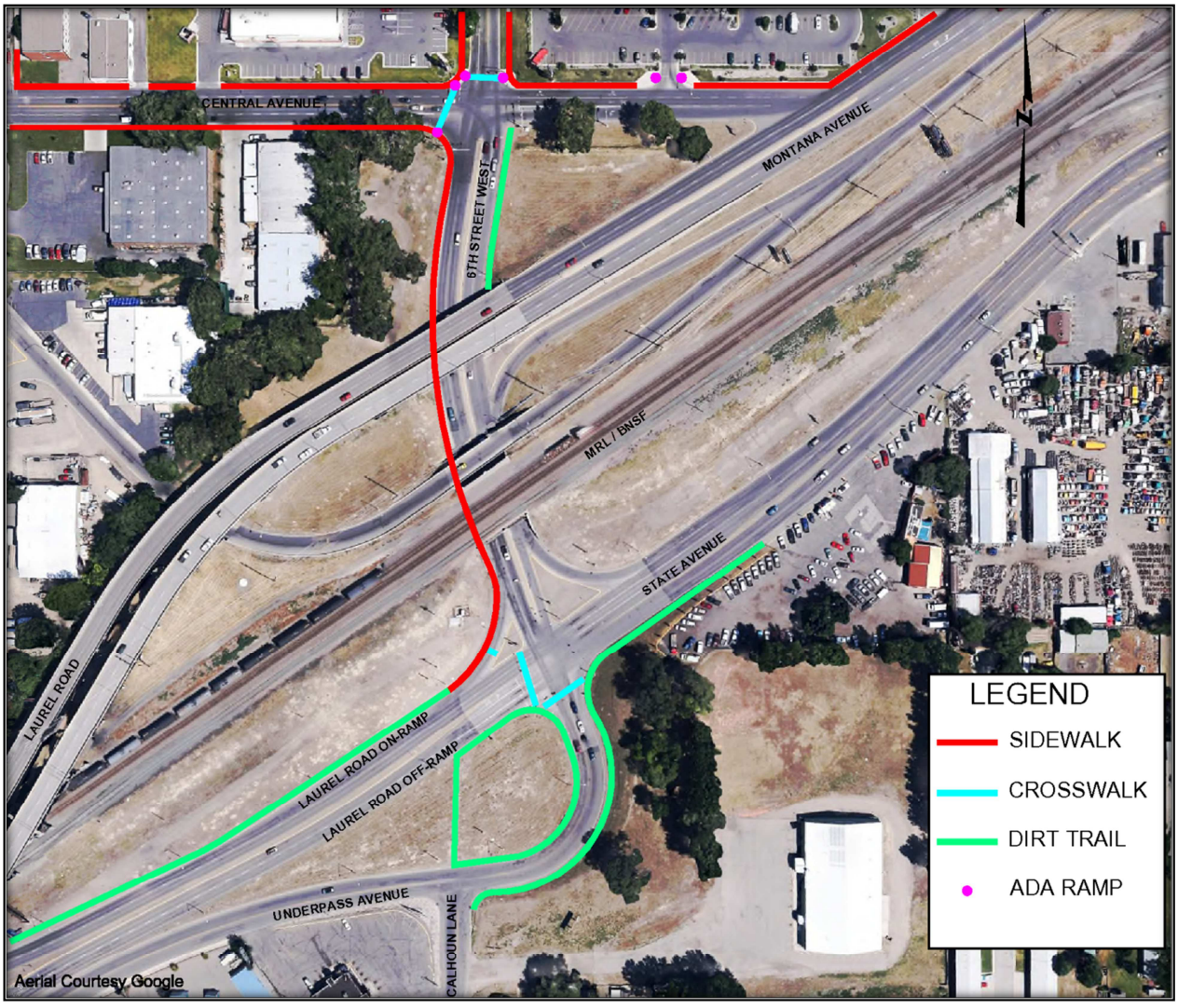
Currently, there are no pedestrian accommodations at the intersection of Underpass Avenue and Calhoun Lane. There are dirt trails, however, on the north, east, and west sides of the intersection indicating moderate pedestrian usage. The City of Billings has recently reconstructed and widened Calhoun to the three-lane typical section with bicycle lanes and new sidewalk adjacent to this project. Figure 4 depicts the existing pedestrian accommodations.

No bicycles lanes are located within the project vicinity. With limited shoulders along 6th Street West, most bicyclists are utilizing the protected sidewalk through the underpass rather than the roadway. There is significant public interest in providing pedestrian, bicyclist and accessible features at the Underpass Avenue and State Avenue intersection. Comments received at the

public meeting on June 10, 2015 indicate that pedestrians and bicyclists should be considered with the potential design of any project.

The 1st Avenue South – ADA, CMDP 114-1(1)0 design-build project (UPN 9082000) is anticipated to begin in February, 2017. The project includes sidewalk and ADA ramps along State Avenue and Underpass Avenue continuing west to Laurel Road. Accessibility improvements made with this project will likely be removed at the time intersection and signal work is performed due to additional vehicle and bicycle lanes that would be included with a reconstruction project. Coordination with the successful design-build team would potentially reduce the amount of rework at the intersection. Figure 4 illustrates the existing pedestrian facilities in the project vicinity.

Figure 4: Existing Pedestrian Accommodations



2.7 Hydraulics

The existing underpass drainage area is collected by a series of 11 inlets. The inlets are connected to a wet well at the pump house located near the northwest corner of the State Avenue and Underpass Avenue intersection. A preliminary hydrologic and hydraulic study was conducted to gain an understanding of the hydraulic performance within the study area and provide conceptual drainage recommendations for a future intersection design improvement project.

The underpass area has known drainage issues. Flooding at the low point of the underpass has been an issue and can be attributed to hydraulic inefficiencies associated with the site. DOWL met with several MDT Maintenance staff including Randy Roth, the district Maintenance Chief, during a site visit held on April 7, 2015 to discuss the hydraulic performance of the storm water facilities around the study area.

MDT maintenance personnel informed DOWL the underpass area is a common maintenance problem and typically requires weekly maintenance to clean up after pigeons that have nested under the railroad bridge. Deterring avian nesting in and around the underpass area is of high concern. Both MDT and members of the public requested that avian deterrents be incorporated into the proposed concepts for this project. Avian nesting in the underpass area causes an unpleasant environment under the bridges and the volume of avian waste accumulates in the inlets and laterals creating drainage issues with the storm water system.

Pumps discharge runoff and groundwater collected in the wet well through a 20-inch steel force main to a 33-inch storm drain pipe along Calhoun Lane just north of Arden Avenue, where runoff flows to the south to the City-County drain and flows east along King Avenue East. The City-County drain has a Municipal Separate Storm Sewer System (MS4) permit. Under this permit, the City is responsible for regulating the quality of the water being discharged into the City-County drain. The proposed designs are expected to improve water quality above existing conditions through the implementation of retention and detention ponds.

An inspection of the 20-inch steel force main was conducted on August 22, 2016 in conjunction with MDT Maintenance staff. The main was inspected by camera from the manhole location in Calhoun Lane for a distance of approximately 130 feet. As the camera reached approximately 100 feet, there was significant sedimentation and accumulation of aggregates. The pipe condition appears to be in acceptable condition throughout this reach. Considering the amount of sediment and aggregate in the main, methods to capture and remove these materials from the wet well should be considered. A collection manhole with a sump prior to the pump house would significantly reduce these issues.

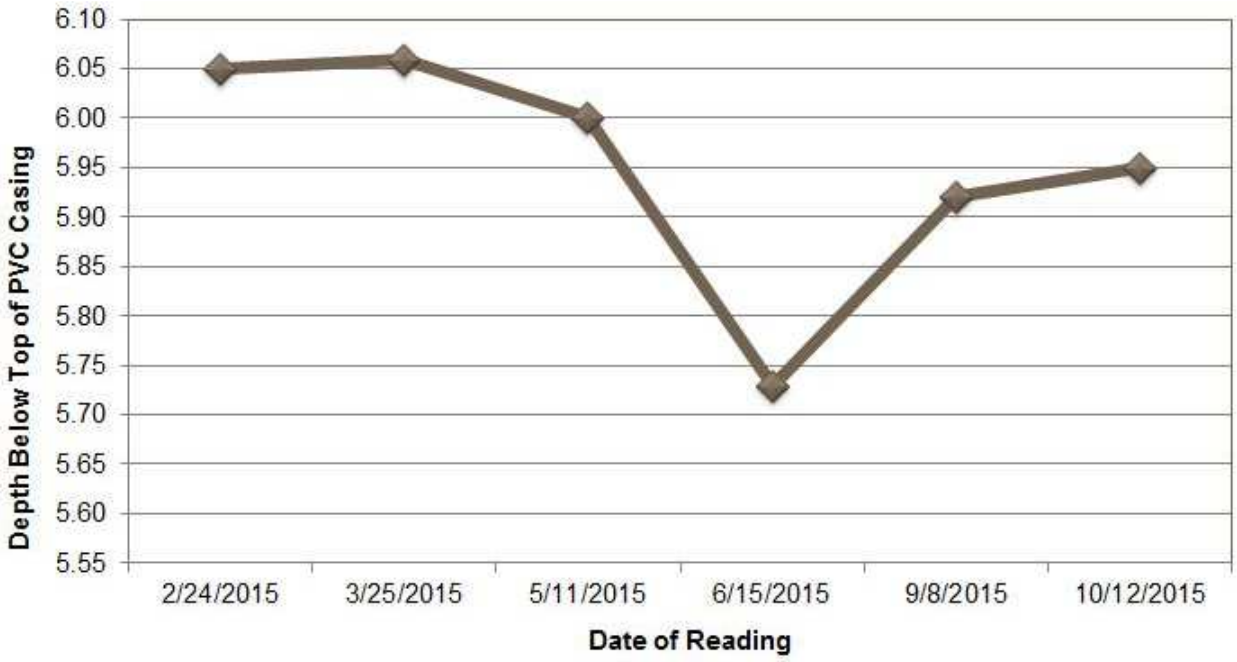
In general, runoff east of South Billings Boulevard, west of 5th Street West, south of Central Avenue, and north of Arden Avenue (off Calhoun Lane) will reaches the underpass area. The boundary consisting of the runoff areas listed above is considered the study area for the project. The project is not located within any delineated floodplain. The City of Billings does not have a storm water master plan study completed at this time. As such, the project will be designed to improve existing conditions and meet current City of Billings and MDT design criteria when feasible. A 72-hour infiltration requirement would likely be assumed for any new retention/detention facilities. The extent of the proposed project concepts are anticipated to be constructed primarily within the existing right-of-way limits.

2.8 Groundwater

Field work was performed on January 16, 2015, that consisted of site observations and advancing one soil boring at the site. The soil boring was drilled with a truck-mounted BK-81 hollow-stem auger drilling rig, extended to a depth of approximately 16.5 feet below existing grade and was completed as a monitor well. Well construction consisted of installation of a solid 2-inch PVC pipe from the ground surface to a depth of approximately five feet below existing grade. From that point, a screened 2-inch PVC pipe was installed and extended to a depth of approximately 15 feet below existing grade. A sand pack was placed around the PVC pipe in the annular space and extended to approximately two feet above the 2-inch screen. A bentonite seal was placed above the sand pack and a flush mounted cap was encased in concrete at the existing ground surface.

Groundwater was encountered in the boring during the field exploration at a depth of approximately six feet. Subsequent to the field exploration, a DOWL representative measured groundwater from a mark placed at the top of the PVC casing near the existing ground surface elevation of 3139.5 feet. Figure 5 below depicts the groundwater measurement monitoring results.

Figure 5: Groundwater Monitoring Results



2.9 Utilities

Utilities adjacent to and through the study area were identified through the development of a Phase I Subsurface Utility Exploration (SUE) field study conducted by Utility Mapping Services (UMS). A depiction of the found utilities is provided in Appendix A of this report. The information collected as part of the Phase I SUE will be utilized during subsequent design phases.

Through the course of the Phase I SUE, several utilities were located, including storm sewer, sanitary sewer, telephone, natural gas, water mains, power, fiber optic communication cable,

CATV, pressurized petroleum pipeline (CHS Front Range – Cenex), and traffic signals. It should be noted that special care and consideration will likely be required for the petroleum pipeline located near the Underpass Avenue and Calhoun Lane intersection during the design phase of this project, and may affect design considerations.

Minor utility relocations and adjustments are expected with any concept. The extent of the utility conflicts varies with each design concept. Storm sewer infrastructure will likely be reconstructed as part of the proposed improvements which will likely impact utilities; however, the reconstructed system will function at a higher level of service compared to the existing system.

Although utility relocations and adjustments are expected with proposed improvements, the pressurized petroleum pipeline (Cenex) in the study area will not be disturbed in any of the proposed design concepts. If applicable, the final design for the project will include a special provision for working around the pipeline and coordinating with the pipe owner.

2.10 Environmental Considerations and Public Involvement

Information was gathered from previously-published documents, websites, field observation, mapping and GIS data to document environmental conditions at the project site. The scope of this project includes finalizing the environmental documentation through a Categorical Exclusion.

Biological

As part of the environmental review process, a Biological Resources Report was completed to evaluate the project's potential impacts on terrestrial and aquatic plant and animal species, wetlands and waterways (aquatic resources), state species of concern, special status species, and threatened or endangered species.

A review of the MNHP database for a 3-mile buffer around the project area and the USFWS species list for threatened or endangered species for Yellowstone County was conducted. Although potential habitat exists within the project's vicinity, no records for any threatened or endangered species or critical habitat occur within the project area.

This project would have no effect on federally-listed species, state species of concern, or state special status species. No wetlands or other aquatic resources were identified within the project area.

Cultural

A cultural resource inventory was conducted for the project area by Ethnoscience, Inc. The study determined that four historic properties are located within the project area. Two sites; a railroad (Site 24YL277) and an irrigation ditch (Site 24YL659) were previously determined eligible for NRHP listing. Two residential properties (Sites 24YL2039 and 24YL659) are located within the property but determined to not be eligible for NRHP listing. The report determined that the proposed project will not have any effect on cultural or historic properties. Concurrence from the State Historic Preservation Office (SHPO) is pending on this project.

Amend, Central, and Optimist Parks are in the vicinity of the project and were constructed using Land and Water Conservation Fund grants. However, none of these parks are within or immediately adjacent to the project area, and will not be affected by the project. This project will

not impact any of the adjacent recreational parks or have any impact on the historical sites within or adjacent to the project area.

Hazardous Materials

The DEQ database shows two unresolved leaking underground storage tanks (LUSTs) within the project area. These are located near the intersection of Underpass Avenue and South Billings Boulevard (ID# 5600625) and Morey Street and Underpass Avenue (ID# 5608594). If project design determines that ground disturbance activities are proposed in this area, further coordination may be required.

Two other resolved underground storage tanks (USTs) are located within project area according to the DEQ database. They are located at the intersection of Laurel Road and Moore Lane; and adjacent to LUST #5600625.

The DEQ database also maps the Billings Tetrachlorethene (PCE) Groundwater Comprehensive Environmental Cleanup and Responsibility Act (CECRA) site to the northwest of the project area at the intersection of Central Avenue and South 7th Street West. With the pump house collecting groundwater, there is potential that this contamination would impact future drainage improvements. A sample was taken from the vault by MDT staff on June 17, 2015 and tested for Volatile Petroleum Hydrocarbons (VPH), Extractable Petroleum Hydrocarbons (EPH), and Volatile Organic Compounds (VOCs) among other substances. The analysis detected PCE at 0.16 ug/L and Total Extractable Hydrocarbons at 451 ug/L. These levels are below the regional screening level (RSL) and risk-based screening level (RBSL) for those compounds. These levels are similar to a sample collected in 2007.

Public Involvement

An informational meeting was held at the Orchard Elementary School located at 120 Jackson Street in Billings, Montana from 4:00 p.m. to 8:00 p.m. on June 10, 2015. The intent of the meeting was to discuss the existing conditions of the project site and present preliminary improvement options for the Underpass Avenue and State Avenue intersection and the Underpass Avenue and Calhoun Lane intersection. The following summarizes the public input received at the meeting and through subsequent collection of written comments.

<u>Traffic Comments</u>

Several citizens expressed concern about the existing traffic queues and how the queues may affect the improved intersections. Traffic currently backs up from the intersection from Underpass Avenue and State Avenue to the intersection of Underpass Avenue and Calhoun Lane. Also, traffic currently backs up from the intersection of Underpass Avenue and Central Avenue to the intersection of Underpass Avenue and State Avenue.

A statement was made that improvements to all three intersections must occur to fix the current queuing issues. Two written comments were received stating the citizen's support of signals and dislike for roundabouts. The citizens don't believe people use roundabouts properly and believe they are unsafe compared to signals. The sight distance from Calhoun to the west leg of Underpass Avenue and the speed limit on Underpass were mentioned.

<u>Non-Motorized Comments</u>

Sidewalk installation on the northeast quadrant and pedestrian crossings on State Avenue was requested. Installation of bike lanes was requested by numerous attendees. Written comments

were received requesting sidewalks and a safe pedestrian route from the project location to the Albertsons grocery store.

Drainage Comments

Concern regarding the pigeons and their impact on the drainage system was expressed along with the unpleasant conditions and potential safety hazards associated with the birds.

3.0 Existing Traffic Conditions

Methodology

The intersection capacities and operations are reported as Level of Service (LOS) based on the *Highway Capacity Manual* (HCM) methodology. Traffic operation at the Calhoun Lane intersection is evaluated using HCM 2010 methodology. Traffic operations at the Central Avenue intersection and the State Avenue intersection are evaluated using HCM 2000 methodology, because HCM 2010 does not support the layout of the Central Avenue intersection which consists of four approach legs with one-way westbound approach, and also does not support the channelized right-turn lanes at the State Avenue intersection. Signalized and stop-controlled intersections are analyzed using Synchro 9 software. Roundabouts are analyzed using SIDRA 6 software, based on HCM 2010 methodology.

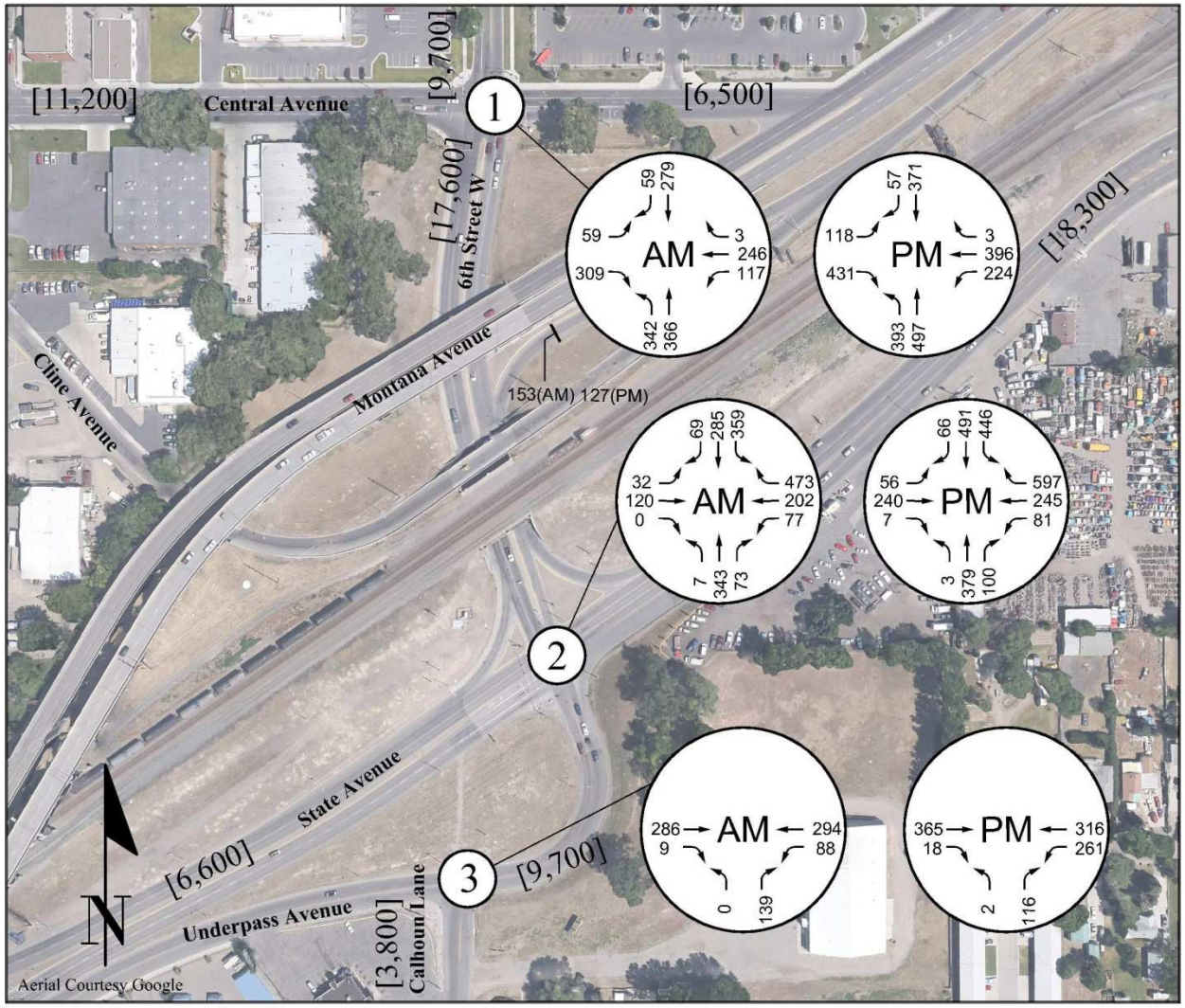
LOS describes the quality of traffic operations based on driver perception and is graded from A to F; with LOS A representing free-flow conditions and LOS F representing heavily congested conditions. While LOS for a signalized intersection is primarily based on the average delay per vehicle traveling through the intersection (control delay), LOS for an unsignalized intersection is primarily based on the stop-controlled approach with the longest delay. For urban minor arterials, MDT targets LOS B conditions at the design year (2038) with LOS C determined to be acceptable intersection performance, when LOS B cannot be achieved cost effectively. For Urban Collector Streets, MDT targets LOS C at the design year, but may accept LOS D based on site-specific constraints.

3.1 Traffic Volumes

Existing traffic volumes were collected on March 24, 2015. Turning movement counts were collected at the study intersections for 24 hours using video detection, and directional traffic volume was collected on the Montana Avenue on-ramp for 24 hours using a tube counter. Historic Annual Average Daily Traffic (AADT) for the roadways within study area was obtained from MDT. The 24-hour turning movement counts showed that the noon peak period does not demand a greater level of traffic over the a.m. or the p.m. peak periods; therefore, only the a.m. and the p.m. peak hours were analyzed. Figure 6 shows the existing 2015 a.m. and p.m. peak hour turning movement volumes and 2014 AADT. Turning movement volumes were adjusted as necessary to reflect zero vehicle loss between adjacent intersections.

Seasonal adjustment factors are typically applied to the traffic counts to better represent the annual average traffic conditions. The seasonal adjustment factor identified in MDT's *Seasonal Day of the Week for Axle Counts* on Urban Minor Arterial/Collector roads for the month of March is 0.98 for 2015. Changes to the traffic counts by this factor is considered insignificant, therefore it was not applied to the traffic counts for this project.

Figure 6: Existing 2015 Peak Hour Turning Movement Volumes and 2014 AADT



3.2 Truck Movement Observations

Truck movements at the study intersections were observed during the morning and evening peak hours (7:00-9:00 a.m., 4:00-6:00 p.m.). In an effort to identify travel patterns, each truck movement was recorded on the basis of truck type and the direction of travel through the intersection. Quantitative data for each truck movement were considered with the intersection geometric analysis.

6th Street West & Central Avenue

Truck movements at the 6th Street & Central Avenue intersection were observed on Wednesday, July 27, 2016. The results of the observations are as follows:

- During the morning peak hours, half (50%) of the observed trucks approached the intersection from the south, among those trucks nearly half (41%) traveled to the west.

- During the evening peak hours, the majority of observed trucks approached the intersection from the west and from the south (37% and 34%, respectively), among those trucks half (50%) traveled to the south.
- Truck traffic was more frequent during the morning peak hours (58 total movements) than the evening peak hours (38 total movements).
- About 15% of the observed trucks (morning and evening) were semi-trucks greater than 50 feet in length.
- Frequent municipal garbage truck traffic entering from the south was observed during the morning peak hours only.
- During the evening peak hours, a notable amount of eastbound truck traffic on Central Avenue were turning right onto 7th Street to enter eastbound Montana Avenue.

Underpass Avenue & State Avenue

Truck movements at the Underpass Avenue & State Avenue intersection were observed on Thursday, July 28, 2016. The results of the observations are as follows:

- During the morning peak hours, nearly half (44%) of the observed trucks approached the intersection from the east, among those trucks a majority traveled either west or north (30% and 28%, respectively).
- During the evening peak hours, only a few (9%) approached from the south (Underpass Avenue). From the intersection, nearly half (41%) of the trucks traveled to the east.
- Truck traffic was more frequent during the morning peak hours (87 total movements) than the evening peak hours (69 total movements).
- About 30% of the observed trucks (morning and evening) were semi-trucks greater than 50 feet in length.
- A frequent municipal garbage truck traffic entering from the south was observed during the morning peak hours only.

Underpass Avenue & Calhoun Lane

Truck movements at the Underpass Avenue & Calhoun Lane intersection were also observed on Thursday, July 28, 2016. The results of the observations are as follows:

- During both morning and evening peak hours, half (50%) of the observed trucks approached the intersection from the east.
- A frequent municipal garbage truck traffic traveling to the east was observed during the morning peak hours only.

3.3 Intersection Operational Analysis

Table 1 shows the results of the existing (2015) traffic operational analysis. This table provides the delay and LOS for each approach leg, as well as the intersection control delay and LOS for the signalized intersections. The Appendix includes detailed analysis results for each study intersection.

Table 1: Existing Traffic Delay and LOS

Intersection	AM Peak Hour		PM Peak Hour	
	Delay (s)	LOS	Delay (s)	LOS
6th Street West / Central Avenue				
Control Delay	21.7	C	39.3	D
EB Approach	*21.8*	*C*	*45.1*	*D*
WB Approach	*24.5*	*C*	*28.2*	*C*
NB Approach	*18.8*	*B*	*49.8*	*D*
SB Approach	*24.7*	*C*	*26.0*	*C*
State Avenue / Underpass Avenue				
Control Delay	21.6	C	27.5	C
EB Approach	*28.7*	*C*	*30.7*	*C*
WB Approach	*7.8*	*A*	*7.8*	*A*
NB Approach	*33.3*	*C*	*37.6*	*D*
SB Approach	*27.8*	*C*	*39.7*	*D*
Underpass Avenue / Calhoun Lane				
NB Approach	11.4	B	12.2	B
EB Approach	*0.0*	*A*	*0.0*	*A*
WB Approach	*1.9*	*A*	*4.1*	*A*

4.0 Projected Traffic Conditions

The traffic analysis presented in this report is an update and revision to the MDT Activity 112 – Preliminary Traffic Report (September 2015) based on additional analysis conducted through Amendment Number 1 and discussions with MDT Traffic. Future concepts have been refined based on the findings of the Preliminary Traffic Report.

4.1 Historic Traffic and Growth Rates

A growth in traffic volumes is generally expected for the study area. For this project, 2018 is assumed as the letting year and 2038 as the design year. A detailed growth rate calculation and the expected future traffic volumes are provided. Historic AADT from 2010 to 2014 were obtained from MDT. An annual growth rate (AGR) for each count location was determined by plotting the historic AADT on a chart, and placing an exponential best-fit trend line through those points. Table 2 and Figure 7 show the historic AADT at the MDT count locations and the AGR within the study area.

Table 2: Historic AADT and Growth Rates

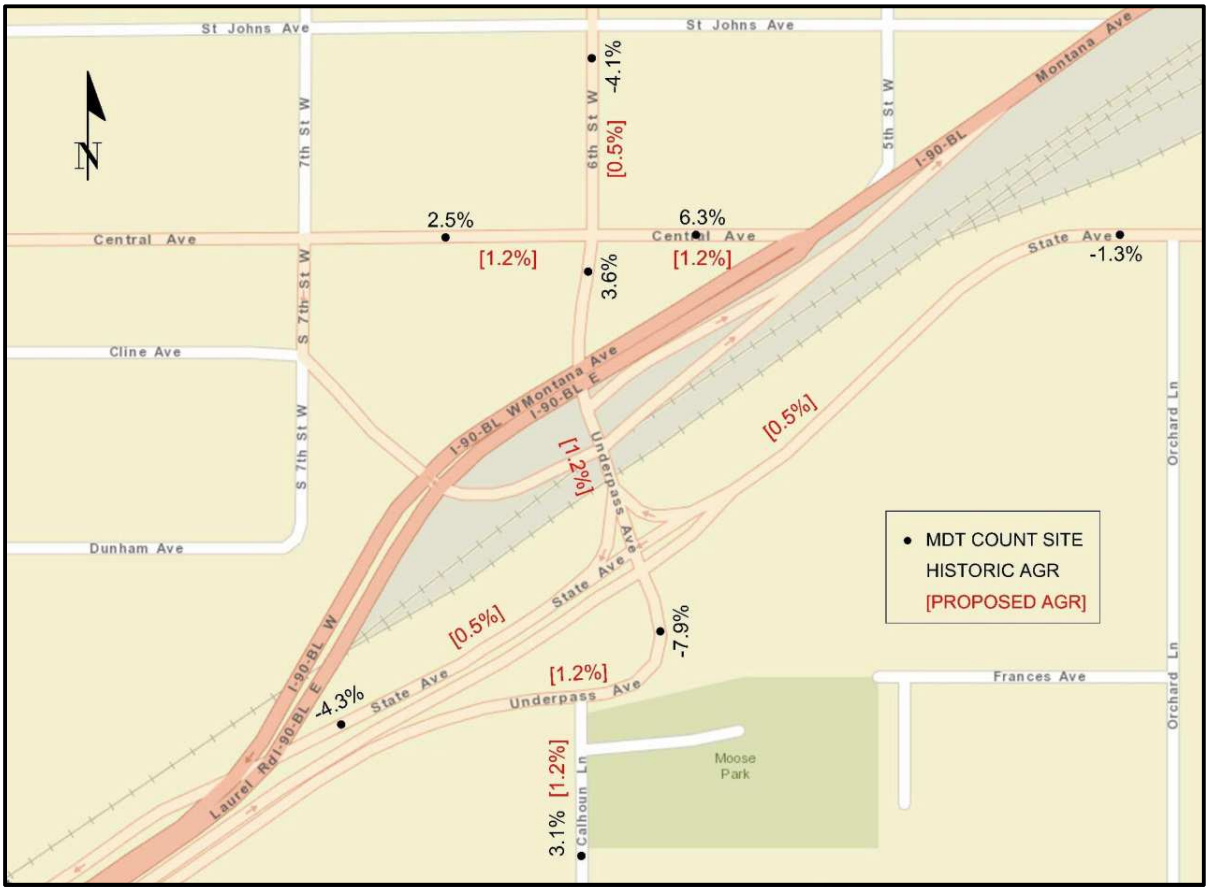
Location	MDT Count Site	2010	2011	2012	2013	2014	AGR
Calhoun Lane, south of Underpass Avenue	(56-4A-205)	3330	3320	3824	3610	3728	3.1%
Underpass Avenue, south of State Avenue	(56-4A-208)	12980	12930	1058	1000	9681	-7.9%
State Avenue, west of Underpass Avenue	(56-4A-218)	7530	7500	6510	6440	6550	-4.3%
State Avenue, east of Underpass Avenue	(56-4A-219)	18430	18360	17499	16490	18236	-1.3%
6th Street West, south of Central Avenue	(56-4A-210)	17260	17190	18250	17250	17540	3.6%
6th Street West, north of Central Avenue	(56-4A-211)	11000	10960	10110	9550	9620	-4.1%
Central Avenue, west of 6th Street West	(56-4A-67)	10870	10870	13260	13260	11133	2.5%
Central Avenue, east of 6th Street West	(56-4A-68)	5000	5000	5590	5670	6439	6.3%
Note: Yellow highlighted cells were not included in AGR calculation.							

As shown in Table 2, historic AADT show negative growth trends for 6th Street, State Avenue, and Underpass Avenue south of State Avenue. However, new developments are planned for the area to the south of this project that would generate a higher rate of future growth. After coordination with the MDT Billings District and Traffic, the following AGR were assumed for this project:

- 1.2% AGR on:
  - Calhoun Lane,
  - Underpass Avenue,
  - 6th Street West, south of Central Avenue, and
  - Central Avenue.
- 0.5% AGR on:
  - State Avenue, and
  - 6th Street West, north of Central Avenue

These rates appear appropriate based on the land use characteristics and anticipated changes in travel patterns. If traffic in this area appears to grow in a different manner over time, the analysis and conclusions in this report may need to be revisited. Figure 7 shows the historic and proposed AGR for this project.

Figure 7: Historic and Proposed AGR



4.2 Traffic Volumes

Existing traffic volumes were projected to the letting year 2018 and the design year 2038, using the AGR as annual compounded rate.

Figure 8 and Figure 9 show the future 2018 and 2038 a.m. and p.m. peak hour turning movement volumes. Due to the various growth trends on adjacent links, future volumes on the Montana Avenue eastbound on-ramp appear to be decreasing.

Figure 8: Future 2018 Peak Hour Turning Movement Volumes

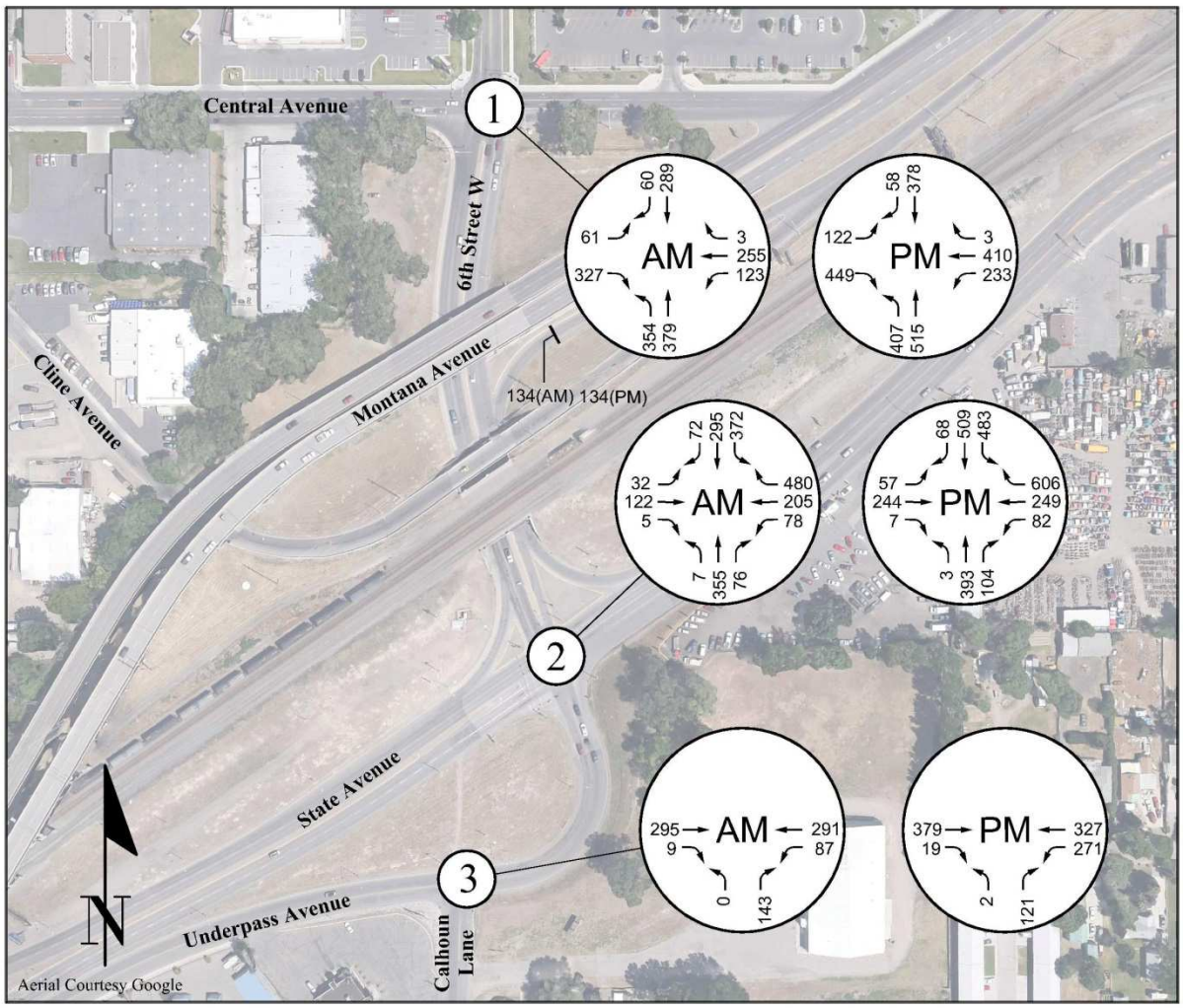
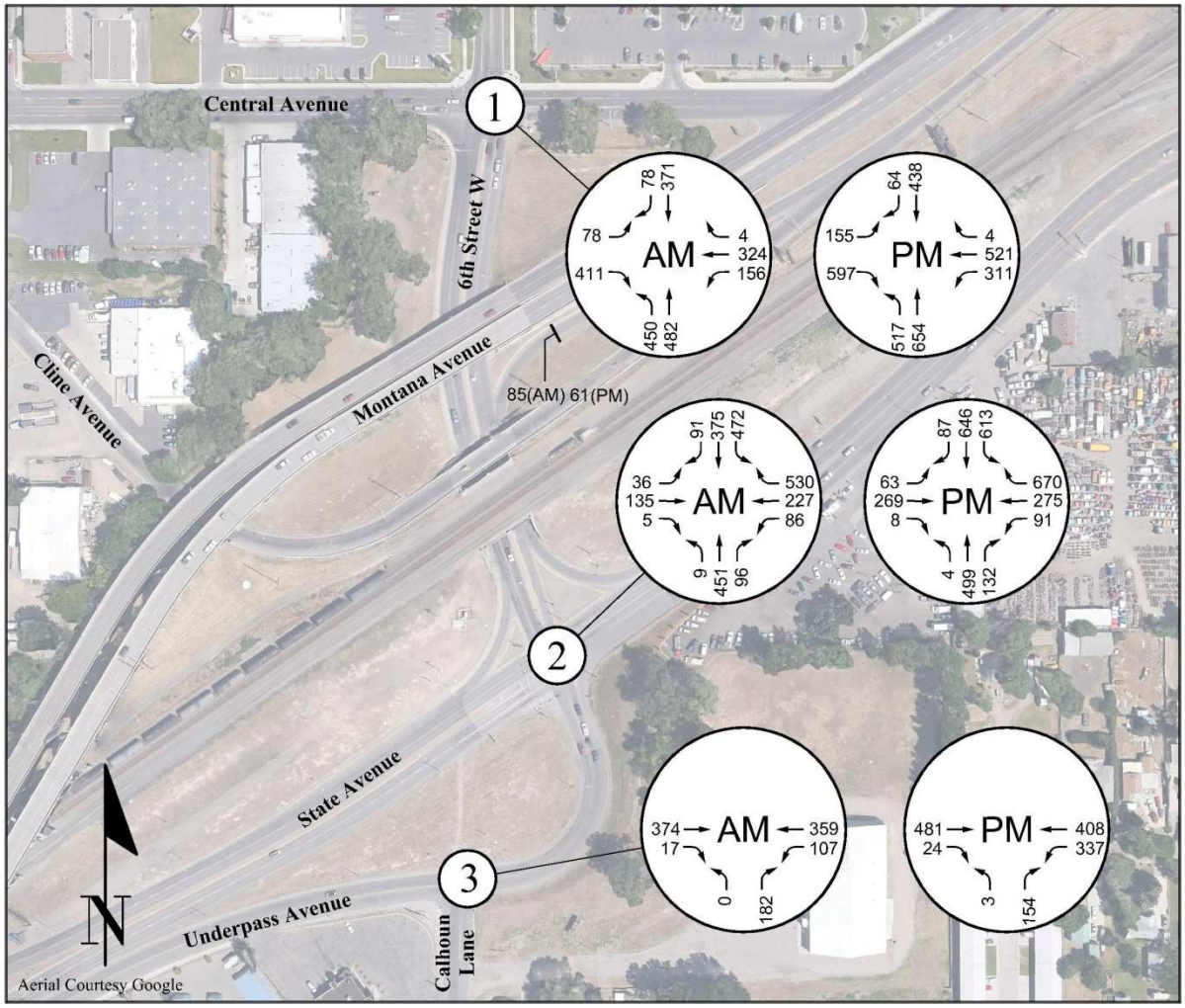


Figure 9: Future 2038 Peak Hour Turning Movement Volumes



4.3 Signal Warrant Analysis

Signal warrant analysis was performed for the Underpass Avenue and Calhoun Lane intersection. A field observation of the existing conditions showed that the northbound queue at the State Avenue and Underpass Avenue intersection often spills back beyond the Underpass Avenue and Calhoun Lane intersection, and vehicles in this queue block the Calhoun Lane intersection. This effectively prevents other drivers from making westbound left turns onto Calhoun Lane. This queue is also observed to delay northbound movements from Calhoun Lane onto Underpass Avenue. The 24-hour intersection count data were used to evaluate Warrant 1 (Eight-Hour) and Warrant 2 (Four-Hour) of the signal warrants as instructed in the *Manual on Uniform Traffic Control Devices* (MUTCD) 2009 Edition. Traffic conditions for the existing 2015 conditions and the forecasted 2018 and 2038 volumes were analyzed.

The Eight-Hour and Four-Hour signal warrants are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic signal. Since the intersecting eastbound movements and westbound left-turning movements are of primary concern, the eastbound movements are identified as the major movement and the westbound

left-turning movements as the opposing minor movement. Under this assumption, analysis showed that neither of the two warrants was met for any of the study years.

Table 3 shows the summary of the signal warrant analysis for Underpass Avenue and Calhoun Lane intersection. Detailed analysis documentation is included in Appendix. Additional storage at the northbound leg of Underpass Avenue & State Avenue would alleviate the current issues at the Calhoun intersection.

Table 3: Signal Warrant Analysis Results

MUTCD Warrant	Underpass Avenue & Calhoun Lane		
	2015	2018	2038
Warrant 1: Eight-Hour Vehicle Volume Condition A	0 hour out of 8 hours	0 hour out of 8 hours	1 hour out of 8 hours
Warrant 1: Eight-Hour Vehicle Volume Condition B	0 hour out of 8 hours	0 hour out of 8 hours	0 hour out of 8 hours
Warrant 2: Four-Hour Vehicle Volume	0 hour out of 4 hours	0 hour out of 4 hours	2 hours out of 4 hours

4.4 Intersection Operational Analysis

6th Street West / Central Avenue

The intersection of 6th Street West and Central Avenue is at failure during the PM peak hour and is not expected to improve with time. High vehicle delay is occurring at the eastbound and northbound approaches with the southbound and westbound approaches expected to degrade by the design year.

Table 4: 6th Street West / Central Avenue Projected Operations

6th Street West / Central Avenue	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
Control Delay	22.8	C	37.3	D
EB Approach	*22.5*	*C*	*28.1*	*C*
WB Approach	*24.7*	*C*	*55.1*	*E*
NB Approach	*21.0*	*C*	*26.6*	*C*
SB Approach	*24.8*	*C*	*50.6*	*D*
PM Peak Hour				
Control Delay	46.0	D	62.6	E
EB Approach	*58.1*	*E*	*55.5*	*E*
WB Approach	*28.7*	*C*	*75.8*	*E*
NB Approach	*60.0*	*E*	*60.8*	*E*
SB Approach	*26.3*	*C*	*55.2*	*E*

State Avenue / Underpass Avenue

The intersection of Underpass Avenue and State Avenue is expected to reach LOS D by 2038. Most legs incur significant delay during both the AM and PM peak hour, but the westbound approach is expected to perform well into the design year.

Table 5: State Avenue / Underpass Avenue Projected Operations

State Avenue / Underpass Avenue	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
Control Delay	23.8	C	35.4	D
EB Approach	*29.5*	*C*	*45.1*	*D*
WB Approach	*8.1*	*A*	*13.4*	*B*
NB Approach	*35.7*	*D*	*44.7*	*D*
SB Approach	*31.9*	*C*	*47.9*	*D*
PM Peak Hour				
Control Delay	30.8	C	48.0	D
EB Approach	*31.0*	*D*	*48.6*	*D*
WB Approach	*7.9*	*A*	*13.0*	*B*
NB Approach	*38.3*	*D*	*51.4*	*D*
SB Approach	*47.5*	*D*	*73.1*	*E*

Underpass Avenue / Calhoun Lane

The intersection of Underpass Avenue and Calhoun Lane is expected to perform acceptably into the design year if queuing storage is provided at the northbound approach at the Underpass Avenue and State Avenue intersection.

Table 6: Underpass Avenue / Calhoun Lane Projected Operations

Underpass Avenue / Calhoun Lane	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
NB Approach	11.6	B	13.6	B
EB Approach	*0.0*	*A*	*0.0*	*A*
WB Approach	*1.9*	*A*	*2.0*	*A*
PM Peak Hour				
NB Approach	12.7	B	16.4	C
EB Approach	*0.0*	*A*	*0.0*	*A*
WB Approach	*4.2*	*A*	*4.6*	*A*

4.5 Safety

MDT provided crash data, person data, and vehicle data for crashes contained in the MDT crash database occurring in the area of Underpass Avenue for the six-year period from January 1, 2009, to December 31, 2014. MDT noted that the crash data for 2014 may not be complete and that 2014 crash reports have not yet been reviewed to verify crash locations. During the six-year analysis period, a total of 167 crashes were reported. As a result of the crashes, a total of 67 injuries and two fatalities occurred during the analysis period.

The two fatalities occurred during a single vehicle right angle type crash with a fixed object. Crash data identifies the motorist as driving in a distracted, inattentive or careless manner. Alcohol and drugs were not attributed to this crash.

Rear end type crashes were the highest frequency of reported crashes. Rear end crashes made up 46.1% of crashes and 44.8% of injuries. The majority of crashes and injuries in the Underpass Avenue/6th Street West area occurred during clear weather, dry roadway, and daylight conditions. Crash data identified alcohol as being present in 17 crashes and not present in 100 crashes. The remaining 50 crashes did not include data on whether alcohol was present. As a result of the 17 crashes that identified alcohol as being present, three injuries occurred with no fatalities.

5.0 Design Criteria

5.1 Geometric Design Criteria

The MDT Roadway Design Manual was consulted for guidance regarding horizontal and vertical alignment elements. The geometric design criteria tables were used for the analysis and preliminary design of the concepts. Design criteria to be used during the final design activities will be addressed during Phase II, and may differ from the criteria used at this stage of the study.

Table 7: Assumed Design Criteria - Urban Principal Arterials

Urban Principal Arterials		
Terrain Type	Level[1]	Rolling[2]
Design Speed	40 mph	
Maximum Grade	6.0%[1]	7%[2]
Vertical Curve (Crest) K_{min}	44	
Vertical Curve (Sag) K_{min}	64	
Superelevation Rate e_{max}	4.0%	

Source: MDT Road Design Manual

[1]Geometric design criteria pertains toLaurel Road and Central Avenue.

[2]Geometric design criteria pertains to Montana Avenue.

Table 8: Assumed Design Criteria - Urban Minor Arterials

Urban Minor Arterials		
Terrain Type	Level[1]	Rolling[2]
Design Speed	30 mph	
Maximum Grade	7.0%[1]	8.0%[2]
Vertical Curve (Crest) K_{min}	19	
Vertical Curve (Sag) K_{min}	37	
Superelevation Rate e_{max}	4.0%	

Source: MDT Road Design Manual

[1]Geometric design criteria pertains to State Avenue.

[2]Geometric design criteria pertains to Underpass Avenue and 6th Street West.

Table 9: Assumed Design Criteria - Urban Collector Streets

Urban Collector Streets[(1)]	
Terrain Type	Level
Design Speed	30 mph
Maximum Grade	9.0%
Vertical Curve (Crest) K_{min}	19
Vertical Curve (Sag) K_{min}	37
Superelevation Rate e_{max}	4.0%

Source: MDT Road Design Manual

[(1)]Urban collector streets geometric design criteria pertains to Calhoun Lane.

5.2 Pavement Section and Surfacing Criteria

The borings revealed a subsurface profile generally consisting of approximately six feet of sand and gravel fill overlying natural poorly graded gravel with silt and sand. Due to the shallow drilling depths, bedrock was not encountered.

In general, A-1 and A-2 soils were encountered in the boring. Since this boring was not drilled within the existing roadway and conditions in that area are unknown at this time, an R-value of 10 was used for the below preliminary recommendations. This R-value roughly correlates to a resilient modulus of 6,550 psi. Tables 14 and 15 detail the preliminary pavement section options and provide approximate unit costs for each section. Additional borings within the roadway should be conducted with Phase II.

Flexible Pavement

The most recent traffic data estimates maximum anticipated 2038 ADT volumes of 24,828 vehicles per day, with a truck percentage of roughly 4 percent and an annual growth rate of roughly 1.2 percent. Based on truck factor assumptions, 6,800,000 Equivalent Single Axial Loads (ESALs) over a 20-year design life was estimated. For the flexible pavement design, a terminal serviceability of 2.5, reliability of 90 percent, and standard deviation of 0.45 were selected. Based on these design parameters and the *AASHTO Guide for Design of Pavement Structures,* the pavement section options presented in the following tables are proposed for conceptual design. These sections will likely be refined once a refined 20-year ESAL value has been calculated by MDT.

Table 10: AASHTO Flexible Pavement Design

AASHTO Flexible Pavement Design **Required SN = 4.91 (Soil Resilient Modulus = 6,550 psi)**							
Material	Thickness		Structural Coefficient	Drainage Coefficient	Structural Number	Unit Cost (yd^3)	Cost (yd^2)
	(inches)	(feet)					
Option 1- Flexible Pavement, Crushed Base							
Plant Mix Surfacing	6.0*	0.50	0.41	1.0	2.46	$170.0	$28.33
Crushed Aggregate Base Course	18.0	1.50	0.14	1.0	2.52	$26.57	$13.29
Total Thickness	24.0	2.00			4.98		$41.62
Option 2- Flexible Pavement, Cement Treated Base, Crushed Base							
Plant Mix Surfacing	6.0*	0.50	0.41	1.0	2.46	$170.0	$28.33
Cement Treated Crushed Aggregate	9.0	0.75	0.20	1.0	1.80	$42.67	$10.67
Crushed Aggregate Base Course	6.0	0.50	0.14	1.0	0.84	$26.57	$4.43
Total Thickness	21.0	1.75			5.10		$43.43

*MDT required minimum thickness for > 300 daily ESALs or as generally required for pavement sections.

Rigid Pavement

The rigid analysis was conducted utilizing the Darwin computer program for rigid pavement design that follows the 1993 *AASHTO Guide for Design of Rigid Pavements*. The following data was utilized for the analysis:

Design Life = 20 years
Total Equivalent 18-kip Single Axle Loads = 6,800,000
Modulus of Subgrade Reaction, k = 300 psi/in
Initial Serviceability Index = 4.5
Terminal Serviceability =2.5
Regional Factor = 2.5
Reliability = 90%
Overall Deviation =0.45
Modulus of Rupture=600 psi

Modulus of Elasticity concrete=5,000,000 psi
Load Transfer, J=3.0
Drainage Coefficient=1

The results of the analysis indicated a minimum design thickness of 9.75 inches of Portland Cement Concrete Pavement. The rigid pavement section alternative should also include doweled joints and construction joints per MDT requirements.

Table 11: AASHTO Rigid Pavement Design

AASHTO Rigid Pavement Design K Value = 300 pci				
Material	Thickness		Unit Cost (yd^3)	Cost (yd^2)
	(inches)	(feet)		
Option 3 - Rigid Pavement				
Portland Cement Concrete	10.2	0.85	$353.35	$100.00
Crushed Aggregate Base Course	9.0	0.75	$26.50	$6.62
Total Thickness	20.5	1.71		$106.62

6.0 Traffic Improvement Options

Intersection and ramp improvement concepts were developed to address operational, geometric and safety needs within the study area. Operational improvements were identified to decrease congestion and improve traffic operations at locations where LOS is projected to drop below desirable levels by 2038. Traffic operation improvements were recommended to provide improved traffic flow while maintaining a desirable LOS.

The following details the concepts considered for the Underpass Avenue study area. The options discussed within this report are conceptual and will require further refinement during subsequent activities within the detailed design phase. Each improvement option includes a brief description and a list of advantages and disadvantages. Estimated costs based on 2016 average bid prices were developed including preliminary engineering, construction engineering, right-of-way and indirect costs (IDC). Preliminary Conceptual detail drawings are included in Appendix A of this document.

N.1 No Build

The study area currently consists of three intersections: 6th Street West and Central Avenue, Underpass Avenue and State Avenue, and Calhoun Lane and Underpass Avenue. The intersections of 6th Street West and Central Avenue, and Underpass Avenue and State Avenue are signal controlled. Calhoun Lane and Underpass Avenue consist of a one way stop on Calhoun Lane.

The No Build option includes existing geometrics and traffic control of all three intersections. This option was used to establish baseline conditions and to calibrate the traffic analysis models as accurately as possible.

Advantages:

- No cost.

Disadvantages:

- Does not address queueing and storage issues.
- Does not address hydraulic deficiencies.
- Does not address noncompliant ADA pedestrian facilities.

Potential Challenges:
N/A

Planning-level Cost Estimate:
N/A

Conclusion:
ADVANCED - The “No Build” option was used to compare potential improvement options.

6.1 6th Street West / Central Avenue

R.1 Roundabout

This concept includes replacing the signalized intersections at 6th Street West and Central Avenue with a dual lane roundabout. The dual lane roundabout will match the existing lane configuration with the exception of Central Avenue traveling west; traffic will remain in two dual through and turn lanes instead of the existing dedicated left turn lane, dedicated through lane, and dual through and right turn lane.

Traffic Operations:

6th Street West / Central Avenue	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
Control Delay	9.4	A	13.7	B
EB Approach	*10.8*	*B*	*16.8*	*C*
WB Approach	*11.2*	*B*	*17.8*	*C*
NB Approach	*7.6*	*A*	*9.5*	*A*
SB Approach	*9.8*	*A*	*14.5*	*B*
PM Peak Hour				
Control Delay	14.1	B	36.2	E
EB Approach	*14.8*	*B*	*41.0*	*E*
WB Approach	*20.7*	*C*	*72.5*	*F*
NB Approach	*9.2*	*A*	*12.6*	*B*
SB Approach	*13.8*	*B*	*23.3*	*C*

Advantages:

- Improved safety.
- Improved off-peak performance.

Disadvantages:

- PM queues interfere with Montana Avenue.
- Requires right-of-way.

Potential Challenges:

Additional right-of-way is needed on the north half of the roundabout. Unbalanced volumes will likely result in queuing issues.

Estimated Cost:

N/A - Conceptual geometric design of this option was not completed as part of this project.

Conclusion:

ADVANCED – Potential operational benefits may exist with paired roundabouts at both major intersections.

6th Street West / Central Avenue

S.1 Traffic Signal

This concept includes the installation of a new traffic signal at the intersection of 6th Street West and Central Avenue. The proposed intersection would add an additional northbound left turn lane through removal of the existing median. This optional left turn lane will decrease queue lengths, but may not be immediately necessary. The signal would be coordinated with the State Avenue / Underpass Avenue intersection to accommodate peaking demands.

Traffic Operations:

6th Street West / Central Avenue	2018		2038	
	Delay	LOS	Delay (s)	LOS
AM Peak Hour				
Control Delay	20.6	C	30.4	C
EB Approach	*14.3*	*B*	*20.1*	*C*
WB Approach	*27.7*	*C*	*41.7*	*D*
NB Approach	*14.6*	*C*	*19.8*	*B*
SB Approach	*32.5*	*C*	*51.3*	*D*
PM Peak Hour				
Control Delay	23.4	C	34.9	C
EB Approach	*16.9*	*B*	*25.8*	*C*
WB Approach	*25.5*	*C*	*36.6*	*D*
NB Approach	*21.5*	*C*	*32.7*	*C*
SB Approach	*32.6*	*C*	*50.9*	*D*

Advantages:

- Improved peak hour LOS.
- Minimal right-of-way.

Disadvantages:

- Some induced delay during off-peak hours.

Potential Challenges:

Potential utility impacts may result from this option. Additional coordination with the City of Billings is required to improve this intersection.

Estimated Cost:

$1,086,000

Conclusion:

ADVANCED - This option would serve to add additional capacity with the addition of a NB left turn lane. With MDT right-of-way on the SE and SW corners of the intersection, the typical section could be widened.

6.2 State Avenue / Underpass Avenue

R.2 Roundabout

This dual lane roundabout concept closely matches the existing lane configurations to reduce the project limits. The roundabout would include a westbound right slip lane.

Traffic Operations:

State Avenue / Underpass Avenue	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
Control Delay	8.2	A	13.3	B
EB Approach	*8.2*	*A*	*10.1*	*B*
WB Approach	*2.5*	*A*	*2.9*	*A*
NB Approach	*13.6*	*B*	*26.7*	*D*
SB Approach	*10.9*	*B*	*15.3*	*C*
PM Peak Hour				
Control Delay	10.8	B	21.9	C
EB Approach	*11.9*	*B*	*17.1*	*C*
WB Approach	*2.5*	*A*	*2.9*	*A*
NB Approach	*16.8*	*C*	*41.9*	*E*
SB Approach	*14.9*	*B*	*28.3*	*D*

Advantages:

- Improved safety.
- Minimal right-of-way.

Disadvantages:

- NB queuing extends through the Calhoun intersection.

Potential Challenges:
Circulating volumes reduce available gaps for the northbound approach.

Estimated Cost:
$2,794,000

Conclusion:
ADVANCED – Potential operational benefits may exist with paired roundabouts at both major intersections.

State Avenue / Underpass Avenue

S.2 Traffic Signal

This concept includes the installation of a new traffic signal at the intersection of Underpass Avenue and State Avenue. An additional southbound left turn lane could be included if the existing median is removed. The existing slip lanes would be perpetuated. The northbound approach would include a shared through/left, through and dedicated right turn lane to better store queues. The shared through/left could also be a protected left turn. Signal timing would be coordinated with the 6th Street West / Central Avenue intersection.

Traffic Operations:

State Avenue / Underpass Avenue	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
Control Delay	22.8	C	30.4	C
EB Approach	*27.8*	*C*	*47.0*	*D*
WB Approach	*19.2*	*B*	*30.5*	*C*
NB Approach	*38.3*	*D*	*48.6*	*D*
SB Approach	*16.3*	*B*	*16.4*	*B*
PM Peak Hour				
Control Delay	24.7	C	33.4	C
EB Approach	*29.6*	*C*	*47.9*	*D*
WB Approach	*22.2*	*C*	*33.1*	*C*
NB Approach	*37.0*	*D*	*48.5*	*D*
SB Approach	*19.7*	*B*	*22.8*	*C*

Advantages:

- Minimal right-of-way required.
- Improved long-term performance.

Disadvantages:

- Significant reconstruction required.

Potential Challenges

Significant disruption to traffic will occur during construction considering the extensive storm drain improvements required with the project.

Estimated Cost:

$2,122,000

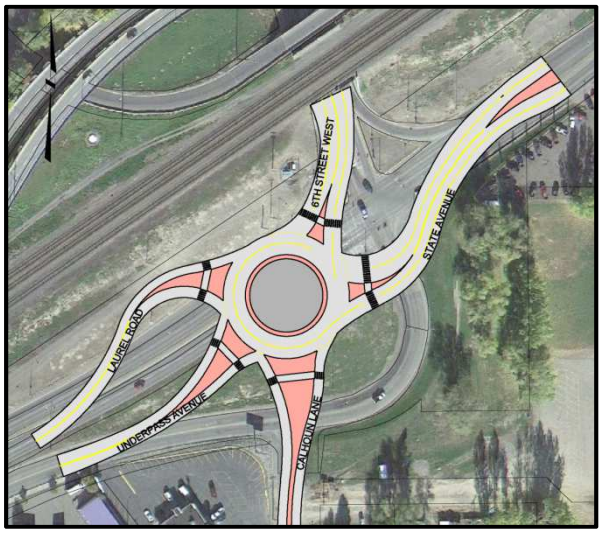
Conclusion:

ADVANCED - This option would better accommodate directional flows during the peak hours and reduce queuing conflicts.

6.3 State Avenue / Underpass Avenue / Calhoun Lane

R.3 5-Legged Roundabout

A five-legged roundabout was analyzed at this location, but was ruled out as a viable concept and will not be advanced further due to geometric issues. The intent of the roundabout was to accommodate all traffic on Laurel Road, State Avenue, Underpass Avenue, Calhoun Lane, and North 6th Street West by utilizing a large roundabout in place of the two existing intersections. The roundabout configuration was deemed infeasible due to the complicated geometry, specifically the acute angles between the three legs on the west and south side of the intersection (Laurel Road, Underpass Avenue, and Calhoun Lane).



Advantages:

- Reduction of intersections.

Disadvantages:

- Difficult geometrics.
- Extensive tie-ins required.

Potential Challenges:

Accommodating five legs would require realignment of all legs and less than desirable geometrics. The concept would require additional right-of-way to better align the roundabout at the current intersection location.

Estimated Cost:

N/A - Not analyzed due to geometric constraints.

Conclusion:

NOT ADVANCED – Challenging geometrics and inadequate approach angles make this option infeasible.

6.4 Calhoun Lane / Underpass Avenue

C.1 Stop Control

This concept includes the reconstruction of the intersection to tie into the new Calhoun Lane project and perpetuate the existing stop control. A three-lane typical section would allow for a dedicated northbound left and right turn lane. The typical section also accommodates bicycle lanes. A signal warrant analysis indicates the intersection will likely not meet warrants within the design horizon of the study (2038).

Traffic Operations:

Calhoun Lane / Underpass Avenue	2018		2038	
	Delay (s)	LOS	Delay (s)	LOS
AM Peak Hour				
NB Approach	11.6	B	13.6	B
EB Approach	*0.0*	*A*	*0.0*	*A*
WB Approach	*1.9*	*A*	*2.0*	*A*
PM Peak Hour				
NB Approach	12.5	B	15.1	C
EB Approach	*0.0*	*A*	*0.0*	*A*
WB Approach	*4.2*	*A*	*4.6*	*A*
Note: LOS for this intersection is based on the NB approach, the stop-controlled approach with the longest delay.				

Advantages:

- Improved queue storage.

Disadvantages:

- Right-of-way or construction permits may be required.

Potential Challenges:
The need for additional right-of-way is anticipated, particularly from the Moose Lodge and Reno Club properties.

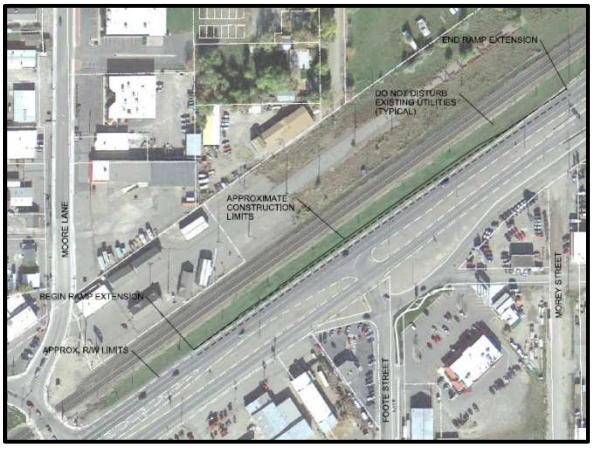
Estimated Cost:
$727,000

Conclusion:
ADVANCED - This is a feasible option that will tie into the newly reconstructed Calhoun Lane typical section.

6.5 Laurel Road / Moore Lane

L.1 On-Ramp Extension

This concept includes the extension of the westbound on-ramp along Laurel Road between State Avenue and Moore Lane. The lane extension is approximately 1,200 feet in length and would eliminate the merge movement on Laurel Road. The intersection of Laurel Road and Moore Lane has an existing right turn lane on the east leg for westbound traffic; therefore, the lane extension would not affect the existing intersection configuration.



Advantages:

- Reduced merge /weave conflicts.
- Increased capacity along Laurel Road.

Disadvantages:

- Right-of-way required from BNSF/MRL.
- Relocation of utilities.

Potential Challenges:

The anticipated fill limits for the ramp extension are in close proximity to existing utility poles. Relocation of the MRL/BNSF telecommunication line is likely. The need for additional right-of-way is anticipated.

Estimated Cost:

$409,000

Conclusion:

ADVANCED - This is a feasible option that will reduce conflicts related to merging maneuvers along Laurel Road.

6.6 Corridor Analysis

The individual traffic improvement options pertaining to the intersections of 6th Street West / Central Avenue, State Avenue / Underpass Avenue, and Calhoun Lane / Underpass Avenue were modeled through PTV Vision's Vissim software to identify operational issues prior to advancement. Synchro and Sidra outputs were imported to Vissim to create the corridor models. The Vissim models were reviewed by DOWL and MDT staff to determine which traffic improvement options would perform at the design horizon (2038).

Calibration of the Vissim traffic model was performed through travel time and queue length measurements taken in the field on June 8-9, 2016. The data included queue verification and lengths during the peak hours and travel times through the intersections to ensure Vissim was portraying the existing conditions and driver behavior relative to the local conditions. Calibration of the Vissim model resulted in an accurate representation of the queuing through a peak 15-minute Vissim model with the current (2015) turning movement counts. The following narratives qualitatively describe the operations of each corridor analysis and summarize its effectiveness as a corridor-wide improvement option. Additional traffic analysis results are presented in the Appendix.

No Build

The No Build option was analyzed at the estimated letting year (2018) and design horizon year (2038) to determine how the existing conditions would perform.

- 6th Street West / Central Avenue (Existing Signal)
  - The southbound approach exhibits extensive queuing back to the Montana Avenue on-ramp and the State Avenue intersection. It is possible that the queue would potentially fail the State Avenue / Underpass Avenue intersection at some point within the 20-year design horizon. In addition, the eastbound queuing along Central is significant.
- State Avenue / Underpass Avenue (Existing Signal)
  - The southbound left turn maneuver generates a large queue nearly extending to Central Avenue at times. It is possible that this queue may eventually fail the Central Avenue intersection.
- Underpass Avenue / Calhoun Lane (Stop Control)
  - Queuing along Underpass Avenue frequently extends through the Calhoun Lane intersection, effectively blocking several movements including the westbound to southbound left turn.

S.1 / R.1 / C.1 (Signal / Roundabout / Stop Control)

- 6th Street West / Central Avenue (Signal)
  - The northbound leg has the longest queue. However, with the roundabout to the south of the intersection, the traffic volume is more spread out as opposed to remaining platooned. This causes a smaller queue at the intersection compared to the fully signalized option.
- State Avenue / Underpass Avenue (Roundabout)
  - The northbound leg queue stretches to the Calhoun Lane intersection. This is due to the high volume of vehicles in the roundabout conflicting with this leg (this includes the southbound left, eastbound left, and eastbound through movements). This queuing would fail the Calhoun intersection and create a queue of westbound traffic that would extend back to the roundabout. Vissim is unable to portray this

interaction as it will keep an intersection clear for other movements although this is not realistic.
    - The southbound leg has another high volume movement, but only a small amount of delay due to the small volume from the conflicting movements within the roundabout at that leg (this includes the westbound left, westbound through, and northbound left movements).
- Underpass Avenue / Calhoun Lane (Stop Control)
    - The northbound right has longest delay, mostly due to the queue from the State Avenue intersection. This does not include the eastbound through vehicles because the delay for this movement is caused by the State Avenue queue, and not caused specifically by the Calhoun Lane intersection.
    - The westbound lefts have similar delays to northbound right, due to the queue from the State Avenue intersection. The westbound leg queue at this intersection almost reaches the roundabout at State Avenue, but does not appear to ever interfere with traffic within the roundabout.

Conclusion:
NOT ADVANCED – Queuing through the Calhoun Lane intersection is anticipated to fail both the roundabout and the stop controlled intersections.

R.1 / R.2 / C.1 (Roundabout / Roundabout / Stop Control)

- 6th Street West / Central Avenue (Signal)
    - The leg with the longest delay is the westbound queue. The queue develops because of the high conflicting traffic within the roundabout. Specifically, the northbound left and northbound through movements. These high volume movements create very little opportunity for the vehicles on the westbound leg to enter the roundabout. The queue extends beyond the limits of the VISSIM model along Montana Avenue, effectively failing that intersection as well.
    - The northbound leg includes the highest volumes, but has little delay entering the roundabout. This is due to the low volume of its one conflicting movement; the eastbound left.
- State Avenue / Underpass Avenue (Roundabout)
    - The northbound queue stretches to the Calhoun Lane intersection. This is due to the high volume of vehicles in the roundabout conflicting with this leg (this includes the southbound left and eastbound through movements).
    - The southbound leg has high volume movements, but only a small amount of delay due to the small volume from the conflicting movements within the roundabout at that leg (this includes the westbound through and northbound left movements).
- Underpass Avenue / Calhoun Lane (Stop Control)
    - The northbound right has longest delay, mostly due to the queue from the State Avenue intersection. This does not include the eastbound through vehicles because the delay for this movement is caused by the State Avenue queue, and not caused specifically by the Calhoun Lane intersection.
    - Westbound lefts see a similar delay as the northbound right due to the queue along Underpass Avenue.

Conclusion:
NOT ADVANCED – Excessive westbound queuing will interrupt traffic flow on Montana Avenue. Queuing along Underpass Avenue will extend through the Calhoun Lane intersection as well.

S.1 / S.2 / C.1 (Signal / Signal / Stop Control)

- 6th Street West / Central Avenue (Signal)
  - The longest queues are on the northbound leg of the intersection. This is mainly due to the split phasing on Central Avenue increasing the cycle length. Queuing does not interfere with any other intersection. An optional dual left turn lane could be included with removal of the existing median and widening of 6th Street West.
- State Avenue / Underpass Avenue (Signal)
  - The dual northbound through lane helps to reduce queuing and eliminates interference with the Calhoun Lane intersection.
  - The optional dual southbound left turn lane allows for shorter green time for that movement. This helps allocate more green time to other movements. The turn lane could be included with removal of the existing median.
- Underpass Avenue / Calhoun Lane (Stop Control)
  - The northbound right has the longest delay at the intersection, but the delay is improved over the other corridor options.
  - Westbound lefts have similar delay to northbound rights, but not as high a volume as the northbound right movement.

Conclusion:
ADVANCED – Queuing is not anticipated to interfere with adjacent intersections and the potential inclusion of additional left turn lanes would benefit the 6th Street West / Central Avenue and State Avenue / Underpass Avenue intersections.

Coordination Recommendations:
Traffic signal progression analysis was performed to determine coordination settings for the two signal systems. The goal of the analysis was to provide an optimal progression bandwidth for the northbound and southbound traffic. The State Avenue intersection carries higher traffic volume than the Central Avenue intersection; therefore, it was assumed as the critical intersection. Cycle lengths, green time, yellow and all-red time were determined prior to this analysis during the traffic operations analysis. For the southbound traffic, coordination preference were given to the southbound left-turn and southbound thru movements at the State Avenue intersection. For the northbound traffic, coordination preference were given to the northbound left-turn and northbound thru movements at the Central Avenue intersection.

Figure 10 and Figure 11 show the time-space diagram of the signal coordination. The horizontal bars represent each junction, including the Montana Avenue eastbound On-ramp. The bars for the Central Avenue intersection and State Avenue intersection are broken into different segments that represent green, yellow and all-red times. The diagonal shaded areas represent the band, within which the vehicles can travel through without stopping. The red-shaded band is for northbound, and the blue-shaded band is for southbound. As shown in Figure 10, signals in 2018 can be coordinated such that a 40-second offset will allow northbound bandwidth of 20 seconds and southbound bandwidth of 24 seconds. As shown in Figure 11, signals in 2038 can be coordinated such that a 67-second offset will allow northbound bandwidth of 32 seconds and southbound bandwidth of 33 seconds. These coordination schemes appear to provide optimal signal progression.

Figure 10: Future 2018 Signal Coordination

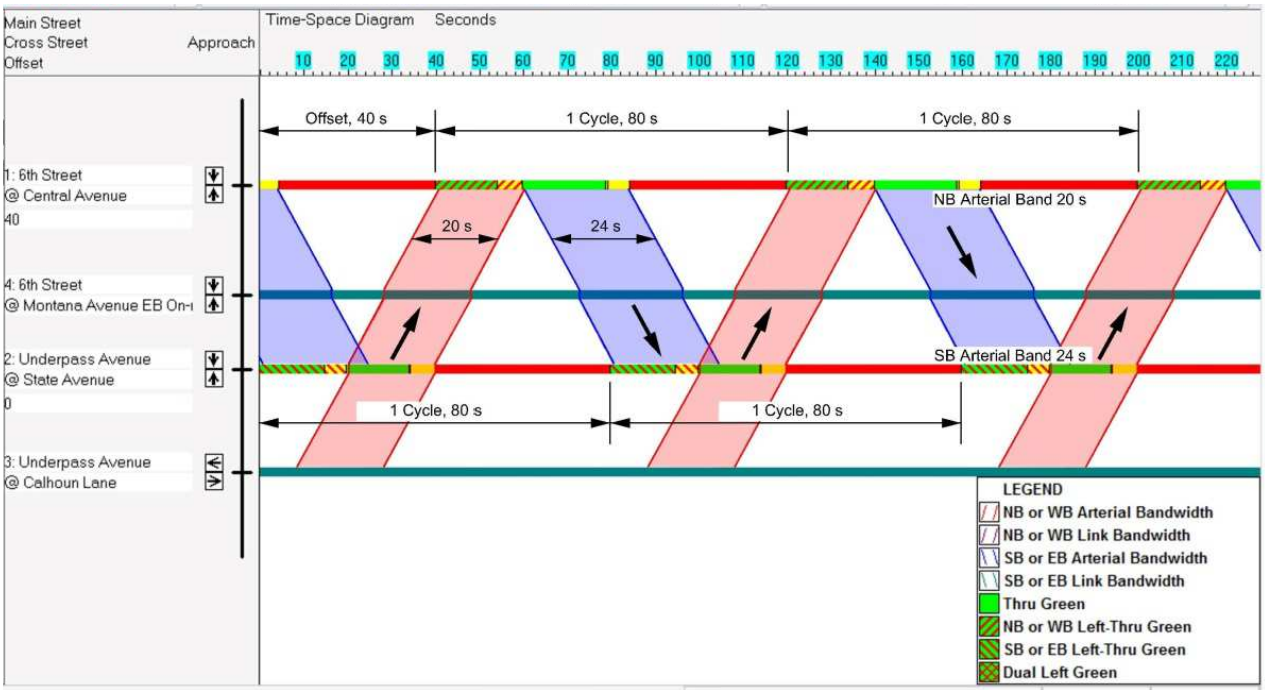
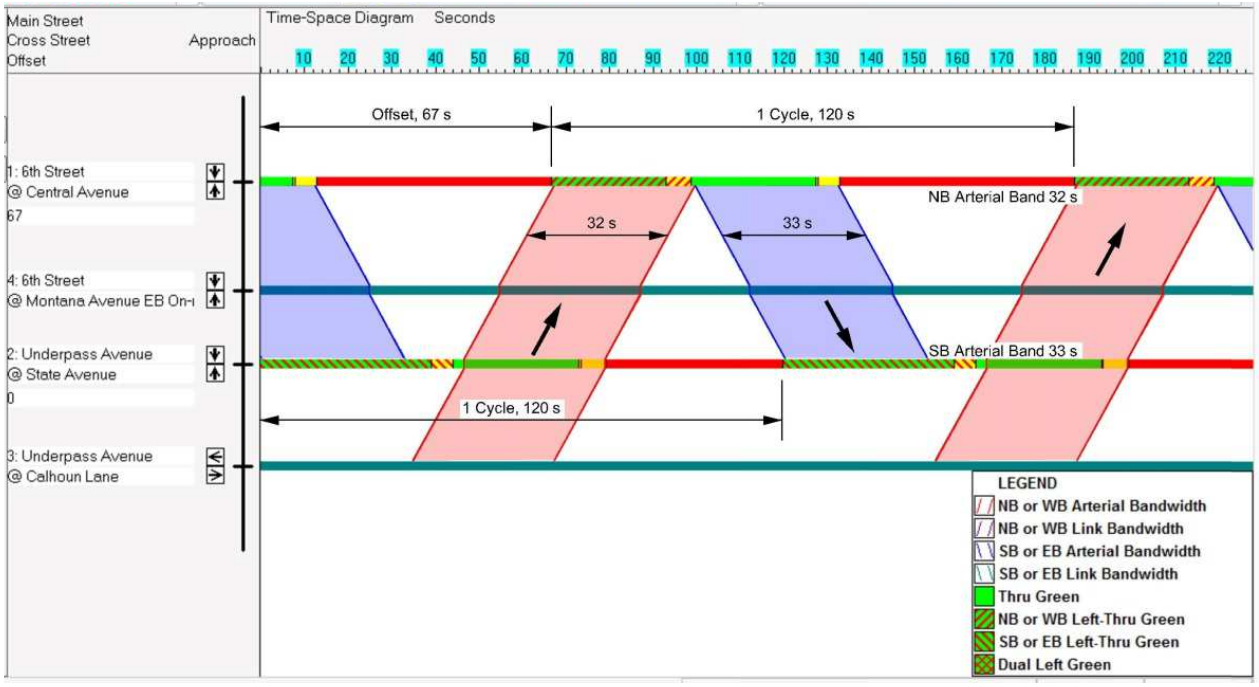


Figure 11: Future 2038 Signal Coordination

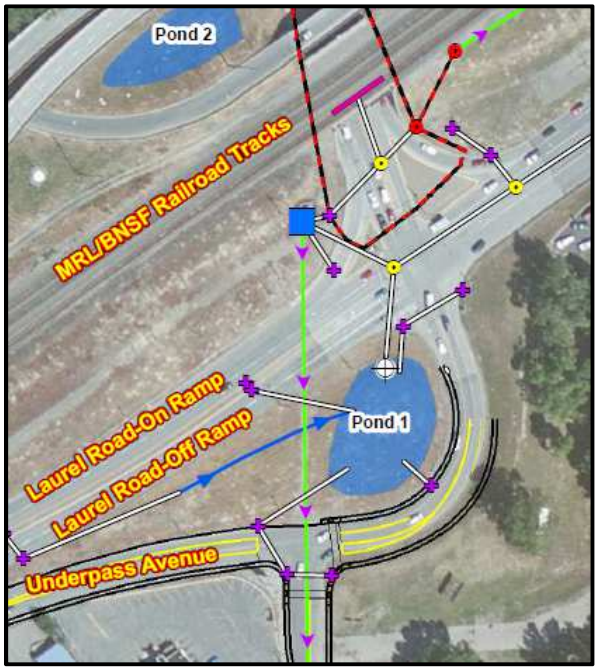


7.0 Hydraulics Improvement Options

Hydraulic concepts were developed to address poor drainage in the study area. These improvements were identified to develop a system with additional capacity to handle the storm water runoff, decrease the flood occurrence at the underpass, and explore alternate means of handling storm water runoff onsite through retention/detention facilities.

H.1 Existing Pump House

This concept would leave the existing pump house in place and improve the surrounding storm water system. Improvements include adding additional inlets, storm water pipes, retention ponds, and a detention pond.



Five additional inlets would be installed along Laurel Road and Underpass Avenue. To reduce demand on the storm water system during peak flow events, Pond 1 would be built to route runoff from the five additional inlets to the pump house. An outfall structure would be constructed at the outlet of Pond 1 to control outflow into the pump house. Additionally, two other ponds would be built as retention facilities that drain by infiltration.

Installation of additional inlets along State Avenue (East) to eliminate large spread widths that exist near the west end of State Avenue is also proposed as part of this option. Additionally, a new high capacity grate system at the roadway sag beneath the railroad underpass will be installed to increase interception capacity and decrease the risk of grate clogging due to debris buildup. This inlet will be similar to the sag inlet installed at the railroad underpass in Laurel, MT. Median inlets would be installed in each roadway lobe to intercept runoff and prevent it from spilling the roadway curb and entering the proposed intersection.

Advantages:

- Less expensive than other options.
- Minimal MRL involvement.
- Pond 1 will reduce the peaking.

Disadvantages:

- Wet well is undersized.
- Limited maintenance accessibility.

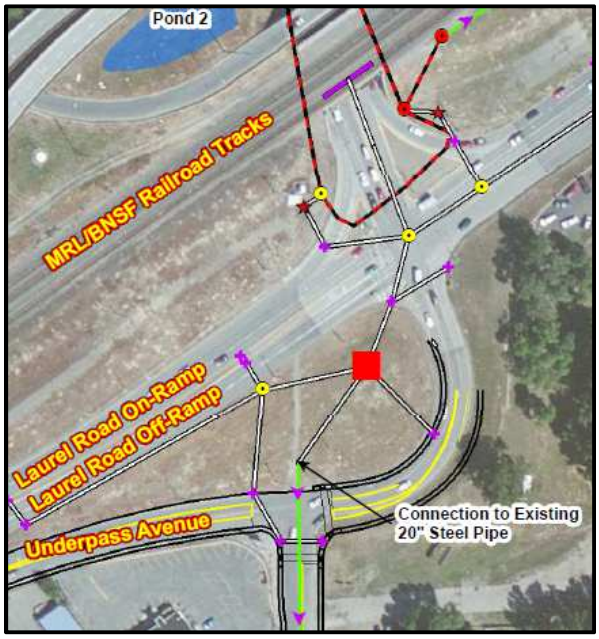
Estimate Cost:
$340,000

Potential Challenges:
Pump life and maintenance will continue to be an issue with the undersized wet well.

Conclusion:
NOT ADVANCED – Additional wet well capacity is desired to improve pump life.

H.2 Relocate Pump House to Southwest Corner

This concept would relocate the pump house to the southwest corner of the intersection and improve the surrounding storm water system. This would allow for better maintenance access and increased safety for maintenance personnel.



Like option H.1, five additional inlets would be installed along both Laurel Road and Underpass Avenue to intercept water prior to reaching the intersection and railroad underpass. All runoff intercepted by these inlets would be conveyed directly to the wet well at the new pump house. Two additional inlets would be installed along State Avenue. A new high capacity grate would be installed at the roadway sag beneath the railroad underpass to increase interception and reduce flooding issues due to inlet clogging. Median inlets would be installed at each roadway lobe to intercept runoff and prevent it from spilling over the roadway curb and entering the intersection.

The new pump house system would replicate the design for the Laurel underpass system. This system would consist of a large high capacity grate at its sag location, an 18-ft circular underground wet well, and three submersible pumps inside the wet well. The three submersible pumps work together to convey flows out of the wet well. For low flows, one pump operates to drain the incoming groundwater and when a high inflow occurs, the two other pumps activate. The submersible pumps are smaller and more manageable to remove and transport.

Advantages:

- Improved maintenance access.
- Larger wet well.
- Utilize existing pump station during construction.

Disadvantages:

- Highest construction cost.
- No pond at the pump house location, which increases the inflows into the wet well.

Estimated Cost:

$530,000

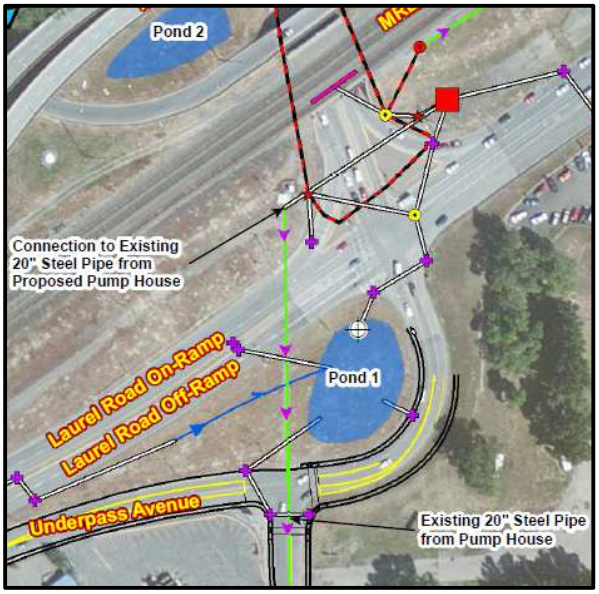
Potential Challenges:

Potential impacts to utilities may result from this option. The need for additional right-of-way is anticipated, particularly to the BNSF/MRL property.

Conclusion:

NOT ADVANCED – This option would not accommodate Pond 1, which would require a larger pump house wet well.

H.3. Relocate Pump House to Northeast Corner



This concept would relocate the storm water pump house and improve the surrounding storm water system. The pump house would be relocated to the northeast corner of the State Avenue and Underpass Avenue intersection to allow for better maintenance access and increased safety for maintenance personnel.

The location of the new pump house would allow for the installation of up to three ponds to route and control runoff. Pond 1 would be a detention facility with controlled outflow while Ponds 2 and 3 would be retention facilities and drain by infiltration. Proposed new inlet locations would be very similar to other proposed options, but the piping network would be different. A high capacity grate would be installed beneath the railroad structure in the sag curve to increase inlet efficiency and reduce the chance of ponding due to inlet plugging. Runoff would be pumped from the proposed pump house to a location near the existing pump house where it would tie into the existing 20-inch steel force main and be pumped south to Calhoun Lane. The proposed pump house and wet well would be similar to the Laurel Underpass system.

Advantages:

- Improved maintenance access.
- Larger wet well.
- Utilize existing pump station during construction.
- Pond 1 will reduce the peaking.

Disadvantages:

- Higher construction cost.
- May require larger pumps due to extended force main.

Estimated Cost:
$500,000

Potential Challenges:
Extension of the 20-inch steel force main to the proposed pump house location.

Conclusion:
ADVANCED - This option allows for all of the proposed retention/detention ponds and relocates the pump house to a more desirable location.

8.0 Miscellaneous Improvement Options

Members of the public voiced concern over the existing congestion and queuing, conveyed the need for bicycle and pedestrian facilities, mentioned existing avian issues, and expressed the need to correct existing drainage issues. These comments from the public involvement period and MDT staff observations were considered and included in the cost estimates for the various traffic and hydraulic improvement options.

Bicycle Lanes

The study area contains a high volume of bicycle traffic. The City of Billings has recently adopted a Complete Streets policy which encourages consideration of all roadway users when making improvements to the City's transportation system. The section of the policy relating to bicyclists notes the City has worked towards increasing biking infrastructure to increase safety and encourage active transportation.

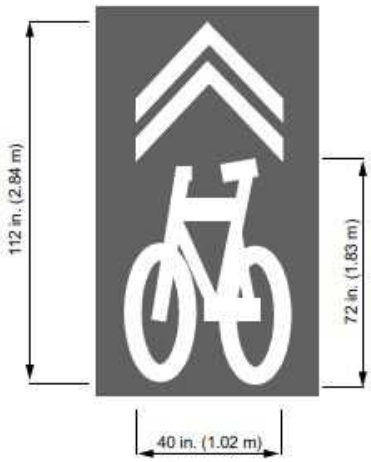
This option would provide a 4' bike lane in each direction of travel along all legs of the State Avenue and Underpass Avenue Intersection. Dedicated bicycle lanes will not be accommodated on 6th Street West due to the limited width available. The Calhoun Lane project contains bike lanes; therefore, utilization of bike lanes along 6th Street West would provide a connection from Calhoun Lane to the area north of the railroad tracks. Bike lanes will terminate prior to the roundabout and bicyclists would merge with motorized traffic. Bike lane signs should accompany all bike lanes.

During the design phase, consider transition of the bike lane to the sidewalk thru a curb opening to allow the bicycle traffic access the sidewalk to cross at the designated crosswalk.

Bicycle Shared Lane Markings and Signage

This option would provide shared bicycle lane markings along with appropriate bike route signage in the following locations:

- 6th Street West
- State Avenue
- Underpass Avenue



The existing conditions and proposed intersection configurations contain a sufficient room to stripe bike lanes, which is the safer of the two options since bike lanes better separate bicycles from vehicles. Since bike lanes are feasible, shared lane markings and signage may not necessary for the study area. Shared lanes should contain a minimum width of 12 feet.

Pedestrian Access

The study area contains a relatively high volume of pedestrian traffic due to the adjacent neighborhood and nearby commercial locations and facilities, specifically Albertsons and CVS. The City's Complete Streets policy relating to pedestrians suggests installation of sidewalks and crosswalks as part of improvements to aid in pedestrian mobility and safety.

This option would provide 5-foot minimum (6-foot preferable) sidewalks and crosswalks at the Underpass Avenue and State Avenue intersection, along Underpass Avenue between State Avenue and Calhoun Lane, and at the Underpass Avenue and Calhoun Lane intersection. New sidewalks are not proposed where sidewalks currently exist unless impacted by the proposed intersection improvements.

Sidewalks and crosswalks will be excluded from the following locations:

- South side of Central Avenue east of 6th Street West.
- East side of 6th Street West between State Avenue and Central Avenue.
- North and south side of the Laurel Road ramps west of Underpass Avenue.
- North side of Underpass Avenue west of Calhoun Lane.

Underpass Handrail

This option consists of removal of the existing handrail and installation of an ADA compliant handrail. The handrail is located adjacent to the sidewalk beneath the railroad structure. The proposed handrail would be continuous, extending the length of the structure and approximately 105 feet south of the structure and 45 feet north of the structure to protect pedestrians from the fall hazard caused by the vertical face created by the curb height.

Retrofitting the handrail to the existing concrete may be difficult depending on its condition. Maintaining minimum pedestrian clearances (48 inches) after the installation may also need to be considered.

Pedestrian and Median Lighting

This option consists of installing lighting beneath the MRL/BNSF railroad structure to improve safety for pedestrian traffic. Lighting will be placed along 6th Street West to increase the safety of both pedestrians and vehicles. These will be placed throughout the bridge crossings as well as the median on the north end of 6th Street West.

Underpass lighting is not required by the MDT Traffic Engineering design manual due to the length-to-height ratio of the railroad structure, but it is recommended to enhance driver visibility and pedestrian safety after daylight hours.

This proposed option would install LED underpass luminaires on the various structures. The luminaires would be installed along the existing sidewalk locations running on the west side of the structures. Lighting would promote pedestrian use of the sidewalk after daylight hours and improve pedestrian safety. Connecting lighting to the MRL structure without physical alteration to the structure may pose a challenge. Coordination with the railroad will be required.

Low Clearance Signage

This option entails the installation of “Low Clearance” signs on the MRL/BNSF railroad structure, the Montana Avenue on-ramp Structure, and the Montana Avenue and Laurel Road Structures. Per Chapter 12 Geometric Design Tables of the MDT Roadway Design Manual, the minimum vertical clearance for an urban minor arterial is 17’0”. The minimum clearance on the structures is as follows:

- MRL/BNSF railroad structure – 14’10”
- Montana Avenue on-ramp structure – 15’6”

- Montana Avenue structure – 15’6”
- Laurel Road structure – 15’6”

The installed signs should comply with the Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways and should display the minimum clearance for each structure.

Avian Deterrent System

This option consists of an avian deterrent system on the MRL/BNSF and the Montana Avenue on-ramp structures. The system would likely consist of multiple measures to ensure maximum effectiveness. An anti-roosting spike system would be placed on all exposed ledges on the exterior of the underpass structure. This system consists of stainless steel wire spike strips that are placed on ledges to deter birds from landing on exposed ledges and netting stretched along the underside of the structures. The wire strips and netting could be installed using glue, clamps or tie-downs depending on the installation area. The recommended netting is a heavy duty polyethylene blend with ¾” openings. Stainless steel hardware should be used for the installation. In discussions with MRL/BNSF, the avian deterrent system must allow for visual inspection of their structure. In addition, no physical modification may be made to the structure including welding or attaching the system with screws. The wire spike strips and netting should be checked regularly and replaced as warranted. MDT would be required to pay to install and maintain the avian deterrents.

Anti-Graffiti Treatment

This option involves the installation of anti-graffiti treatment along the abutments and piers for the MRL/BNSF structure, Montana Avenue on-ramp structure and the Montana Avenue and Laurel Road structures. In the past, the existing structures have been painted with graffiti. Installation of anti-graffiti treatment is recommended due to the high pedestrian use of the area and the anticipated increase in use associated with future improvements. The treatment is typically applied as a sacrificial coating which is removed along with the graffiti. Reapplication of the coating is necessary following removal of graffiti in conjunction with the sacrificial coating.

9.0 Recommendations

This conceptual design project identified a number of improvements that could mitigate traffic operational challenges and hydraulic issues within the study area. The preferred improvement options include a new signal at the 6th Street North / Central Avenue Intersection (S.1), a new signal at the State Avenue / Underpass Avenue intersection (S.2) and perpetuating stop control at the Underpass Avenue / Calhoun Lane intersection (C.1). The new signals would be run in coordination to maximize throughput during peak periods. Minimal right-of-way is anticipated, but coordination with the City of Billings would be required to improve the signal at 6th Street West / Central Avenue.

An additional improvement to traffic operations along Laurel Road could include the extension of the on-ramp from State Avenue to Moore Lane (L.1). While this improvement would reduce merging maneuvers along Laurel Road, it would require additional right-of-way from MRL and potential relocation of their communications line.

Other recommended improvement options within the study area include construction of bike lanes and pedestrian access including sidewalk, ADA compliant curb ramps, and crosswalks. Moving forward, bike lanes and/or shared lane markings should be considered along with the City's Complete Streets policy. ADA compliant handrail, underpass lighting, "low clearance" signs on structures, an avian deterrent system, and anti-graffiti treatment on the structures are also recommended.

The recommended hydraulic options include relocation of the pump house to the northeast corner of the State Avenue / Underpass Avenue intersection (H.3). Providing additional detention and retention facilities within the study area will reduce the necessary wet well volume and place less strain on the pumps.

Based on this evaluation, the recommended improvement options summarized in Table 12 best address the geometric, operational and hydraulic issues within the study area. The recommended options may be implemented together or in phases depending on available funding.

Table 12: Recommended Improvement Options

Option Category	Option ID	Option Description	Planning Level Cost Estimate
Traffic	S.1	6th Street West / Central Avenue Signal	$1,086,000
	S.2	State Avenue / Underpass Avenue Signal	$2,122,000
	C.1	Calhoun Lane / Underpass Avenue Stop Control	$727,000
	L.1	On-Ramp Extension	$409,000
Hydraulics	H.3	Relocate Pump House to Northeast Corner of State Avenue and Underpass Avenue Intersection	$500,000
		Cost Estimate Total	**$4,844,000**

10.0 References

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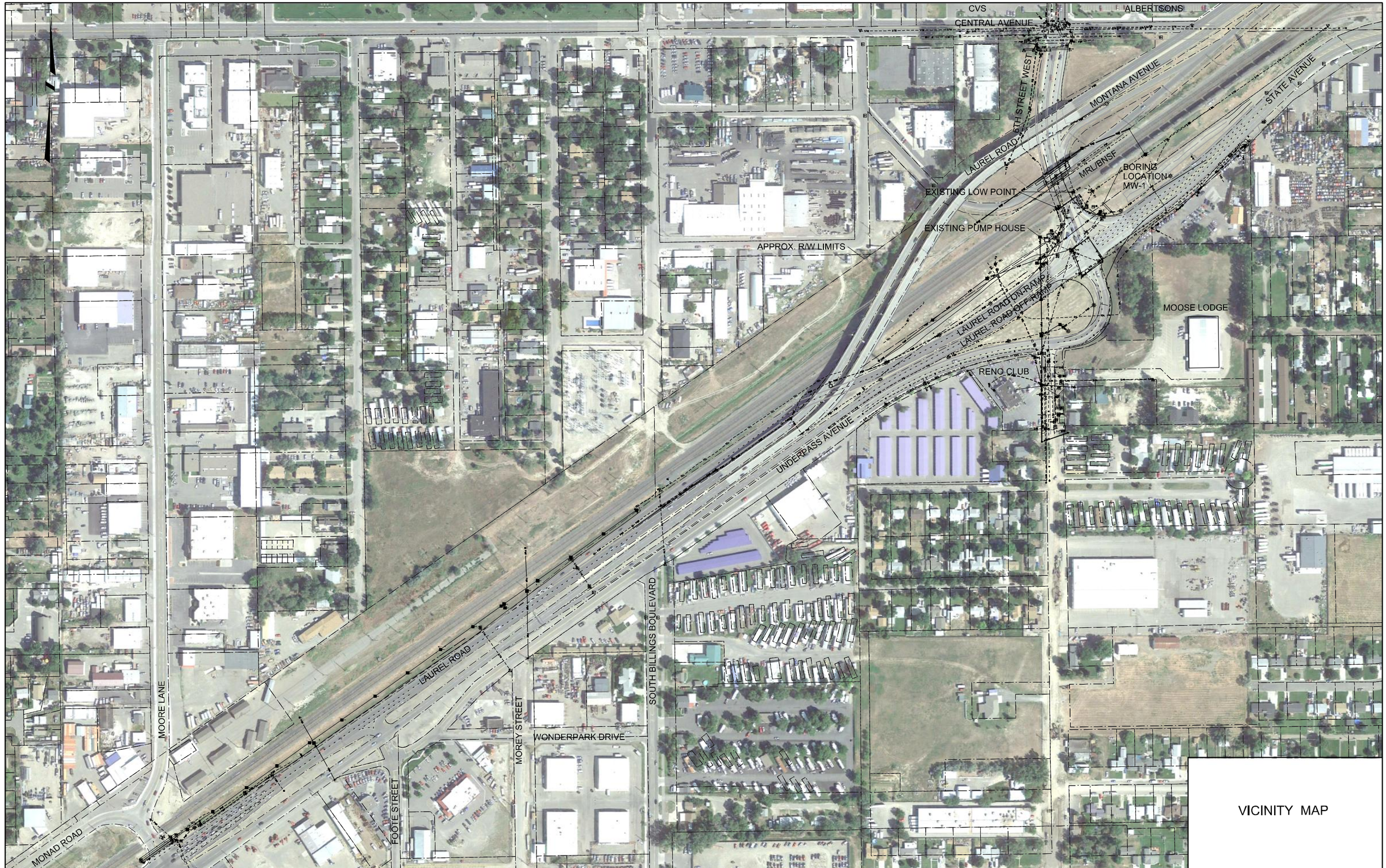
Appendix A
Improvement Options Exhibits and Cost Estimates



DOWL

VICINITY MAP

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2		8/26/2016	REVIEWED BY				
1		9:09:20 AM hmcdermott	CHECKED BY		YELLOWSTONE COUNTY	PRELIMINARY AGR	UPN 8669000

CENTRAL AVENUE

6TH STREET WEST

MONTANA AVENUE

MONTANA AVENUE ON-RAMP

LAUREL ROAD

MRL/BNSF

BORING LOCATION MW-1

STATE AVENUE

EXISTING LOW POINT

EXISTING PUMP HOUSE

APPROX. R/W LIMITS

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

UNDERPASS AVENUE

CALHOUN LANE

MOOSE LODGE

RENO CLUB

DOWL

EXISTING SITE MAP

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1		11:30:26 AM hmcdermott	CHECKED BY		YELLOWSTONE COUNTY		UPN 8669000

DOWL

WB-50
WB-50
WB-50
WB-57
WB-67

CENTRAL AVENUE

6TH STREET WEST

PB
SG

6TH STREET WEST /
CENTRAL AVENUE

TURNING MOVEMENTS

EXISTING CONDITIONS

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1		10:14:56 AM hmcdermott					

N

DOWNTOWN BILLINGS BYPASS

CENTRAL AVENUE

6TH STREET WEST

WB-50
AASHTO 2004 (LS)

WB-50
AASHTO 2004 (LS)

WB-50
AASHTO 2004 (LS)

WB-50
AASHTO 2004 (LS)

PB

6TH ST W & CENTRAL AVE INTERSECTION

TURNING MOVEMENTS

EXISTING CONDITIONS

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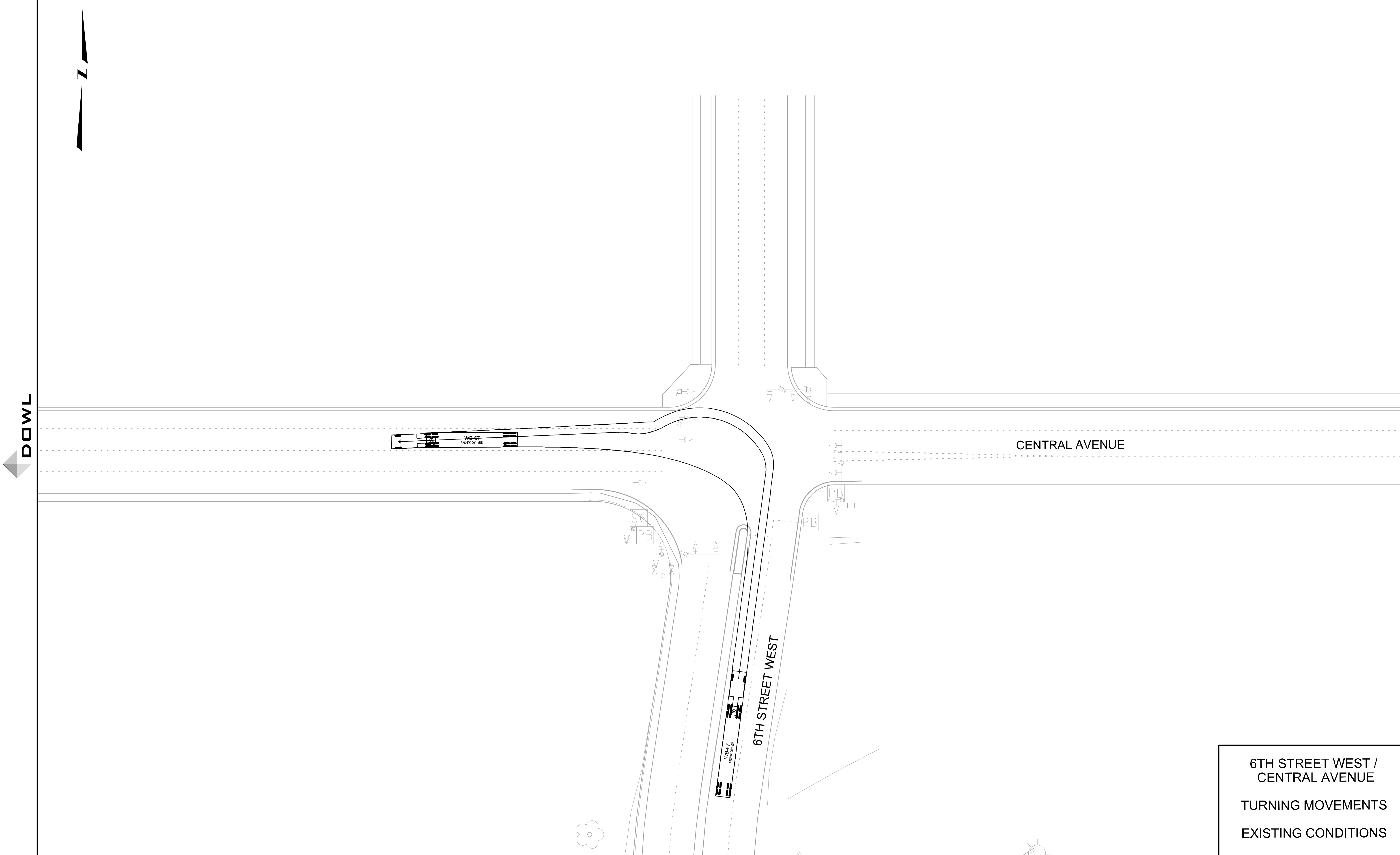

6TH STREET WEST /
CENTRAL AVENUE

TURNING MOVEMENTS

EXISTING CONDITIONS

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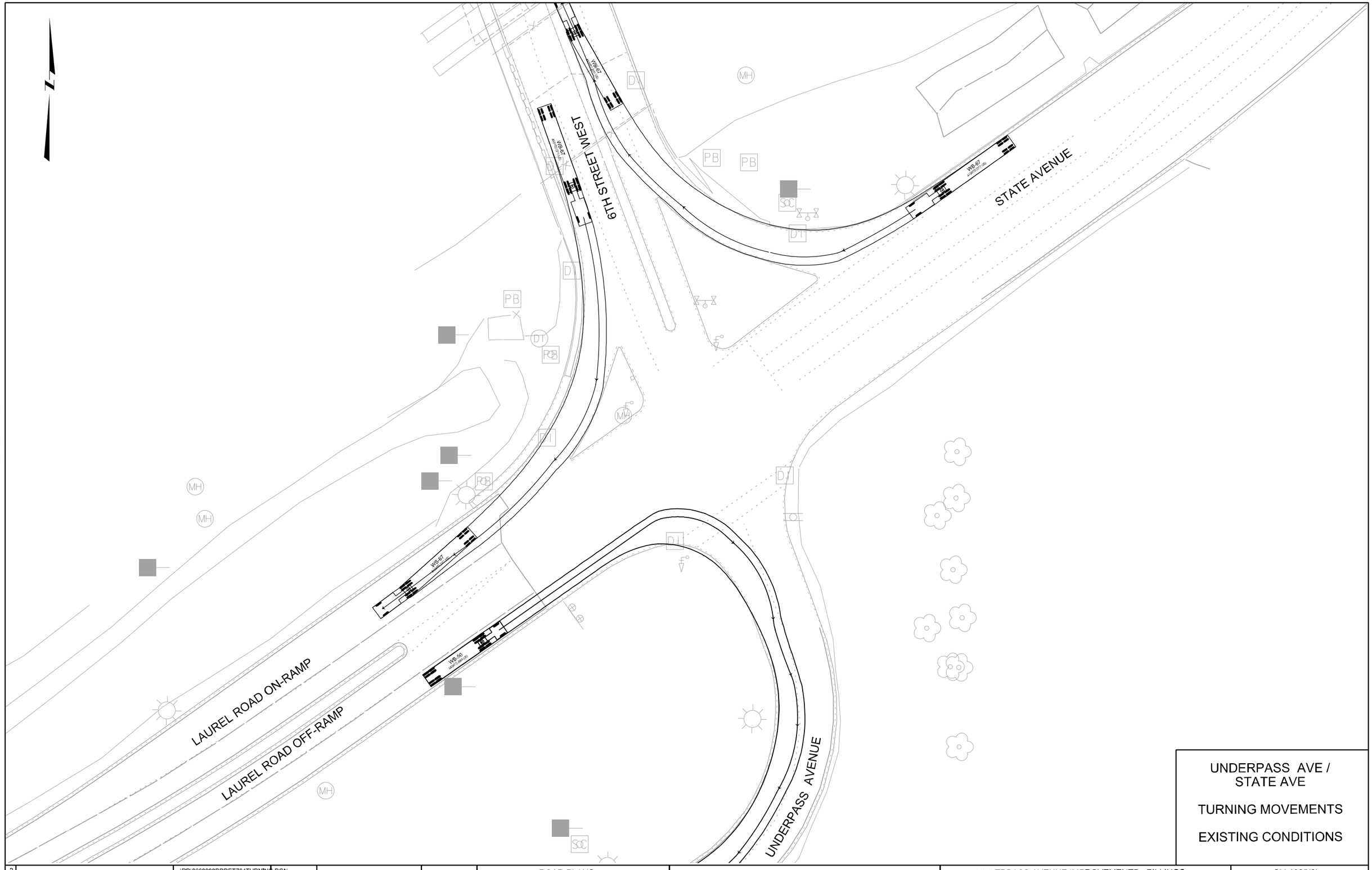
			YELLOWSTONE COUNTY		UPN 8669000	



DOWL

UNDERPASS AVE /
STATE AVE

TURNING MOVEMENTS

EXISTING CONDITIONS

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1		9:58:14 AM hmcdermott					

DOWL

6TH STREET WEST

STATE AVENUE

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

UNDERPASS AVENUE

WB-50
AXLES 1&2

WB-50
AXLES 3&4

WB-50
AXLES 1&2

WB-50
AXLES 3&4

UNDERPASS AVE / STATE AVE

TURNING MOVEMENTS

EXISTING CONDITIONS

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\RD\8669000RDDETZ04TURNING.DGN			ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
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DOWL

6TH STREET WEST

STATE AVENUE

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

UNDERPASS AVENUE

WB-50 (WB-62 AASHTO)

WB-50 (WB-62 AASHTO)

WB-50 (WB-62 AASHTO)

WB-50 (WB-62 AASHTO)

UNDERPASS AVE / STATE AVE

TURNING MOVEMENTS

EXISTING CONDITIONS

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\RD\8669000RDDETZ04TURNING.DGN			ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS / CM 1025(8)
2		8/25/2016					
1		9:59:05 AM hmcdermott			YELLOWSTONE COUNTY		UPN 8669000

DOWNTOWN BILLINGS BYPASS

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

UNDERPASS AVENUE

CALHOUN LANE

WB-50
AASHTO 2004 (SR)

WB-50
AASHTO 2004 (SR)

WB-50
AASHTO 2004 (SR)

WB-50
AASHTO 2004 (SR)

WB-50
AASHTO 2004 (SR)

UNDERPASS AVENUE / CALHOUN LANE

TURNING MOVEMENTS

EXISTING CONDITIONS

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\RD\8669000RDDETZ06TURNING.DGN			ROAD PLANS	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/25/2016					
1		10:23:41 AM hmcdermott			YELLOWSTONE COUNTY	PRELIMINARY AGR / UPN 8669000	

DOWNTOWN BILLINGS BYPASS

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

UNDERPASS AVENUE

CALHOUN LANE

WB-50 AASHTO 2004 (US)

WB-50 AASHTO 2004 (CB)

WB-50 AASHTO 2004 (RB)

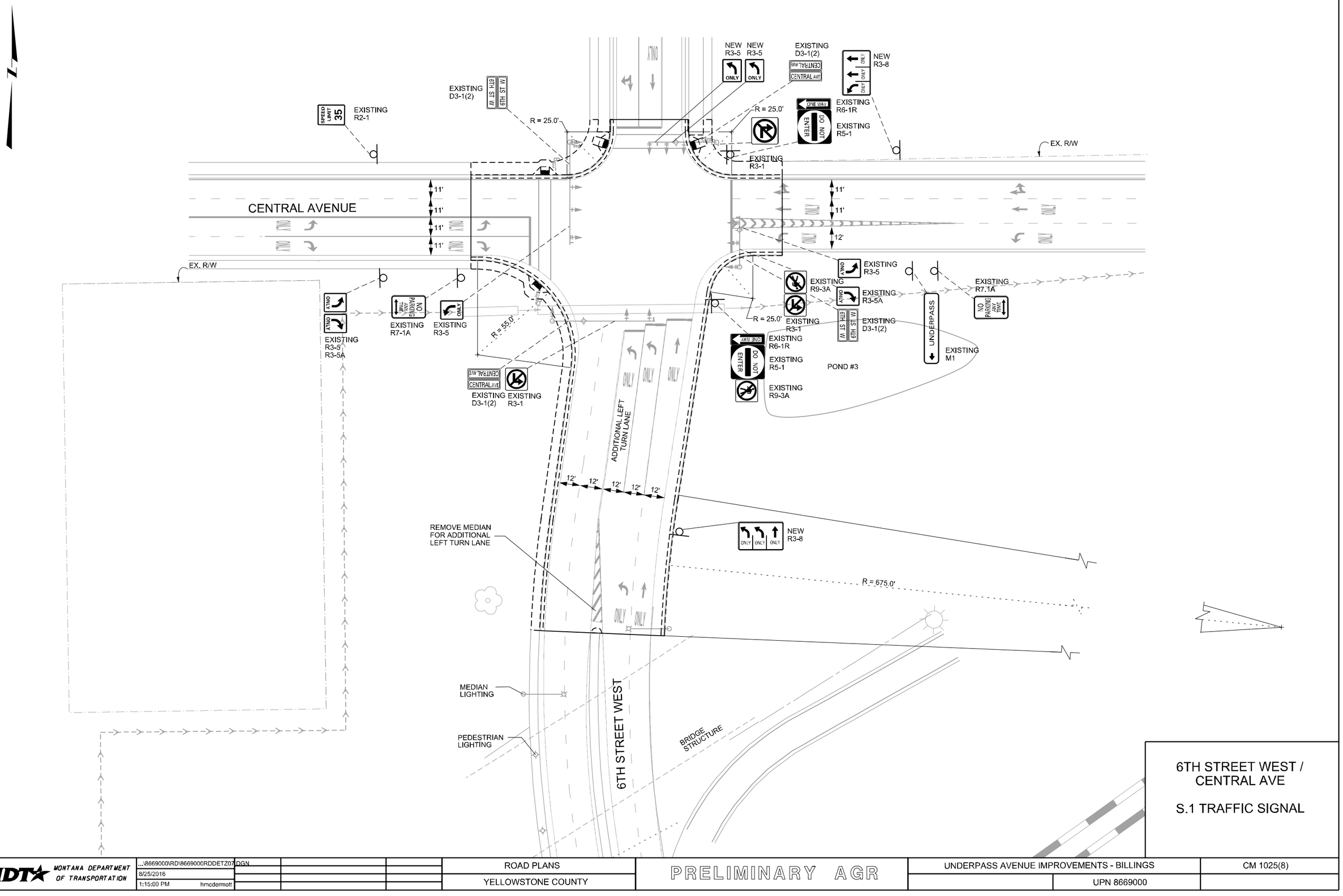
SINGLE UNIT TRUCK (SU-30)

UNDERPASS AVENUE / CALHOUN LANE

TURNING MOVEMENTS

EXISTING CONDITIONS

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\RD\8669000RDDETZ06TURNING.DGN			ROAD PLANS	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/25/2016					
1		10:24:15 AM hmcdermott			YELLOWSTONE COUNTY	PRELIMINARY AGR	UPN 8669000

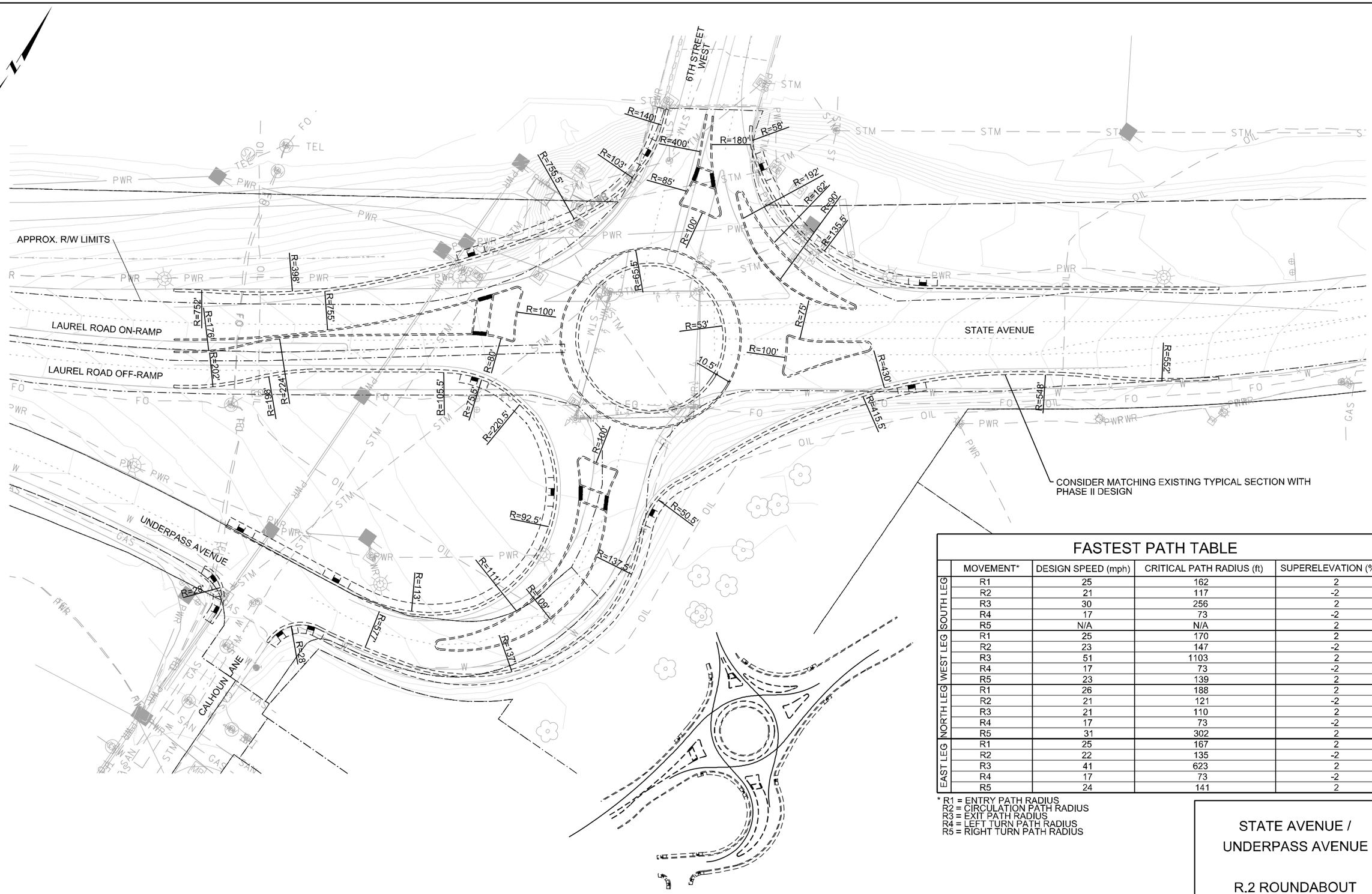


6TH STREET WEST / CENTRAL AVE

S.1 TRAFFIC SIGNAL

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ07.DGN			ROAD PLANS	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/25/2016			YELLOWSTONE COUNTY	PRELIMINARY AGR	UPN 8669000
1		1:15:00 PM hmcdermott					

DOWL



FASTEST PATH DIAGRAM

FASTEST PATH TABLE

	MOVEMENT*	DESIGN SPEED (mph)	CRITICAL PATH RADIUS (ft)	SUPERELEVATION (%)
SOUTH LEG	R1	25	162	2
	R2	21	117	-2
	R3	30	256	2
	R4	17	73	-2
	R5	N/A	N/A	2
WEST LEG	R1	25	170	2
	R2	23	147	-2
	R3	51	1103	2
	R4	17	73	-2
	R5	23	139	2
NORTH LEG	R1	26	188	2
	R2	21	121	-2
	R3	21	110	2
	R4	17	73	-2
	R5	31	302	2
EAST LEG	R1	25	167	2
	R2	22	135	-2
	R3	41	623	2
	R4	17	73	-2
	R5	24	141	2

* R1 = ENTRY PATH RADIUS
R2 = CIRCULATION PATH RADIUS
R3 = EXIT PATH RADIUS
R4 = LEFT TURN PATH RADIUS
R5 = RIGHT TURN PATH RADIUS

STATE AVENUE /
UNDERPASS AVENUE

R.2 ROUNDABOUT

DOWL

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ02.DGN	DESIGNED BY		ROAD PLANS	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/26/2016	REVIEWED BY				
1		9:22:00 AM hmcdermott	CHECKED BY		YELLOWSTONE COUNTY	PRELIMINARY AGR	UPN 8669000

DOWNTOWN BILLINGS BYPASS

POND #2

PEDESTRIAN LIGHTING

ADA COMPLIANT HANDRAIL

FIRST AVE S

WEST 90 BUSINESS

EXISTING M1

EXISTING M1

HIGH CAPACITY GRATE

6TH STREET WEST

BSNF/MRL STRUCTURE

EXISTING M1

EXISTING M1

SIX STREET W

90 WEST MONTANA AVE

EX. ABUTMENT RETAINING WALL

NEW R3-8

ONLY

CONNECTION TO EXISTING 20" STEEL FORCE MAIN

R = 140.0'

NEW R1.5L

6TH ST WEST UNDERPASS AVE

EXISTING R1-2

EXISTING OHD3

NEW R3-5

EX. R/W

EXISTING R4-7

EXISTING R1-2 NEW W4-2R

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

NEW R3-8D

ONLY

AHEAD

POND #1

STM

MH

D1

EXISTING R1-2

R = 100.0'

EX. R/W

NEW R3-8

PROPOSED PUMP HOUSE (30' X 30')

STATE AVENUE

R = 1.0'

R = 1.0'

EXISTING W4-1

R = 5.0'

14'

12'

12'

12'

12'

12'

12'

11'

12'

12'

11'

11'

R = 1.0'

R = 5.0'

R = 1.0'

STATE AVE

EXISTING D3-1(2)

RETAINING WALL

NEW R3-5

R = 60.0'

EXISTING OHD3

EAST INTERSTATE 90

TRUCK ROUTE

EXISTING R14-1 M6-1

EXISTING M3-2 M1-1 M6-3

ROLL OVER CURB

18.5'

12'

12'

12'

NEW R3-5

NEW R3-5

ROLL OVER CURB

UNDERPASS AVENUE

ONLY

ONLY

R = 60.0'

EXISTING D3-1(2)

STATE AVE

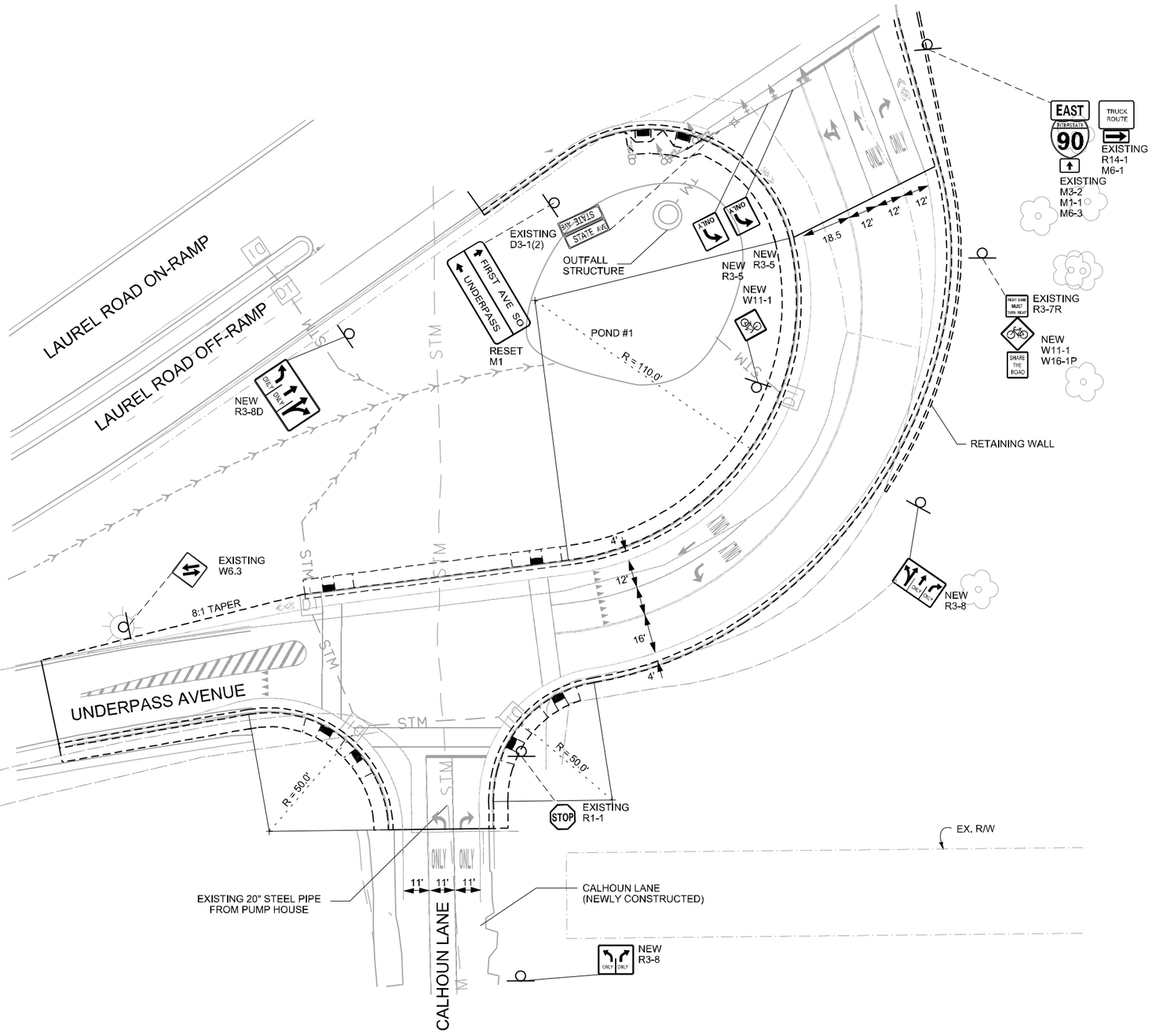
AHEAD

ONLY

UNDERPASS AVENUE / STATE AVENUE

S.2 TRAFFIC SIGNAL

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ07.DGN			ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS / CM 1025(8)
2		8/25/2016			YELLOWSTONE COUNTY		UPN 8669000
1		1:22:54 PM hmcdermott					



DOWL

UNDERPASS AVE / CALHOUN LANE

C.1 STOP CONTROL

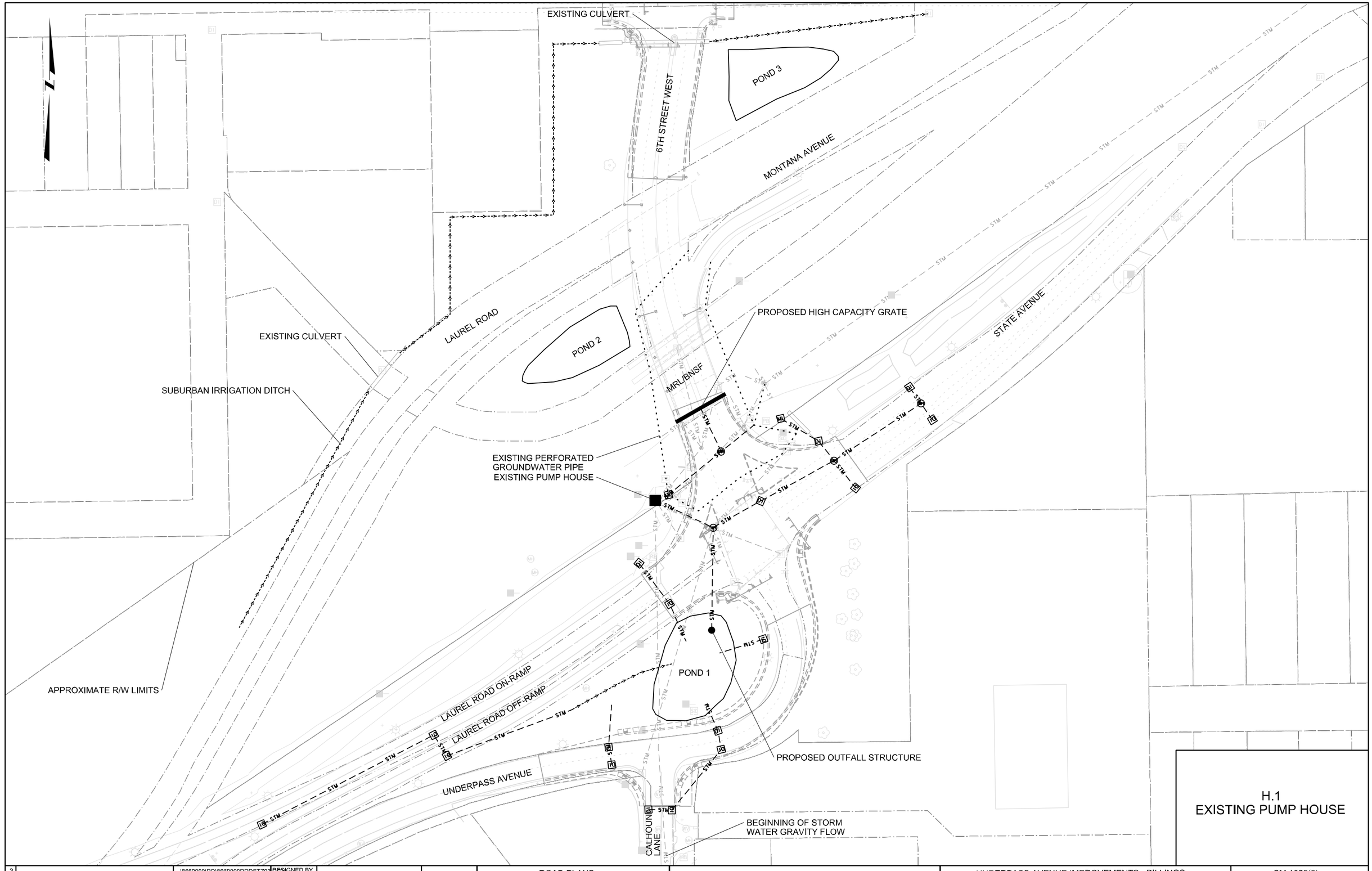
3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ07.DGN			ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/26/2016						
1		8:34:06 AM hmcdermott			YELLOWSTONE COUNTY		UPN 8669000	

DOWNTOWN BILLINGS BYPASS

MOORE LANE /
LAUREL ROAD

L.1 ON-RAMP EXTENSION

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ02.DGN	DESIGNED BY			ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS / CM 1025(8)
2		8/26/2016	REVIEWED BY					UPN 8669000
1		9:14:03 AM hmcdermott	CHECKED BY			YELLOWSTONE COUNTY		



3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ03.DGN	DESIGNED BY		ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/26/2016	REVIEWED BY					
1		8:36:20 AM hmcdermott	CHECKED BY		YELLOWSTONE COUNTY		UPN 8669000	

EXISTING CULVERT

POND 3

6TH STREET WEST

MONTANA AVENUE

LAUREL ROAD

EXISTING CULVERT

POND 2

PROPOSED HIGH CAPACITY GRATE

STATE AVENUE

MRL/BNSF

SUBURBAN IRRIGATION DITCH

EXISTING PERFORATED
GROUNDWATER PIPE

APPROXIMATE R/W LIMITS

LAUREL ROAD ON-RAMP

LAUREL ROAD OFF-RAMP

PROPOSED PUMP HOUSE

UNDERPASS AVENUE

CONNECTION TO EXISTING
20" STEEL PIPE

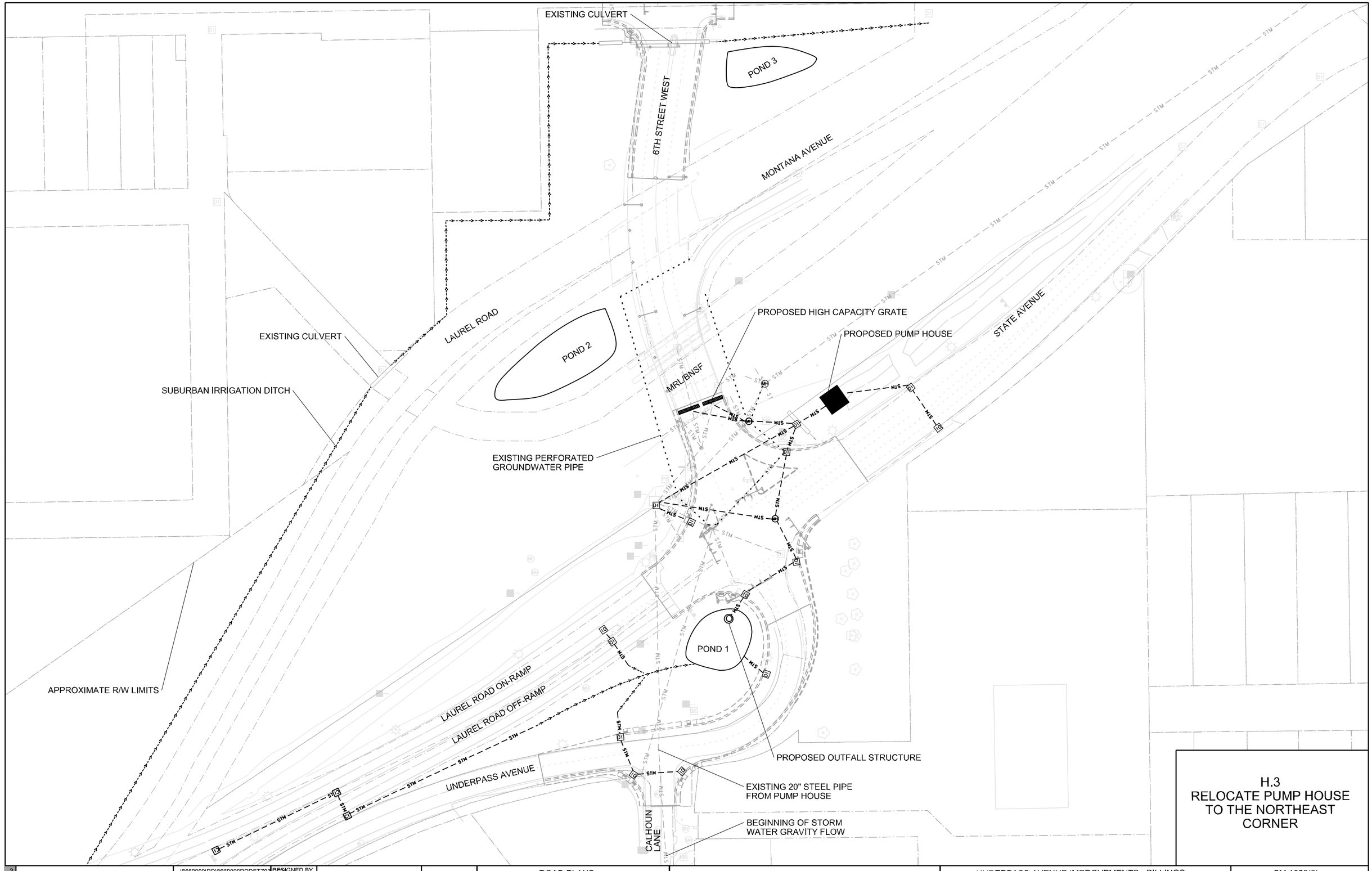
CALHOUN LANE

BEGINNING OF STORM
WATER GRAVITY FLOW

H.2
RELOCATE PUMP HOUSE
TO THE SOUTHWEST
CORNER

DOWL

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ03.DGN	DESIGNED BY			ROAD PLANS	PRELIMINARY AGR	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS / CM 1025(8)
2		8/26/2016	REVIEWED BY					
1		8:36:34 AM hmcdermott	CHECKED BY			YELLOWSTONE COUNTY		UPN 8669000



H.3
RELOCATE PUMP HOUSE
TO THE NORTHEAST
CORNER

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\8669000\RD\8669000RDDETZ03.DGN	DESIGNED BY		ROAD PLANS	UNDERPASS AVENUE IMPROVEMENTS - BILLINGS	CM 1025(8)
2		8/24/2016	REVIEWED BY				
1		7:28:11 PM hmcdermott	CHECKED BY		YELLOWSTONE COUNTY	PRELIMINARY AGR	UPN 8669000

Montana Department of Transportation

BID PRICES
June 2016

Preliminary Estimate

Project Number: CM 1025(8)
Project Name: Underpass Avenue Improvements
UPN Number: 8669000
Project Length: Miles
Design Stage: S.1 Traffic Signal

Prepared By: DOWL
Date: August 26, 2016
County: Yellowstone
District:
Type of Work:

Item Number	Quantity	Description	Unit	G-Match	Average Bid Prices		Adjusted Unit Prices	
					Unit Price	Amount	Unit Price	Amount
					Dollars	Dollars	Dollars	Dollars
202020140	2935	REMOVE BITUMINOUS PAVEMENT	SQYD	N	$2.22	$6,516.00		$6,516.00
203020225	1957	EXCAVATION-STREET	CUYD	N	$16.17	$31,639.00		$31,639.00
301020340	1468	CRUSHED AGGREGATE COURSE	CUYD	N	$26.31	$38,610.00	$26.57	$38,991.00
401020021	1018	COMMERCIAL MIX-PG 70-28	TON	N	$70.45	$71,751.00	$170.00	$173,140.00
608010020	456	SIDEWALK-CONCRETE 4 IN	SQYD	N	$67.22	$30,652.00		$30,652.00
608010067	342	REMOVE SIDEWALK	SQYD	N	$6.05	$2,070.00		$2,070.00
608010125	4.4	DETEC WARNING DEVICES-TYPE 1	SQYD	N	$400.66	$1,781.00		$1,781.00
609010030	10	CURB-CONC MEDIAN TYPE A	LNFT	N	$9.52	$95.00		$95.00
609010203	705	REMOVE CURB	LNFT	N	$4.40	$3,102.00		$3,102.00
610010100	306	TOPSOIL	CUYD	N	$21.65	$6,632.00		$6,632.00
610100101	0.75	SEEDING AREA NO 1	ACRE	N	$478.23	$359.00		$359.00
610100555	0.75	CONDITION SEEDBED SURFACE	ACRE	N	$109.47	$82.00		$82.00
617903250	4	PUSH BUTTON/PEDESTRIAN	EACH	Y	$1,000.00	$4,000.00		$4,000.00
618030080	1	TRAFFIC CONTROL	LS	N	$21,117.00	$21,117.00	$80,500.00	$80,500.00
619010230	26	REMOVE SIGN	EACH	N	$46.20	$1,201.00		$1,201.00
620010301	7	CURB MARKING-YELLOW EPOXY	GAL	Y	$254.45	$1,781.00		$1,781.00
620011260	8	WORDS AND SYMBOLS-WHITE EPOXY	GAL	Y	$295.94	$2,368.00		$2,368.00
620013960	20	STRIPING-WHITE EPOXY	GAL	Y	$65.51	$1,310.00		$1,310.00
620014960	3	STRIPING-YELLOW EPOXY	GAL	Y	$56.12	$168.00		$168.00
	1	TRAFFIC SIGNAL	EACH				$160,000.00	$160,000.00
	26	SIGN	EACH				$500.00	$13,000.00
						$225,234.00		$559,387.00
	12%	Mobilization				$27,028.08		$67,126.44
		Subtotal				$252,262.08		$626,513.44
	25%	Contingency				$63,065.52		$156,628.36
		Construction Total				$315,327.60		$783,141.80
	25%	Preliminary and Construction Engineering						$195,785.45
		Total						$978,927.25
	10.97%	Indirect Cost (IDC)-Construction						$85,910.66
		Total Construction w/IDC						$869,052.46
	10.97%	Indirect Cost (IDC) - Construction Engineering						$21,477.66
		Total Construction Engineering w/IDC						$217,263.11
		Total w/IDC						$1,086,315.57

Project Length	Miles						
Project Average Finish Top Width	Feet						
Cost per Mile (Uses Construction Total)							#DIV/0!
Cost per Sq. Yard (Uses Construction Total)							#DIV/0!

Montana Department of Transportation

BID PRICES
June 2016

Preliminary Estimate

Project Number: CM 1025(8)
Project Name: Underpass Avenue Improvements
UPN Number: 8669000
Project Length: Miles
Design Stage: R.2 Roundabout

Prepared By: DOWL
Date: August 26, 2016
County: Yellowstone
District:
Type of Work:

Item Number	Quantity	Description	Unit	G-Match	Average Bid Prices		Adjusted Unit Prices	
					Unit Price	Amount	Unit Price	Amount
					Dollars	Dollars	Dollars	Dollars
203020100	7237	EXCAVATION-UNCLASSIFIED	CUYD	N	$3.98	$28,803.00		$28,803.00
203020200	14474	EXCAVATION-UNCLASS BORROW	CUYD	N	$6.73	$97,410.00		$97,410.00
301020340	4408	CRUSHED AGGREGATE COURSE	CUYD	N	$26.31	$115,974.00		$115,974.00
401020021	1469	COMMERCIAL MIX-PG 70-28	TON	N	$70.45	$103,491.00	$170.00	$249,730.00
501010125	4719	PORT CEM CONC PAVE 9 IN	SQYD	N	$101.71	$479,969.00		$479,969.00
607000030	65	FENCE-CHAIN LINK 4 FT	LNFT	N	$16.58	$1,078.00		$1,078.00
608010112	942	DECORATIVE CONCRETE	SQYD	N	$68.56	$64,584.00		$64,584.00
609010030	1998	CURB-CONC MEDIAN TYPE A	LNFT	N	$9.52	$19,021.00		$19,021.00
609010200	2138	CURB AND GUTTER-CONC	LNFT	N	$25.55	$54,626.00		$54,626.00
609010203	2454	REMOVE CURB	LNFT	N	$4.40	$10,798.00		$10,798.00
609010209	440	REMOVE MEDIAN CURB	LNFT	N	$3.58	$1,575.00		$1,575.00
610010100	807	TOPSOIL	CUYD	N	$21.65	$17,472.00		$17,472.00
610100101	1.5	SEEDING AREA NO 1	ACRE	N	$478.23	$717.00		$717.00
610100555	1.5	CONDITION SEEDBED SURFACE	ACRE	N	$109.47	$164.00		$164.00
610100720	164	LANDSCAPE ROCK	CUYD	N	$91.88	$15,068.00		$15,068.00
618030080	1	TRAFFIC CONTROL	LS	N	$21,117.00	$21,117.00	$207,000.00	$207,000.00
619010230	23	REMOVE SIGN	EACH	N	$46.20	$1,063.00		$1,063.00
620010300	15	CURB MARKING-YELLOW PAINT	GAL	Y		$0.00	$70.00	$1,050.00
620010301	15	CURB MARKING-YELLOW EPOXY	GAL	Y	$254.45	$3,817.00		$3,817.00
620011105	15	WORDS AND SYMBOLS-WHITE PAINT	GAL	Y	$166.10	$2,492.00		$2,492.00
620011260	15	WORDS AND SYMBOLS-WHITE EPOXY	GAL	Y	$295.94	$4,439.00		$4,439.00
620013000	125	STRIPING-WHITE PAINT	GAL	Y	$29.06	$3,633.00		$3,633.00
620013955	357	REMOVE PAVEMENT MARKINGS	LNFT	N	$1.93	$689.00		$689.00
620013960	125	STRIPING-WHITE EPOXY	GAL	Y	$65.51	$8,189.00		$8,189.00
620014000	80	STRIPING-YELLOW PAINT	GAL	Y	$25.37	$2,030.00		$2,030.00
620014960	80	STRIPING-YELLOW EPOXY	GAL	Y	$56.12	$4,490.00		$4,490.00
622011087	983	SEPARATION GEOTEXTILE - MOD	SQYD	N	$3.00	$2,949.00		$2,949.00
	20	SIGN	EACH				$500.00	$10,000.00
	0.5	RIGHT OF WAY	ACRE				$60,000.00	$30,000.00
						$1,065,658.00		$1,438,830.00
	12%	Mobilization				$127,878.96		$172,659.60
		Subtotal				$1,193,536.96		$1,611,489.60
	25%	Contingency				$298,384.24		$402,872.40
		Construction Total				$1,491,921.20		$2,014,362.00
	25%	Preliminary and Construction Engineering						$503,590.50
		Total						$2,517,952.50
	10.97%	Indirect Cost (IDC)-Construction						$220,975.51
		Total Construction w/IDC						$2,235,337.51
	10.97%	Indirect Cost (IDC) - Construction Engineering						$55,243.88
		Total Construction Engineering w/IDC						$558,834.38
		Total w/IDC						$2,794,171.89

Project Length	Miles						
Project Average Finish Top Width	Feet						
Cost per Mile (Uses Construction Total)							#DIV/0!
Cost per Sq. Yard (Uses Construction Total)							#DIV/0!

Montana Department of Transportation

BID PRICES
June 2016

Preliminary Estimate

Project Number: CM 1025(8)
Project Name: Underpass Avenue Improvements
UPN Number: 8669000
Project Length: Miles
Design Stage: S.2 Traffic Signal

Prepared By: DOWL
Date: August 26, 2016
County: Yellowstone
District:
Type of Work:

Item Number	Quantity	Description	Unit	G-Match	Average Bid Prices		Adjusted Unit Prices	
					Unit Price	Amount	Unit Price	Amount
					Dollars	Dollars	Dollars	Dollars
202020140	5057	REMOVE BITUMINOUS PAVEMENT	SQYD	N	$2.22	$11,227.00		$11,227.00
203020225	20	EXCAVATION-STREET	CUYD	N	$16.17	$323.00		$323.00
301020340	1359	CRUSHED AGGREGATE COURSE	CUYD	N	$26.31	$35,753.00		$35,753.00
501010125	5436	PORT CEM CONC PAVE 9 IN	SQYD	N	$101.71	$552,896.00		$552,896.00
557010110	270	HAND RAIL	LNFT	N	$118.08	$31,882.00		$31,882.00
608010020	702	SIDEWALK-CONCRETE 4 IN	SQYD	N	$67.22	$47,166.00		$47,166.00
608010067	160	REMOVE SIDEWALK	SQYD	N	$6.05	$967.00		$967.00
608010125	6.7	DETEC WARNING DEVICES-TYPE 1	SQYD	N	$400.66	$2,684.00		$2,684.00
609010030	315	CURB-CONC MEDIAN TYPE A	LNFT	N	$9.52	$2,999.00		$2,999.00
609010203	880	REMOVE CURB	LNFT	N	$4.40	$3,872.00		$3,872.00
610010100	360	TOPSOIL	CUYD	N	$21.65	$7,790.00		$7,790.00
610100101	0.9	SEEDING AREA NO 1	ACRE	N	$478.23	$430.00		$430.00
610100555	0.9	CONDITION SEEDBED SURFACE	ACRE	N	$109.47	$99.00		$99.00
614010010	125	RETAINING WALL	LNFT	N	$122.19	$15,274.00		$15,274.00
617303302	5	UNDERPASS LUMINAIRE LED	EACH	Y	$527.09	$2,635.00	$1,500.00	$7,500.00
617903250	4	PUSH BUTTON/PEDESTRIAN	EACH	Y	$1,000.00	$4,000.00		$4,000.00
618030080	1	TRAFFIC CONTROL	LS	N	$21,117.00	$21,117.00	$160,000.00	$160,000.00
619010230	28	REMOVE SIGN	EACH	N	$46.20	$1,294.00		$1,294.00
620010301	8	CURB MARKING-YELLOW EPOXY	GAL	Y	$254.45	$2,036.00	$300.00	$2,400.00
620011260	8	WORDS AND SYMBOLS-WHITE EPOXY	GAL	Y	$295.94	$2,368.00	$300.00	$2,400.00
620013960	25	STRIPING-WHITE EPOXY	GAL	Y	$65.51	$1,638.00		$1,638.00
620014960	4	STRIPING-YELLOW EPOXY	GAL	Y	$56.12	$224.00	$300.00	$1,200.00
	1	TRAFFIC SIGNAL	EACH				$185,000.00	$185,000.00
	28	SIGN	EACH				$500.00	$14,000.00
	16	ANTI-GRAFFITI COATING	GAL				$420.00	$6,720.00
	1	AVIAN DETERRENT	LS				$32,000.00	$32,000.00
	4	MEDIAN LIGHTING	EACH				$4,000.00	$16,000.00
	6	LOW CLEARANCE SIGNAGE	EACH				$1,000.00	$6,000.00
						$748,674.00		$1,092,794.00
	12%	Mobilization				$89,840.88		$131,135.28
		Subtotal				$838,514.88		$1,223,929.28
	25%	Contingency				$209,628.72		$305,982.32
		Construction Total				$1,048,143.60		$1,529,911.60
	25%	Preliminary and Construction Engineering						$382,477.90
		Total						$1,912,389.50
	10.97%	Indirect Cost (IDC)-Construction						$167,831.30
		Total Construction w/IDC						$1,697,742.90
	10.97%	Indirect Cost (IDC) - Construction Engineering						$41,957.83
		Total Construction Engineering w/IDC						$424,435.73
		Total w/IDC						$2,122,178.63

Project Length	Miles						
Project Average Finish Top Width	Feet						
Cost per Mile (Uses Construction Total)							#DIV/0!
Cost per Sq. Yard (Uses Construction Total)							#DIV/0!

Montana Department of Transportation

BID PRICES
June 2016

Preliminary Estimate

Project Number: CM 1025(8)
Project Name: Underpass Avenue Improvements
UPN Number: 8669000
Project Length: Miles
Design Stage: C.1 Stop Control

Prepared By: DOWL
Date: August 26, 2016
County: Yellowstone
District:
Type of Work:

Item Number	Quantity	Description	Unit	G-Match	Average Bid Prices		Adjusted Unit Prices	
					Unit Price	Amount	Unit Price	Amount
					Dollars	Dollars	Dollars	Dollars
202020140	2200	REMOVE BITUMINOUS PAVEMENT	SQYD	N	$2.22	$4,884.00		$4,884.00
203020225	1940	EXCAVATION-STREET	CUYD	N	$16.17	$31,375.00		$31,375.00
301020340	1450	CRUSHED AGGREGATE COURSE	CUYD	N	$26.31	$38,150.00	$26.57	$38,527.00
401020021	1010	COMMERCIAL MIX-PG 70-28	TON	N	$70.45	$71,122.00	$170.00	$171,622.00
608010020	565	SIDEWALK-CONCRETE 4 IN	SQYD	N	$67.22	$37,994.00		$37,994.00
608010067	145	REMOVE SIDEWALK	SQYD	N	$6.05	$880.00		$880.00
608010125	6.7	DETEC WARNING DEVICES-TYPE 1	SQYD	N	$400.66	$2,671.00		$2,671.00
609010203	1005	REMOVE CURB	LNFT	N	$4.40	$4,422.00		$4,422.00
610010100	345	TOPSOIL	CUYD	N	$21.65	$7,464.00		$7,464.00
610100101	0.9	SEEDING AREA NO 1	ACRE	N	$478.23	$430.00		$430.00
610100555	0.9	CONDITION SEEDBED SURFACE	ACRE	N	$109.47	$99.00		$99.00
614010010	145	RETAINING WALL	LNFT	N	$122.19	$17,718.00		$17,718.00
618030080	1	TRAFFIC CONTROL	LS	N	$21,117.00	$21,117.00	$46,000.00	$46,000.00
619010230	10	REMOVE SIGN	EACH	N	$46.20	$462.00		$462.00
620010301	7	CURB MARKING-YELLOW EPOXY	GAL	Y	$254.45	$1,781.00		$1,781.00
620011260	6	WORDS AND SYMBOLS-WHITE EPOXY	GAL	Y	$295.94	$1,776.00		$1,776.00
620013960	20	STRIPING-WHITE EPOXY	GAL	Y	$65.51	$1,310.00		$1,310.00
620014960	3	STRIPING-YELLOW EPOXY	GAL	Y	$56.12	$168.00		$168.00
	10	SIGN	EACH				$500.00	$5,000.00
						$243,823.00		$374,583.00
	12%	Mobilization				$29,258.76		$44,949.96
		Subtotal				$273,081.76		$419,532.96
	25%	Contingency				$68,270.44		$104,883.24
		Construction Total				$341,352.20		$524,416.20
	25%	Preliminary and Construction Engineering						$131,104.05
		Total						$655,520.25
	10.97%	Indirect Cost (IDC)-Construction						$57,528.46
		Total Construction w/IDC						$581,944.66
	10.97%	Indirect Cost (IDC) - Construction Engineering						$14,382.11
		Total Construction Engineering w/IDC						$145,486.16
		Total w/IDC						$727,430.82

Project Length	Miles						
Project Average Finish Top Width	Feet						
Cost per Mile (Uses Construction Total)							#DIV/0!
Cost per Sq. Yard (Uses Construction Total)							#DIV/0!

Montana Department of Transportation

BID PRICES
June 2016

Preliminary Estimate

Project Number: CM 1025(8)
Project Name: Underpass Avenue Improvements
UPN Number: 8669000
Project Length: Miles
Design Stage: L.1 On-Ramp Extension

Prepared By: DOWL
Date: August 26, 2016
County: Yellowstone
District:
Type of Work:

Item Number	Quantity	Description	Unit	G-Match	Average Bid Prices		Adjusted Unit Prices	
					Unit Price	Amount	Unit Price	Amount
					Dollars	Dollars	Dollars	Dollars
203020100	10	EXCAVATION-UNCLASSIFIED	CUYD	N	$3.98	$40.00		$40.00
203020200	156	EXCAVATION-UNCLASS BORROW	CUYD	N	$6.73	$1,050.00		$1,050.00
301020340	965	CRUSHED AGGREGATE COURSE	CUYD	N	$26.31	$25,389.00		$25,389.00
301020625	1931	AGGREGATE TREATMENT	SQYD	N	$0.44	$850.00		$850.00
401020021	620	COMMERCIAL MIX-PG 70-28	TON	N	$70.45	$43,679.00	$170.00	$105,400.00
609010305	760	REMOVE CURB AND GUTTER	LNFT	N	$3.52	$2,675.00		$2,675.00
610010100	83	TOPSOIL	CUYD	N	$21.65	$1,797.00		$1,797.00
610100101	0.2	SEEDING AREA NO 1	ACRE	N	$478.23	$96.00		$96.00
610100555	0.2	CONDITION SEEDBED SURFACE	ACRE	N	$109.47	$22.00		$22.00
618030080	1	TRAFFIC CONTROL	LS	N	$21,117.00	$21,117.00	$31,000.00	$31,000.00
619010230	3	REMOVE SIGN	EACH	N	$46.20	$139.00		$139.00
620010300	5	CURB MARKING-YELLOW PAINT	GAL	Y		$0.00	$70.00	$350.00
620010301	5	CURB MARKING-YELLOW EPOXY	GAL	Y	$254.45	$1,272.00		$1,272.00
620013000	5	STRIPING-WHITE PAINT	GAL	Y	$29.06	$145.00		$145.00
620013960	5	STRIPING-WHITE EPOXY	GAL	Y	$65.51	$328.00		$328.00
620014000	5	STRIPING-YELLOW PAINT	GAL	Y	$25.37	$127.00		$127.00
620014960	5	STRIPING-YELLOW EPOXY	GAL	Y	$56.12	$281.00		$281.00
	3	SIGN	EACH				$500.00	$1,500.00
	0.5	RIGHT OF WAY	ACRE				$60,000.00	$30,000.00
						$99,007.00		$202,461.00
	12%	Mobilization				$11,880.84		$24,295.32
		Subtotal				$110,887.84		$226,756.32
	30%	Contingency				$33,266.35		$68,026.90
		Construction Total				$144,154.19		$294,783.22
	25%	Preliminary and Construction Engineering						$73,695.80
		Total						$368,479.02
	10.97%	Indirect Cost (IDC)-Construction						$32,337.72
		Total Construction w/IDC						$327,120.93
	10.97%	Indirect Cost (IDC) - Construction Engineering						$8,084.43
		Total Construction Engineering w/IDC						$81,780.23
		Total w/IDC						$408,901.17

Project Length	Miles						
Project Average Finish Top Width	Feet						
Cost per Mile (Uses Construction Total)							#DIV/0!
Cost per Sq. Yard (Uses Construction Total)							#DIV/0!

DOWL

H.1 Existing Pump House
Preliminary Estimate of Costs

Item Description[4]	Approx. Quantity	Unit	Average MDT Bid Prices [1]		Adjusted Unit Prices	
			Unit Price	Amount	Unit Price	Amount [2]
			Dollars	Dollars	Dollars	Dollars
Roundabout Intersection Configuration						
RCP IRR 18 IN CLASS 3	1,902	LNFT	$63.52	$120,815.00	$72.00	$136,944.00
RCP IRR 24 IN CLASS 3	111	LNFT	$75.83	$8,417.00	$115.00	$12,765.00
REMOVE STORM DRAIN	1	LS		$0.00	$25,000.00	$25,000.00
INLET CURB-TYPE B	17	EACH	$2,597.81	$44,163.00	$3,235.00	$54,995.00
INLET GRATE-MODIFIED	2	EACH		$0.00	$10,000.00	$20,000.00
MANHOLE-48 IN TYPE 1	4	EACH		$0.00	$3,150.00	$12,600.00
IRRIGATION STRUCTURE	1	LS		$0.00	$2,800.00	$2,800.00
POND 1 [3]	1	LS		$0.00	$10,000.00	$10,000.00
POND 2 [3]	1	LS		$0.00	$4,500.00	$4,500.00
POND 3 [3]	1	LS		$0.00	$3,000.00	$3,000.00
ALTERNATIVE SUBTOTAL 1					$282,604	
ADDITIONAL COSTS						
MISCELLANEOUS ITEMS SUBTOTAL 1 [4]					5%	$14,100
MOBILIZATION @ 10% OF SUBTOTAL 1 [5]					10%	$28,300
SUBTOTAL 2						$325,000
PRELIMINARY ENGINEERING					10%	$32,500
CONSTRUCTION ENGINEERING					10%	$32,500
INDIRECT COST (IDC) - CONSTRUCTION @10.97% OF SUBTOTAL 2 [6]					10.97%	$36,000
TOTAL IMPROVEMENT OPTION COST @ 25% CONTINGENCY [7,8]					**$533,000**	

[1] Average MDT bid prices provided for the period July 2015.
[2] Cost estimates are provided in 2015 dollars. All dollar amounts are rounded for planning purposes.
[3] Pond bid items include all work and materials necessary for construction including excavation, embankment, special borrow, lining, riprap, and revegetation.
[4] Bid items are subject to change during the design phase.
[5] The Miscellaneous category is estimated at 5 percent due to unknown factors including but not limited to excavation, embankment, BMPs, utilities, noxious weeds, slope treatments, ditch or channel excavation, temporary water pollution/erosion control measures and public relations.
[6] The Mobilization category includes all costs incurred in assembling and transporting materials to the work site.
[7] Indirect costs are costs not directly associated with the construction of a project, but incurred during the construction processes. IDC percentage is subject to change.
[8] A contingency of 25 percent was used due to the high degree of unknown factors over the planning horizon.
[9] The Total Improvement Option Cost reflects an estimate of potential construction costs based on planning-level estimates, and should not be considered an actual cost or encompassing all scenarios and circumstances.
[10] Right of way costs estimated from anticipated impacted area.

DOWL

H.2 Relocate Pump House to Southwest Corner
Preliminary Estimate of Costs

Item Description[8]	Approx. Quantity	Unit	Average MDT Bid Prices [1]		Adjusted Unit Prices	
			Unit Price	Amount	Unit Price	Amount [2]
			Dollars	Dollars	Dollars	Dollars
Roundabout Intersection Configuration						
18" RCP IRR CLASS 3	1,930	LNFT	$63.52	$122,594.00	$72.00	$138,960.00
24" RCP IRR CLASS 3	274	LNFT	$75.83	$20,777.00	$115.00	$31,510.00
20" WELDED STEEL PIPE	133	LNFT		$0.00	$125.00	$16,625.00
CONNECTION TO EXISTING PIPE	1	EACH	$900.00	$900.00	$1,303.00	$1,303.00
STORM DRAIN INLET	17	EACH		$0.00	$3,235.00	$54,995.00
HIGH CAPACITY INLET GRATE	2	EACH		$0.00	$10,000.00	$20,000.00
MANHOLE 48 IN TYPE 3	5	EACH	$3,637.50	$18,188.00	$3,150.00	$15,750.00
POND 2 [3]	1	LS		$0.00	$4,500.00	$4,500.00
POND 3 [3]	1	LS		$0.00	$3,000.00	$3,000.00
NEW PUMP HOUSE [4]	1	LS		$0.00	$80,000.00	$80,000.00
WET WELL [5]	1	LS		$0.00	$36,270.00	$36,270.00
PUMP HOUSE REMOVAL [6]	1	LS		$0.00	$10,000.00	$10,000.00
STORM DRAIN REMOVAL [7]	1	LS	$11,697.00	$11,697.00	$25,000.00	$25,000.00
				ALTERNATIVE SUBTOTAL 1	$437,913.00	
				ADDITIONAL COSTS		
				MISCELLANEOUS ITEMS SUBTOTAL 1 [9]	15%	$65,700
				MOBILIZATION @ 10% OF SUBTOTAL 1 [10]	10%	$43,800
				SUBTOTAL 2		$547,400
				PRELIMINARY ENGINEERING	10%	$54,740
				CONSTRUCTION ENGINEERING	10%	$54,740
				INDIRECT COST (IDC) - CONSTRUCTION @ 10.97% OF SUBTOTAL 2 [11]	10.97%	$60,000
				TOTAL IMPROVEMENT OPTION COST @ 25% CONTINGENCY [12,13]	**$897,000**	

[1] Average MDT bid prices provided for the period July 2015.
[2] Cost estimates are provided in 2015 dollars. All dollar amounts are rounded for planning purposes.
[3] Pond bid items include all work and materials necessary for construction including excavation, embankment, special borrow, lining, riprap, and revegetation.
[4] The new pump house bid item includes all work and materials necessary for construction including structure matierals, system materials, and labor.
[5] The wet well bid item includes all work and materials necessary for construction including materials and labor to conduct work.
[6] The pump house removal bid item includes all work and materials necessary for construction including materials, labor, and disposal of waste.
[7] The storm drain removal bid item includes all work and materials necessary for construction including materials, labor, and disposal of waste.
[8] Bid items are subject to change during the design phase.
[9] The Miscellaneous category is estimated at 5 percent due to unknown factors including but not limited to excavation, embankment, BMPs, utilities, noxious weeds, slope treatments, ditch or channel excavation, temporary water pollution/erosion control measures and public relations.
[10] The Mobilization category includes all costs incurred in assembling and transporting materials to the work site.
[11] Indirect costs are costs not directly associated with the construction of a project, but incurred during the construction processes. IDC percentage is subject to change.
[12] A contingency of 25 percent was used due to the high degree of unknown factors over the planning horizon.
[13] The Total Improvement Option Cost reflects an estimate of potential construction costs based on planning-level estimates, and should not be considered an actual cost or encompassing all scenarios and circumstances.

DOWL

H.3 Relocate Pump House to Northeast Corner
Preliminary Estimate of Costs

Item Description[8]	Approx. Quantity	Unit	Average MDT Bid Prices [1]		Adjusted Unit Prices	
			Unit Price	Amount	Unit Price	Amount [2]
			Dollars	Dollars	Dollars	Dollars
Roundabout Intersection Configuration						
18" RCP IRR CLASS 3	1,710	LNFT	$63.52	$108,619.00	$72.00	$123,120.00
24" RCP IRR CLASS 3	55	LNFT		$0.00	$115.00	$6,325.00
20" WELDED STEEL PIPE	238	LNFT		$0.00	$125.00	$29,750.00
CONNECTION TO EXISTING PIPE	1	EACH	$900.00	$900.00	$1,303.00	$1,303.00
STORM DRAIN INLET	17	EACH		$0.00	$3,235.00	$54,995.00
HIGH CAPACITY INLET GRATE	2	EACH		$0.00	$10,000.00	$20,000.00
MANHOLE 48 IN TYPE 3	2	EACH	$3,637.50	$7,275.00	$3,150.00	$6,300.00
POND 1 OUTFALL STURCUTRE [3]	1	EACH		$0.00	$2,800.00	$2,800.00
POND 1 [3]	1	LS		$0.00	$10,000.00	$10,000.00
POND 2 [3]	1	LS		$0.00	$4,500.00	$4,500.00
POND 3 [3]	1	LS		$0.00	$3,000.00	$3,000.00
NEW PUMP HOUSE [4]	1	LS		$0.00	$80,000.00	$80,000.00
WET WELL [5]	1	LS		$0.00	$36,270.00	$36,270.00
PUMP HOUSE REMOVAL [6]	1	LS		$0.00	$10,000.00	$10,000.00
STORM DRAIN REMOVAL [7]	1	LS	$11,697.00	$11,697.00	$25,000.00	$25,000.00
AVERAGE ALTERNATIVE SUBTOTAL 1					$413,363	
ADDITIONAL COSTS						
MISCELLANEOUS ITEMS SUBTOTAL 1 [9]					15%	$62,000
MOBILIZATION @ 10% OF SUBTOTAL 1 [10]					10%	$41,300
SUBTOTAL 2						$516,700
PRELIMINARY ENGINEERING					10%	$51,670
CONSTRUCTION ENGINEERING					10%	$51,670
INDIRECT COST (IDC) - CONSTRUCTION @ 10.97% OF SUBTOTAL 2 [11]					10.97%	$57,000
TOTAL IMPROVEMENT OPTION COST @ 25% CONTINGENCY [12,13]					**$847,000**	

[1] Average MDT bid prices provided for the period July 2015.
[2] Cost estimates are provided in 2015 dollars. All dollar amounts are rounded for planning purposes.
[3] Pond bid items include all work and materials necessary for construction including excavation, embankment, special borrow, lining, riprap, and revegetation.
[4] The new pump house bid item includes all work and materials necessary for construction including structure matierals, system materials, and labor.
[5] The wet well bid item includes all work and materials necessary for construction including materials and labor to conduct work.
[6] The pump house removal bid item includes all work and materials necessary for construction including materials, labor, and disposal of waste.
[7] The storm drain removal bid item includes all work and materials necessary for construction including materials, labor, and disposal of waste.
[8] Bid items are subject to change during the design phase.
[9] The Miscellaneous category is estimated at 5 percent due to unknown factors including but not limited to excavation, embankment, BMPs, utilities, noxious weeds, slope treatments, ditch or channel excavation, temporary water pollution/erosion control measures and public relations.
[10] The Mobilization category includes all costs incurred in assembling and transporting materials to the work site.
[11] Indirect costs are costs not directly associated with the construction of a project, but incurred during the construction processes. IDC percentage is subject to change.
[12] A contingency of 25 percent was used due to the high degree of unknown factors over the planning horizon.
[13] The Total Improvement Option Cost reflects an estimate of potential construction costs based on planning-level estimates, and should not be considered an actual cost or encompassing all scenarios and circumstances.

Appendix B
2015 Existing LOS

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	59	0	312	119	246	3	342	366	0	0	282	59
Future Volume (vph)	59	0	312	119	246	3	342	366	0	0	282	59
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		6.0	6.3	6.3		5.8	4.9			4.9	
Lane Util. Factor	1.00		1.00	1.00	0.95		1.00	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.97	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1630		1352	1614	3243		1613	1716			3191	
Flt Permitted	0.95		1.00	0.95	1.00		0.32	1.00			1.00	
Satd. Flow (perm)	1630		1352	1614	3243		538	1716			3191	
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	66	0	351	134	276	3	384	411	0	0	317	66
RTOR Reduction (vph)	0	0	253	0	1	0	0	0	0	0	25	0
Lane Group Flow (vph)	66	0	98	134	278	0	384	411	0	0	358	0
Confl. Peds. (#/hr)						2	8					8
Heavy Vehicles (%)	2%	0%	10%	3%	2%	33%	3%	2%	0%	0%	1%	2%
Turn Type	Prot		pt+ov	Split	NA		pm+pt	NA			NA	
Protected Phases	4		4 5	8	8		5	2			6	
Permitted Phases							2					
Actuated Green, G (s)	5.0		17.2	12.1	12.1		31.1	31.1			13.1	
Effective Green, g (s)	5.0		17.2	12.1	12.1		31.1	31.1			13.1	
Actuated g/C Ratio	0.08		0.26	0.19	0.19		0.48	0.48			0.20	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			4.9	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	124		355	298	600		456	816			639	
v/s Ratio Prot	c0.04		0.07	0.08	c0.09		c0.16	0.24			0.11	
v/s Ratio Perm							c0.24					
v/c Ratio	0.53		0.28	0.45	0.46		0.84	0.50			0.56	
Uniform Delay, d1	29.1		19.2	23.7	23.8		12.6	11.8			23.6	
Progression Factor	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Incremental Delay, d2	4.3		0.4	1.1	0.6		13.2	0.5			1.1	
Delay (s)	33.4		19.6	24.8	24.3		25.8	12.3			24.7	
Level of Service	C		B	C	C		C	B			C	
Approach Delay (s)		21.8			24.5			18.8			24.7	
Approach LOS		C			C			B			C	

Intersection Summary			
HCM 2000 Control Delay	21.7	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.77		
Actuated Cycle Length (s)	65.4	Sum of lost time (s)	23.0
Intersection Capacity Utilization	62.4%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	32	120	5	77	202	473	7	343	73	359	285	69
Future Volume (vph)	32	120	5	77	202	473	7	343	73	359	285	69
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	4.0		6.1	6.1	5.0	5.8	5.8
Lane Util. Factor	1.00	0.95		1.00	0.95	1.00		1.00	1.00	1.00	1.00	1.00
Frpb, ped/bikes	1.00	1.00		1.00	1.00	0.99		1.00	1.00	1.00	1.00	0.98
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.99		1.00	1.00	0.85		1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1614	3069		1599	3197	1440		1694	1377	1539	1716	1454
Flt Permitted	0.61	1.00		0.46	1.00	1.00		0.99	1.00	0.25	1.00	1.00
Satd. Flow (perm)	1032	3069		767	3197	1440		1679	1377	404	1716	1454
Peak-hour factor, PHF	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Adj. Flow (vph)	37	138	6	89	232	544	8	394	84	413	328	79
RTOR Reduction (vph)	0	4	0	0	0	0	0	0	60	0	0	36
Lane Group Flow (vph)	37	140	0	89	232	544	0	402	24	413	328	43
Confl. Peds. (#/hr)						2	13					13
Heavy Vehicles (%)	3%	8%	0%	4%	4%	2%	14%	3%	8%	8%	2%	0%
Turn Type	Perm	NA		pm+pt	NA	Free	Perm	NA	Perm	pm+pt	NA	Perm
Protected Phases		4		3	8			2		1	6	
Permitted Phases	4			8		Free	2		2	6		6
Actuated Green, G (s)	12.2	12.2		24.1	24.1	76.6		22.3	22.3	41.9	41.9	41.9
Effective Green, g (s)	12.2	12.2		24.1	24.1	76.6		22.3	22.3	41.9	41.9	41.9
Actuated g/C Ratio	0.16	0.16		0.31	0.31	1.00		0.29	0.29	0.55	0.55	0.55
Clearance Time (s)	6.6	6.6		6.3	4.8			6.1	6.1	5.0	5.8	5.8
Vehicle Extension (s)	3.0	3.0		3.0	3.0			3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	164	488		282	1005	1440		488	400	432	938	795
v/s Ratio Prot		0.05		0.02	0.07					c0.18	0.19	
v/s Ratio Perm	0.04			0.08		c0.38		0.24	0.02	c0.34		0.03
v/c Ratio	0.23	0.29		0.32	0.23	0.38		0.82	0.06	0.96	0.35	0.05
Uniform Delay, d1	28.1	28.4		19.3	19.4	0.0		25.3	19.6	13.8	9.7	8.1
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	0.7	0.3		0.6	0.1	0.8		10.8	0.1	31.9	0.2	0.0
Delay (s)	28.8	28.7		20.0	19.5	0.8		36.1	19.7	45.7	9.9	8.1
Level of Service	C	C		B	B	A		D	B	D	A	A
Approach Delay (s)		28.7			7.8			33.3			27.8	
Approach LOS		C			A			C			C	

Intersection Summary			
HCM 2000 Control Delay	21.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.93		
Actuated Cycle Length (s)	76.6	Sum of lost time (s)	24.0
Intersection Capacity Utilization	78.0%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	2.8

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	285	9	85	282	0	138
Future Vol, veh/h	285	9	85	282	0	138
Conflicting Peds, #/hr	0	1	1	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	100	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	3	11	2	1	0	2
Mvmt Flow	320	10	96	317	0	155

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	331	0	834	326
Stage 1	-	-	-	-	326	-
Stage 2	-	-	-	-	508	-
Critical Hdwy	-	-	4.12	-	6.4	6.22
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.218	-	3.5	3.318
Pot Cap-1 Maneuver	-	-	1228	-	341	715
Stage 1	-	-	-	-	736	-
Stage 2	-	-	-	-	608	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1228	-	308	714
Mov Cap-2 Maneuver	-	-	-	-	308	-
Stage 1	-	-	-	-	735	-
Stage 2	-	-	-	-	550	-

Approach	EB	WB	NB
HCM Control Delay, s	0	1.9	11.4
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	-	714	-	-	1228	-
HCM Lane V/C Ratio	-	0.217	-	-	0.078	-
HCM Control Delay (s)	0	11.4	-	-	8.2	0
HCM Lane LOS	A	B	-	-	A	A
HCM 95th %tile Q(veh)	-	0.8	-	-	0.3	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	118	0	431	224	396	3	393	497	0	0	371	57
Future Volume (vph)	118	0	431	224	396	3	393	497	0	0	371	57
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		6.0	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		1.00	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.98	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1662		1473	1662	3321		1644	1750			3248	
Flt Permitted	0.95		1.00	0.95	1.00		0.30	1.00			1.00	
Satd. Flow (perm)	1662		1473	1662	3321		511	1750			3248	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	124	0	454	236	417	3	414	523	0	0	391	60
RTOR Reduction (vph)	0	0	156	0	1	0	0	0	0	0	16	0
Lane Group Flow (vph)	124	0	298	236	419	0	414	523	0	0	435	0
Confl. Peds. (#/hr)						2	13					13
Heavy Vehicles (%)	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Turn Type	Prot		pt+ov	Split	NA		pm+pt	NA			NA	
Protected Phases	7		7 5	8	8		5	2			6	
Permitted Phases							2					
Actuated Green, G (s)	7.1		16.5	14.6	14.6		31.2	31.2			15.5	
Effective Green, g (s)	7.1		16.5	14.6	14.6		31.2	31.2			15.5	
Actuated g/C Ratio	0.10		0.24	0.21	0.21		0.45	0.45			0.22	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	168		346	346	691		379	778			718	
v/s Ratio Prot	0.07		c0.20	c0.14	0.13		c0.15	0.30			0.13	
v/s Ratio Perm							c0.34					
v/c Ratio	0.74		0.86	0.68	0.61		1.09	0.67			0.61	
Uniform Delay, d1	30.6		25.7	25.6	25.1		16.9	15.4			24.5	
Progression Factor	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Incremental Delay, d2	15.5		19.2	5.5	1.5		73.4	2.3			1.4	
Delay (s)	46.1		44.9	31.1	26.7		90.3	17.7			26.0	
Level of Service	D		D	C	C		F	B			C	
Approach Delay (s)		45.1			28.2			49.8			26.0	
Approach LOS		D			C			D			C	

Intersection Summary			
HCM 2000 Control Delay	39.3	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	1.02		
Actuated Cycle Length (s)	70.1	Sum of lost time (s)	23.5
Intersection Capacity Utilization	77.2%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	56	240	7	81	245	597	3	379	100	467	492	67
Future Volume (vph)	56	240	7	81	245	597	3	379	100	467	492	67
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	4.0		5.5	5.5	5.0	5.8	5.8
Lane Util. Factor	1.00	0.95		1.00	0.95	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		1.00	1.00	1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	1.00	0.85		1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1662	3204		1582	3197	1473		1732	1458	1630	1733	1458
Flt Permitted	0.59	1.00		0.42	1.00	1.00		1.00	1.00	0.20	1.00	1.00
Satd. Flow (perm)	1036	3204		693	3197	1473		1726	1458	349	1733	1458
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	59	253	7	85	258	628	3	399	105	492	518	71
RTOR Reduction (vph)	0	3	0	0	0	0	0	0	76	0	0	32
Lane Group Flow (vph)	59	257	0	85	258	628	0	402	29	492	518	39
Confl. Peds. (#/hr)			2	2			12					
Heavy Vehicles (%)	0%	3%	14%	5%	4%	1%	0%	1%	2%	2%	1%	2%
Turn Type	Perm	NA		pm+pt	NA	Free	Perm	NA	Perm	pm+pt	NA	Perm
Protected Phases		4		3	8			2		1	6	
Permitted Phases	4			8		Free	2		2	6		6
Actuated Green, G (s)	13.2	13.2		25.2	25.2	79.4		21.6	21.6	43.6	43.6	43.6
Effective Green, g (s)	13.2	13.2		25.2	25.2	79.4		21.6	21.6	43.6	43.6	43.6
Actuated g/C Ratio	0.17	0.17		0.32	0.32	1.00		0.27	0.27	0.55	0.55	0.55
Clearance Time (s)	6.6	6.6		6.3	4.8			5.5	5.5	5.0	5.8	5.8
Vehicle Extension (s)	3.0	3.0		3.0	3.0			3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	172	532		263	1014	1473		469	396	470	951	800
v/s Ratio Prot		0.08		0.02	0.08					c0.23	0.30	
v/s Ratio Perm	0.06			0.09		c0.43		0.23	0.02	c0.35		0.03
v/c Ratio	0.34	0.48		0.32	0.25	0.43		0.86	0.07	1.05	0.54	0.05
Uniform Delay, d1	29.3	30.0		19.8	20.1	0.0		27.4	21.5	18.9	11.5	8.3
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	1.2	0.7		0.7	0.1	0.9		14.3	0.1	54.3	0.6	0.0
Delay (s)	30.5	30.7		20.5	20.3	0.9		41.7	21.5	73.1	12.2	8.3
Level of Service	C	C		C	C	A		D	C	E	B	A
Approach Delay (s)		30.7			7.8			37.6			39.7	
Approach LOS		C			A			D			D	

Intersection Summary			
HCM 2000 Control Delay	27.5	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	1.01		
Actuated Cycle Length (s)	79.4	Sum of lost time (s)	23.4
Intersection Capacity Utilization	85.5%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	3.5

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	366	18	262	318	2	116
Future Vol, veh/h	366	18	262	318	2	116
Conflicting Peds, #/hr	0	4	4	0	0	4
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	100	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	96	96	96	96	96	96
Heavy Vehicles, %	2	0	2	2	0	1
Mvmt Flow	381	19	273	331	2	121

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	404	0	1272	399
Stage 1	-	-	-	-	395	-
Stage 2	-	-	-	-	877	-
Critical Hdwy	-	-	4.12	-	6.4	6.21
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.218	-	3.5	3.309
Pot Cap-1 Maneuver	-	-	1155	-	187	653
Stage 1	-	-	-	-	685	-
Stage 2	-	-	-	-	410	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1151	-	132	648
Mov Cap-2 Maneuver	-	-	-	-	132	-
Stage 1	-	-	-	-	682	-
Stage 2	-	-	-	-	291	-

Approach	EB	WB	NB
HCM Control Delay, s	0	4.1	12.2
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	132	648	-	-	1151	-
HCM Lane V/C Ratio	0.016	0.186	-	-	0.237	-
HCM Control Delay (s)	32.7	11.8	-	-	9.1	0
HCM Lane LOS	D	B	-	-	A	A
HCM 95th %tile Q(veh)	0	0.7	-	-	0.9	-

Appendix C
2018 and 2038 Future LOS

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	61	0	327	123	255	3	354	379	0	0	289	60
Future Volume (vph)	61	0	327	123	255	3	354	379	0	0	289	60
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		6.0	6.3	6.3		5.8	4.9			4.9	
Lane Util. Factor	1.00		1.00	1.00	0.95		1.00	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.97	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1630		1352	1614	3244		1613	1716			3192	
Flt Permitted	0.95		1.00	0.95	1.00		0.31	1.00			1.00	
Satd. Flow (perm)	1630		1352	1614	3244		528	1716			3192	
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	69	0	367	138	287	3	398	426	0	0	325	67
RTOR Reduction (vph)	0	0	246	0	1	0	0	0	0	0	24	0
Lane Group Flow (vph)	69	0	121	138	289	0	398	426	0	0	368	0
Confl. Peds. (#/hr)						2	8					8
Heavy Vehicles (%)	2%	0%	10%	3%	2%	33%	3%	2%	0%	0%	1%	2%
Turn Type	Prot		pt+ov	Split	NA		pm+pt	NA			NA	
Protected Phases	4		4 5	8	8		5	2			6	
Permitted Phases							2					
Actuated Green, G (s)	5.0		17.2	12.2	12.2		31.3	31.3			13.3	
Effective Green, g (s)	5.0		17.2	12.2	12.2		31.3	31.3			13.3	
Actuated g/C Ratio	0.08		0.26	0.19	0.19		0.48	0.48			0.20	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			4.9	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	124		353	299	602		453	817			646	
v/s Ratio Prot	c0.04		0.09	0.09	c0.09		c0.16	0.25			0.12	
v/s Ratio Perm							c0.26					
v/c Ratio	0.56		0.34	0.46	0.48		0.88	0.52			0.57	
Uniform Delay, d1	29.3		19.7	23.8	23.9		12.8	12.0			23.6	
Progression Factor	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Incremental Delay, d2	5.3		0.6	1.1	0.6		17.3	0.6			1.2	
Delay (s)	34.6		20.3	25.0	24.5		30.1	12.6			24.8	
Level of Service	C		C	C	C		C	B			C	
Approach Delay (s)		22.5			24.7			21.0			24.8	
Approach LOS		C			C			C			C	

Intersection Summary			
HCM 2000 Control Delay	22.8	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.80		
Actuated Cycle Length (s)	65.7	Sum of lost time (s)	23.0
Intersection Capacity Utilization	63.4%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	32	122	5	78	205	480	7	355	76	372	295	72
Future Volume (vph)	32	122	5	78	205	480	7	355	76	372	295	72
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	4.0		6.1	6.1	5.0	5.8	5.8
Lane Util. Factor	1.00	0.95		1.00	0.95	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		1.00	1.00	1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.99		1.00	1.00	0.85		1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1614	3066		1598	3197	1458		1694	1377	1539	1716	1488
Flt Permitted	0.60	1.00		0.45	1.00	1.00		0.99	1.00	0.23	1.00	1.00
Satd. Flow (perm)	1028	3066		765	3197	1458		1680	1377	376	1716	1488
Peak-hour factor, PHF	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Adj. Flow (vph)	37	140	6	90	236	552	8	408	87	428	339	83
RTOR Reduction (vph)	0	3	0	0	0	0	0	0	62	0	0	37
Lane Group Flow (vph)	37	143	0	90	236	552	0	416	25	428	339	46
Confl. Peds. (#/hr)			1	1			1					
Heavy Vehicles (%)	3%	8%	0%	4%	4%	2%	14%	3%	8%	8%	2%	0%
Turn Type	Perm	NA		pm+pt	NA	Free	Perm	NA	Perm	pm+pt	NA	Perm
Protected Phases		4		3	8			2		1	6	
Permitted Phases	4			8		Free	2		2	6		6
Actuated Green, G (s)	12.2	12.2		24.1	24.1	78.1		22.8	22.8	43.4	43.4	43.4
Effective Green, g (s)	12.2	12.2		24.1	24.1	78.1		22.8	22.8	43.4	43.4	43.4
Actuated g/C Ratio	0.16	0.16		0.31	0.31	1.00		0.29	0.29	0.56	0.56	0.56
Clearance Time (s)	6.6	6.6		6.3	4.8			6.1	6.1	5.0	5.8	5.8
Vehicle Extension (s)	3.0	3.0		3.0	3.0			3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	160	478		276	986	1458		490	401	436	953	826
v/s Ratio Prot		0.05		0.02	0.07					c0.19	0.20	
v/s Ratio Perm	0.04			0.08		c0.38		0.25	0.02	c0.35		0.03
v/c Ratio	0.23	0.30		0.33	0.24	0.38		0.85	0.06	0.98	0.36	0.06
Uniform Delay, d1	28.8	29.2		20.1	20.2	0.0		26.0	19.9	15.9	9.6	8.0
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	0.7	0.4		0.7	0.1	0.8		12.9	0.1	38.1	0.2	0.0
Delay (s)	29.6	29.5		20.8	20.3	0.8		38.9	20.0	54.0	9.8	8.0
Level of Service	C	C		C	C	A		D	C	D	A	A
Approach Delay (s)		29.5			8.1			35.7			31.9	
Approach LOS		C			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	23.8	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.95		
Actuated Cycle Length (s)	78.1	Sum of lost time (s)	24.0
Intersection Capacity Utilization	79.2%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	2.9

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	295	9	87	291	0	143
Future Vol, veh/h	295	9	87	291	0	143
Conflicting Peds, #/hr	0	1	1	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	100	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	3	11	2	1	0	2
Mvmt Flow	331	10	98	327	0	161

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	343	0	860	338
Stage 1	-	-	-	-	338	-
Stage 2	-	-	-	-	522	-
Critical Hdwy	-	-	4.12	-	6.4	6.22
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.218	-	3.5	3.318
Pot Cap-1 Maneuver	-	-	1216	-	329	704
Stage 1	-	-	-	-	727	-
Stage 2	-	-	-	-	599	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1216	-	296	703
Mov Cap-2 Maneuver	-	-	-	-	296	-
Stage 1	-	-	-	-	726	-
Stage 2	-	-	-	-	540	-

Approach	EB	WB	NB
HCM Control Delay, s	0	1.9	11.6
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	-	703	-	-	1216	-
HCM Lane V/C Ratio	-	0.229	-	-	0.08	-
HCM Control Delay (s)	0	11.6	-	-	8.2	0
HCM Lane LOS	A	B	-	-	A	A
HCM 95th %tile Q(veh)	-	0.9	-	-	0.3	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	122	0	449	233	410	3	407	515	0	0	378	58
Future Volume (vph)	122	0	449	233	410	3	407	515	0	0	378	58
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		6.0	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		1.00	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.98	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1662		1473	1662	3321		1628	1750			3248	
Flt Permitted	0.95		1.00	0.95	1.00		0.29	1.00			1.00	
Satd. Flow (perm)	1662		1473	1662	3321		497	1750			3248	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	128	0	473	245	432	3	428	542	0	0	398	61
RTOR Reduction (vph)	0	0	149	0	1	0	0	0	0	0	16	0
Lane Group Flow (vph)	128	0	324	245	434	0	428	542	0	0	443	0
Confl. Peds. (#/hr)						2	13					13
Heavy Vehicles (%)	0%	0%	1%	0%	0%	0%	2%	0%	0%	0%	0%	0%
Turn Type	Prot		pt+ov	Split	NA		pm+pt	NA			NA	
Protected Phases	7		7 5	8	8		5	2			6	
Permitted Phases							2					
Actuated Green, G (s)	7.1		16.5	14.9	14.9		31.4	31.4			15.7	
Effective Green, g (s)	7.1		16.5	14.9	14.9		31.4	31.4			15.7	
Actuated g/C Ratio	0.10		0.23	0.21	0.21		0.44	0.44			0.22	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	167		344	350	700		371	778			722	
v/s Ratio Prot	0.08		c0.22	c0.15	0.13		c0.15	0.31			0.14	
v/s Ratio Perm							c0.36					
v/c Ratio	0.77		0.94	0.70	0.62		1.15	0.70			0.61	
Uniform Delay, d1	30.9		26.6	25.8	25.3		17.0	15.8			24.7	
Progression Factor	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Incremental Delay, d2	18.7		33.7	6.0	1.7		95.5	2.7			1.6	
Delay (s)	49.7		60.3	31.8	27.0		112.5	18.5			26.3	
Level of Service	D		E	C	C		F	B			C	
Approach Delay (s)		58.1			28.7			60.0			26.3	
Approach LOS		E			C			E			C	

Intersection Summary			
HCM 2000 Control Delay	46.0	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	1.07		
Actuated Cycle Length (s)	70.6	Sum of lost time (s)	23.5
Intersection Capacity Utilization	79.0%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	57	244	7	82	249	606	3	393	104	483	509	68
Future Volume (vph)	57	244	7	82	249	606	3	393	104	483	509	68
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	4.0		5.5	5.5	5.0	5.8	5.8
Lane Util. Factor	1.00	0.95		1.00	0.95	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		1.00	1.00	1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	1.00	0.85		1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1662	3204		1582	3197	1473		1732	1458	1630	1733	1458
Flt Permitted	0.59	1.00		0.41	1.00	1.00		1.00	1.00	0.19	1.00	1.00
Satd. Flow (perm)	1032	3204		691	3197	1473		1726	1458	332	1733	1458
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	60	257	7	86	262	638	3	414	109	508	536	72
RTOR Reduction (vph)	0	3	0	0	0	0	0	0	79	0	0	32
Lane Group Flow (vph)	60	261	0	86	262	638	0	417	30	508	536	40
Confl. Peds. (#/hr)			2	2			12					
Heavy Vehicles (%)	0%	3%	14%	5%	4%	1%	0%	1%	2%	2%	1%	2%
Turn Type	Perm	NA		pm+pt	NA	Free	Perm	NA	Perm	pm+pt	NA	Perm
Protected Phases		4		3	8			2		1	6	
Permitted Phases	4			8		Free	2		2	6		6
Actuated Green, G (s)	13.2	13.2		25.1	25.1	79.8		22.2	22.2	44.1	44.1	44.1
Effective Green, g (s)	13.2	13.2		25.1	25.1	79.8		22.2	22.2	44.1	44.1	44.1
Actuated g/C Ratio	0.17	0.17		0.31	0.31	1.00		0.28	0.28	0.55	0.55	0.55
Clearance Time (s)	6.6	6.6		6.3	4.8			5.5	5.5	5.0	5.8	5.8
Vehicle Extension (s)	3.0	3.0		3.0	3.0			3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	170	529		259	1005	1473		480	405	463	957	805
v/s Ratio Prot		0.08		0.02	0.08					c0.24	0.31	
v/s Ratio Perm	0.06			0.09		c0.43		0.24	0.02	c0.37		0.03
v/c Ratio	0.35	0.49		0.33	0.26	0.43		0.87	0.07	1.10	0.56	0.05
Uniform Delay, d1	29.5	30.3		20.1	20.4	0.0		27.4	21.2	19.4	11.6	8.2
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	1.3	0.7		0.8	0.1	0.9		15.3	0.1	70.8	0.8	0.0
Delay (s)	30.8	31.0		20.9	20.6	0.9		42.7	21.3	90.2	12.3	8.2
Level of Service	C	C		C	C	A		D	C	F	B	A
Approach Delay (s)		31.0			7.9			38.3			47.5	
Approach LOS		C			A			D			D	

Intersection Summary			
HCM 2000 Control Delay	30.8	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	1.05		
Actuated Cycle Length (s)	79.8	Sum of lost time (s)	23.4
Intersection Capacity Utilization	87.3%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	3.6

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	379	19	271	327	2	121
Future Vol, veh/h	379	19	271	327	2	121
Conflicting Peds, #/hr	0	4	4	0	0	4
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	100	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	96	96	96	96	96	96
Heavy Vehicles, %	2	0	2	2	0	1
Mvmt Flow	395	20	282	341	2	126

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	419	0	1314	413
Stage 1	-	-	-	-	409	-
Stage 2	-	-	-	-	905	-
Critical Hdwy	-	-	4.12	-	6.4	6.21
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.218	-	3.5	3.309
Pot Cap-1 Maneuver	-	-	1140	-	176	641
Stage 1	-	-	-	-	675	-
Stage 2	-	-	-	-	398	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1136	-	122	636
Mov Cap-2 Maneuver	-	-	-	-	122	-
Stage 1	-	-	-	-	672	-
Stage 2	-	-	-	-	276	-

Approach	EB	WB	NB
HCM Control Delay, s	0	4.2	12.5
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	122	636	-	-	1136	-
HCM Lane V/C Ratio	0.017	0.198	-	-	0.248	-
HCM Control Delay (s)	35	12.1	-	-	9.2	0
HCM Lane LOS	E	B	-	-	A	A
HCM 95th %tile Q(veh)	0.1	0.7	-	-	1	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	78	0	411	156	324	4	450	482	0	0	371	78
Future Volume (vph)	78	0	411	156	324	4	450	482	0	0	371	78
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		6.0	6.3	6.3		5.8	4.9			4.9	
Lane Util. Factor	1.00		1.00	1.00	0.95		1.00	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.97	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1630		1352	1614	3243		1613	1716			3187	
Flt Permitted	0.95		1.00	0.95	1.00		0.18	1.00			1.00	
Satd. Flow (perm)	1630		1352	1614	3243		308	1716			3187	
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	88	0	462	175	364	4	506	542	0	0	417	88
RTOR Reduction (vph)	0	0	72	0	1	0	0	0	0	0	15	0
Lane Group Flow (vph)	88	0	390	175	367	0	506	542	0	0	490	0
Confl. Peds. (#/hr)						2	8					8
Heavy Vehicles (%)	2%	0%	10%	3%	2%	33%	3%	2%	0%	0%	1%	2%
Turn Type	Prot		pt+ov	Split	NA		pm+pt	NA			NA	
Protected Phases	4		4 5	8	8		5	2			6	
Permitted Phases							2					
Actuated Green, G (s)	15.4		50.4	16.0	16.0		61.8	61.8			21.0	
Effective Green, g (s)	15.4		50.4	16.0	16.0		61.8	61.8			21.0	
Actuated g/C Ratio	0.14		0.46	0.14	0.14		0.56	0.56			0.19	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			4.9	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	227		617	233	470		586	960			606	
v/s Ratio Prot	0.05		c0.29	0.11	c0.11		c0.27	0.32			0.15	
v/s Ratio Perm							c0.21					
v/c Ratio	0.39		0.63	0.75	0.78		0.86	0.56			0.81	
Uniform Delay, d1	43.2		22.9	45.3	45.5		25.0	15.6			42.8	
Progression Factor	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Incremental Delay, d2	1.1		2.1	12.8	8.2		12.5	0.8			7.8	
Delay (s)	44.3		25.0	58.1	53.7		37.6	16.4			50.6	
Level of Service	D		C	E	D		D	B			D	
Approach Delay (s)		28.1			55.1			26.6			50.6	
Approach LOS		C			E			C			D	

Intersection Summary			
HCM 2000 Control Delay	37.3	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.84		
Actuated Cycle Length (s)	110.4	Sum of lost time (s)	23.0
Intersection Capacity Utilization	74.1%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	36	135	5	86	227	530	9	451	96	472	375	91
Future Volume (vph)	36	135	5	86	227	530	9	451	96	472	375	91
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	4.0		6.1	6.1	5.0	5.8	5.8
Lane Util. Factor	1.00	0.95		1.00	0.95	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		1.00	1.00	1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.99		1.00	1.00	0.85		1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1614	3067		1597	3197	1458		1694	1377	1539	1716	1488
Flt Permitted	0.59	1.00		0.45	1.00	1.00		0.99	1.00	0.17	1.00	1.00
Satd. Flow (perm)	1003	3067		765	3197	1458		1678	1377	269	1716	1488
Peak-hour factor, PHF	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Adj. Flow (vph)	41	155	6	99	261	609	10	518	110	543	431	105
RTOR Reduction (vph)	0	3	0	0	0	0	0	0	71	0	0	33
Lane Group Flow (vph)	41	158	0	99	261	609	0	528	39	543	431	72
Confl. Peds. (#/hr)			1	1			1					
Heavy Vehicles (%)	3%	8%	0%	4%	4%	2%	14%	3%	8%	8%	2%	0%
Turn Type	Perm	NA		pm+pt	NA	Free	Perm	NA	Perm	pm+pt	NA	Perm
Protected Phases		4		3	8			2		1	6	
Permitted Phases	4			8		Free	2		2	6		6
Actuated Green, G (s)	12.9	12.9		26.0	26.0	108.0		38.0	38.0	71.4	71.4	71.4
Effective Green, g (s)	12.9	12.9		26.0	26.0	108.0		38.0	38.0	71.4	71.4	71.4
Actuated g/C Ratio	0.12	0.12		0.24	0.24	1.00		0.35	0.35	0.66	0.66	0.66
Clearance Time (s)	6.6	6.6		6.3	4.8			6.1	6.1	5.0	5.8	5.8
Vehicle Extension (s)	3.0	3.0		3.0	3.0			3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	119	366		222	769	1458		590	484	508	1134	983
v/s Ratio Prot		0.05		0.02	0.08					c0.28	0.25	
v/s Ratio Perm	0.04			0.09		c0.42		0.31	0.03	c0.43		0.05
v/c Ratio	0.34	0.43		0.45	0.34	0.42		0.89	0.08	1.07	0.38	0.07
Uniform Delay, d1	43.7	44.2		33.8	33.9	0.0		33.1	23.3	27.6	8.3	6.5
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	1.7	0.8		1.4	0.3	0.9		16.0	0.1	59.6	0.2	0.0
Delay (s)	45.4	45.0		35.2	34.2	0.9		49.1	23.4	87.2	8.5	6.6
Level of Service	D	D		D	C	A		D	C	F	A	A
Approach Delay (s)		45.1			13.4			44.7			47.9	
Approach LOS		D			B			D			D	

Intersection Summary			
HCM 2000 Control Delay	35.4	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	1.03		
Actuated Cycle Length (s)	108.0	Sum of lost time (s)	24.0
Intersection Capacity Utilization	90.8%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	3.3

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	374	17	107	359	0	182
Future Vol, veh/h	374	17	107	359	0	182
Conflicting Peds, #/hr	0	1	1	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	100	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	3	11	2	1	0	2
Mvmt Flow	420	19	120	403	0	204

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	440	0	1075	431
Stage 1	-	-	-	-	431	-
Stage 2	-	-	-	-	644	-
Critical Hdwy	-	-	4.12	-	6.4	6.22
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.218	-	3.5	3.318
Pot Cap-1 Maneuver	-	-	1120	-	245	624
Stage 1	-	-	-	-	660	-
Stage 2	-	-	-	-	527	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1120	-	211	623
Mov Cap-2 Maneuver	-	-	-	-	211	-
Stage 1	-	-	-	-	659	-
Stage 2	-	-	-	-	454	-

Approach	EB	WB	NB
HCM Control Delay, s	0	2	13.6
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	-	623	-	-	1120	-
HCM Lane V/C Ratio	-	0.328	-	-	0.107	-
HCM Control Delay (s)	0	13.6	-	-	8.6	0
HCM Lane LOS	A	B	-	-	A	A
HCM 95th %tile Q(veh)	-	1.4	-	-	0.4	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	155	0	597	311	521	4	517	654	0	0	438	64
Future Volume (vph)	155	0	597	311	521	4	517	654	0	0	438	64
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		6.0	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		1.00	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.98	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1662		1473	1662	3321		1645	1750			3248	
Flt Permitted	0.95		1.00	0.95	1.00		0.18	1.00			1.00	
Satd. Flow (perm)	1662		1473	1662	3321		303	1750			3248	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	163	0	628	327	548	4	544	688	0	0	461	67
RTOR Reduction (vph)	0	0	46	0	1	0	0	0	0	0	10	0
Lane Group Flow (vph)	163	0	582	327	551	0	544	688	0	0	518	0
Confl. Peds. (#/hr)						2	13					13
Heavy Vehicles (%)	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Turn Type	Prot		pt+ov	Split	NA		pm+pt	NA			NA	
Protected Phases	7		7 5	8	8		5	2			6	
Permitted Phases							2					
Actuated Green, G (s)	19.0		49.4	22.7	22.7		59.4	59.4			22.7	
Effective Green, g (s)	19.0		49.4	22.7	22.7		59.4	59.4			22.7	
Actuated g/C Ratio	0.16		0.42	0.19	0.19		0.50	0.50			0.19	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	266		615	318	637		496	878			623	
v/s Ratio Prot	0.10		c0.40	c0.20	0.17		c0.28	0.39			0.16	
v/s Ratio Perm							c0.27					
v/c Ratio	0.61		0.95	1.03	0.87		1.10	0.78			0.83	
Uniform Delay, d1	46.2		33.2	47.8	46.3		32.0	24.2			46.0	
Progression Factor	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Incremental Delay, d2	4.1		23.6	57.9	11.8		69.4	4.6			9.3	
Delay (s)	50.4		56.8	105.7	58.1		101.3	28.8			55.2	
Level of Service	D		E	F	E		F	C			E	
Approach Delay (s)		55.5			75.8			60.8			55.2	
Approach LOS		E			E			E			E	

Intersection Summary			
HCM 2000 Control Delay	62.6	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	1.09		
Actuated Cycle Length (s)	118.3	Sum of lost time (s)	23.5
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	63	269	8	91	275	670	4	499	132	613	646	87
Future Volume (vph)	63	269	8	91	275	670	4	499	132	613	646	87
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	4.0		5.5	5.5	5.0	5.8	5.8
Lane Util. Factor	1.00	0.95		1.00	0.95	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		1.00	1.00	1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	1.00	0.85		1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1662	3203		1582	3197	1473		1732	1458	1630	1733	1458
Flt Permitted	0.57	1.00		0.36	1.00	1.00		1.00	1.00	0.12	1.00	1.00
Satd. Flow (perm)	1006	3203		606	3197	1473		1725	1458	210	1733	1458
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	66	283	8	96	289	705	4	525	139	645	680	92
RTOR Reduction (vph)	0	2	0	0	0	0	0	0	90	0	0	32
Lane Group Flow (vph)	66	289	0	96	289	705	0	529	49	645	680	60
Confl. Peds. (#/hr)			2	2			12					
Heavy Vehicles (%)	0%	3%	14%	5%	4%	1%	0%	1%	2%	2%	1%	2%
Turn Type	Perm	NA		pm+pt	NA	Free	Perm	NA	Perm	pm+pt	NA	Perm
Protected Phases		4		3	8			2		1	6	
Permitted Phases	4			8		Free	2		2	6		6
Actuated Green, G (s)	15.7	15.7		28.9	28.9	112.4		37.1	37.1	72.9	72.9	72.9
Effective Green, g (s)	15.7	15.7		28.9	28.9	112.4		37.1	37.1	72.9	72.9	72.9
Actuated g/C Ratio	0.14	0.14		0.26	0.26	1.00		0.33	0.33	0.65	0.65	0.65
Clearance Time (s)	6.6	6.6		6.3	4.8			5.5	5.5	5.0	5.8	5.8
Vehicle Extension (s)	3.0	3.0		3.0	3.0			3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	140	447		200	822	1473		569	481	529	1123	945
v/s Ratio Prot		0.09		0.02	0.09					c0.34	0.39	
v/s Ratio Perm	0.07			0.10		c0.48		0.31	0.03	c0.45		0.04
v/c Ratio	0.47	0.65		0.48	0.35	0.48		0.93	0.10	1.22	0.61	0.06
Uniform Delay, d1	44.5	45.7		33.8	34.1	0.0		36.4	26.1	31.7	11.4	7.2
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	2.5	3.2		1.8	0.3	1.1		21.7	0.1	114.9	0.9	0.0
Delay (s)	47.0	48.9		35.6	34.4	1.1		58.0	26.2	146.6	12.4	7.3
Level of Service	D	D		D	C	A		E	C	F	B	A
Approach Delay (s)		48.6			13.0			51.4			73.1	
Approach LOS		D			B			D			E	

Intersection Summary			
HCM 2000 Control Delay	48.0	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	1.15		
Actuated Cycle Length (s)	112.4	Sum of lost time (s)	23.4
Intersection Capacity Utilization	101.3%	ICU Level of Service	G
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	4.1

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	481	24	337	408	3	154
Future Vol, veh/h	481	24	337	408	3	154
Conflicting Peds, #/hr	0	4	4	0	0	4
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	100	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	96	96	96	96	96	96
Heavy Vehicles, %	2	0	2	2	0	1
Mvmt Flow	501	25	351	425	3	160

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	530	0	1645	522
Stage 1	-	-	-	-	518	-
Stage 2	-	-	-	-	1127	-
Critical Hdwy	-	-	4.12	-	6.4	6.21
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.218	-	3.5	3.309
Pot Cap-1 Maneuver	-	-	1037	-	111	557
Stage 1	-	-	-	-	602	-
Stage 2	-	-	-	-	312	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1033	-	61	553
Mov Cap-2 Maneuver	-	-	-	-	61	-
Stage 1	-	-	-	-	600	-
Stage 2	-	-	-	-	173	-

Approach	EB	WB	NB
HCM Control Delay, s	0	4.6	15.1
HCM LOS			C

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	61	553	-	-	1033	-
HCM Lane V/C Ratio	0.051	0.29	-	-	0.34	-
HCM Control Delay (s)	67.2	14.1	-	-	10.3	0
HCM Lane LOS	F	B	-	-	B	A
HCM 95th %tile Q(veh)	0.2	1.2	-	-	1.5	-

DELAY (CONTROL)

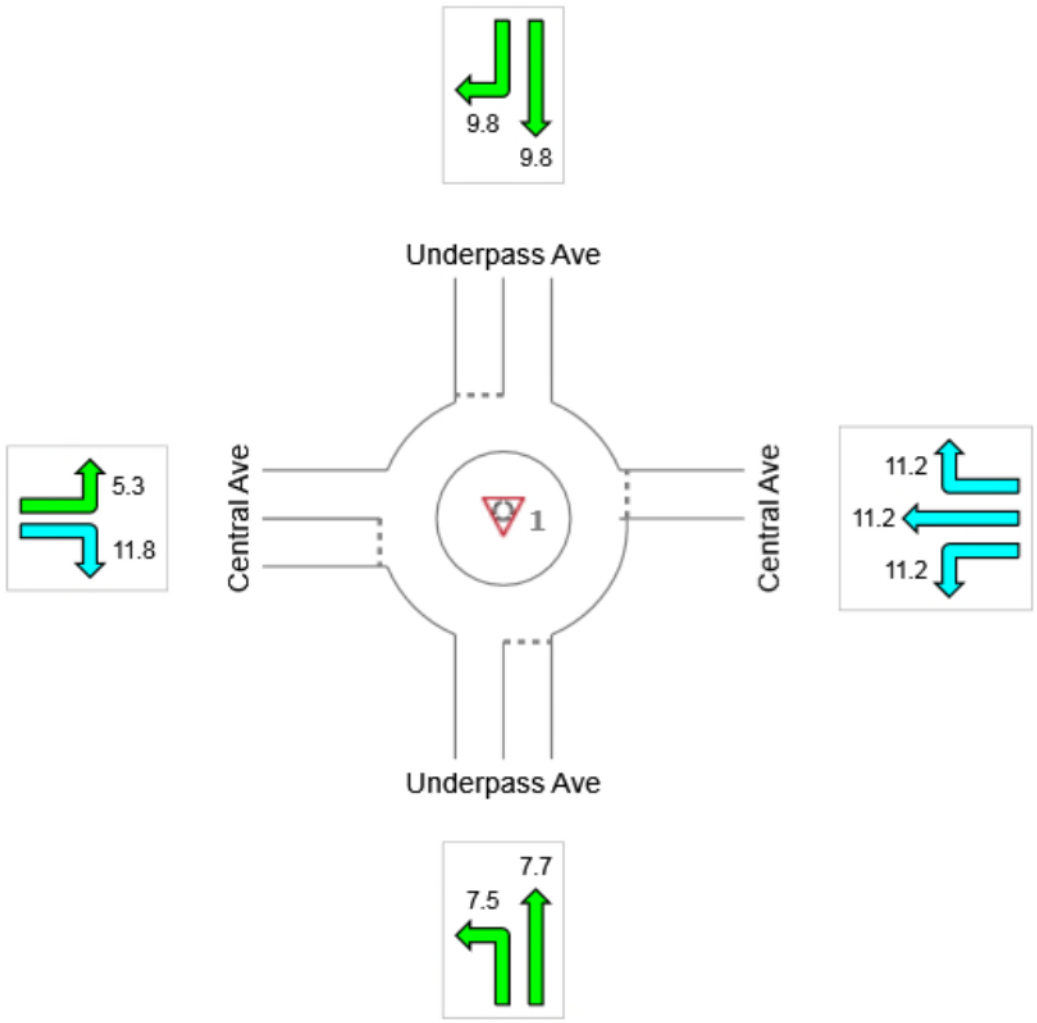
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 1 [2018 AM Central Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	7.6	11.2	9.8	10.8	9.4
LOS	A	B	A	B	A



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

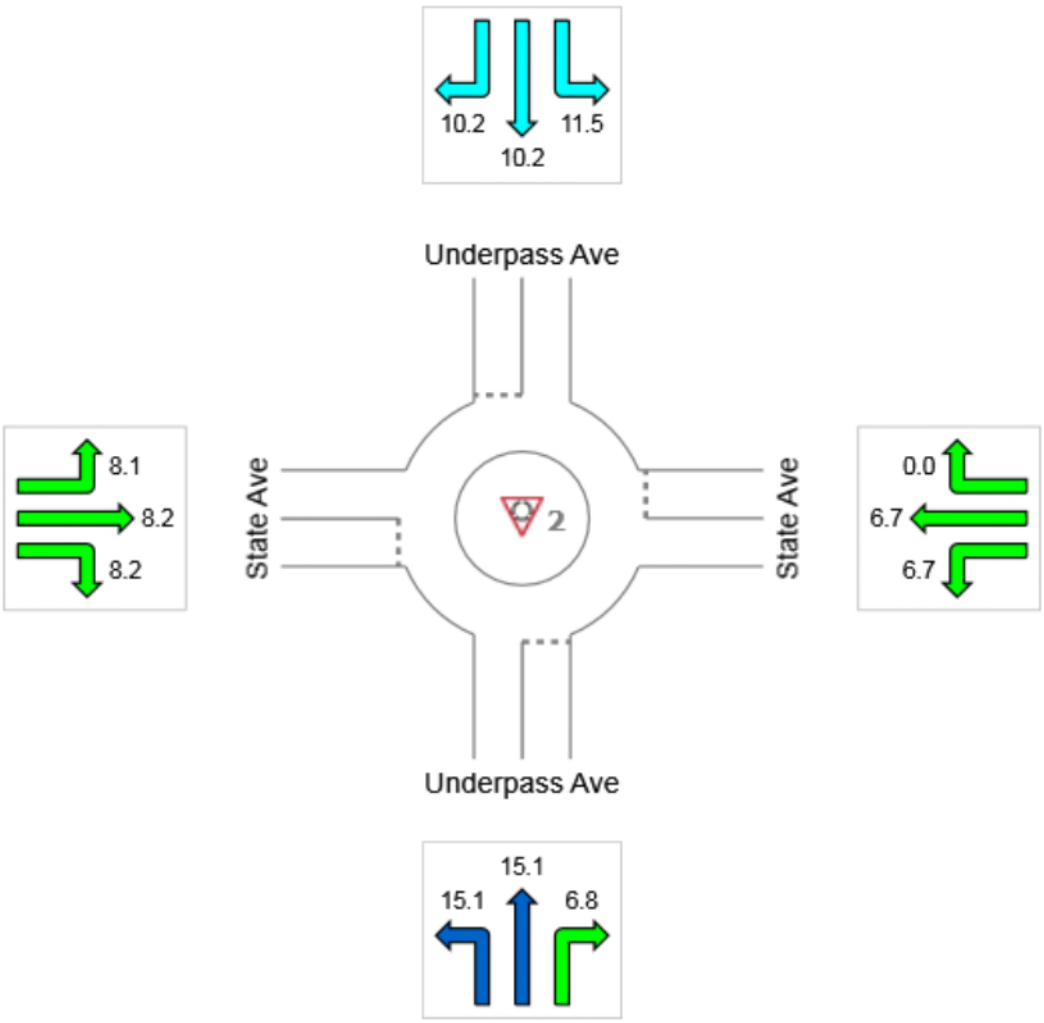
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 2 [2018 AM State Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	13.6	2.5	10.9	8.2	8.2
LOS	B	A	B	A	A



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

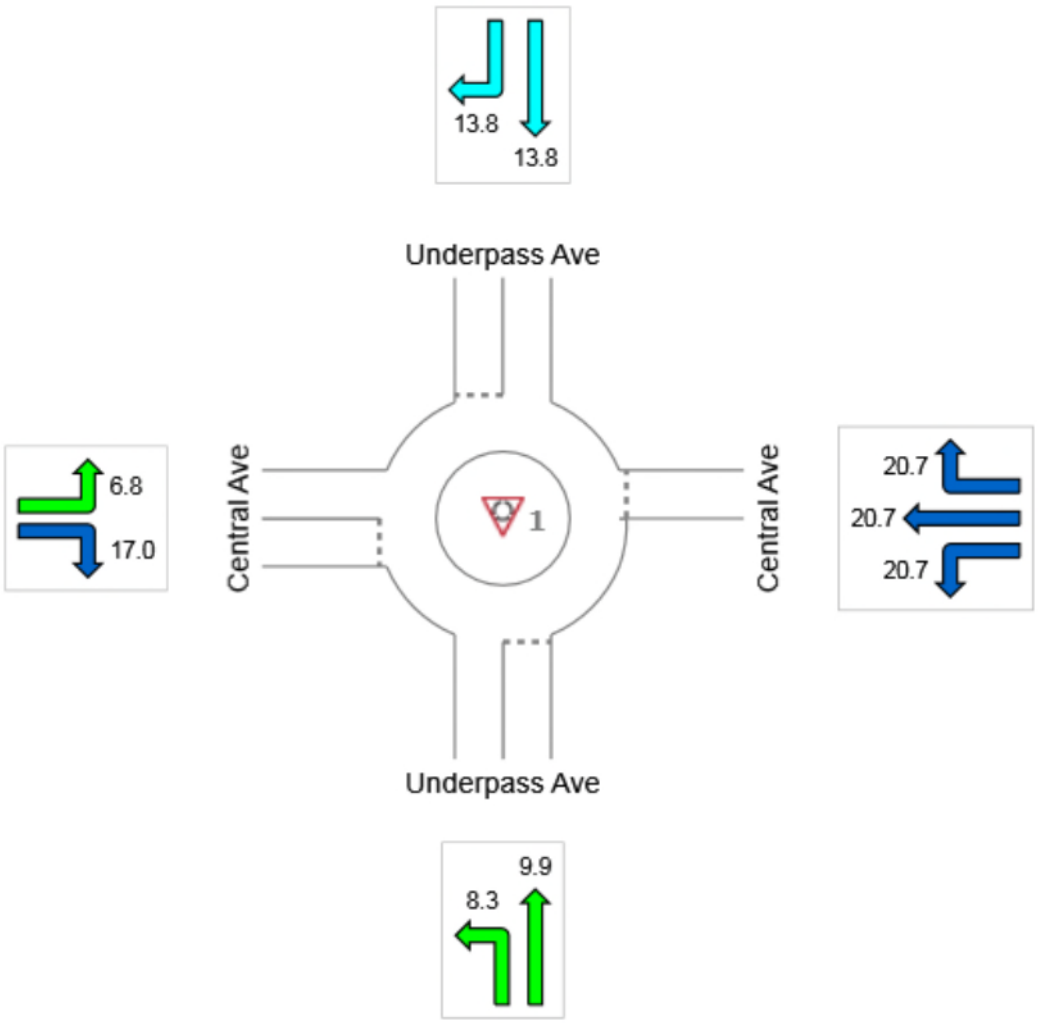
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 1 [2018 PM Central Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	9.2	20.7	13.8	14.8	14.1
LOS	A	C	B	B	B



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

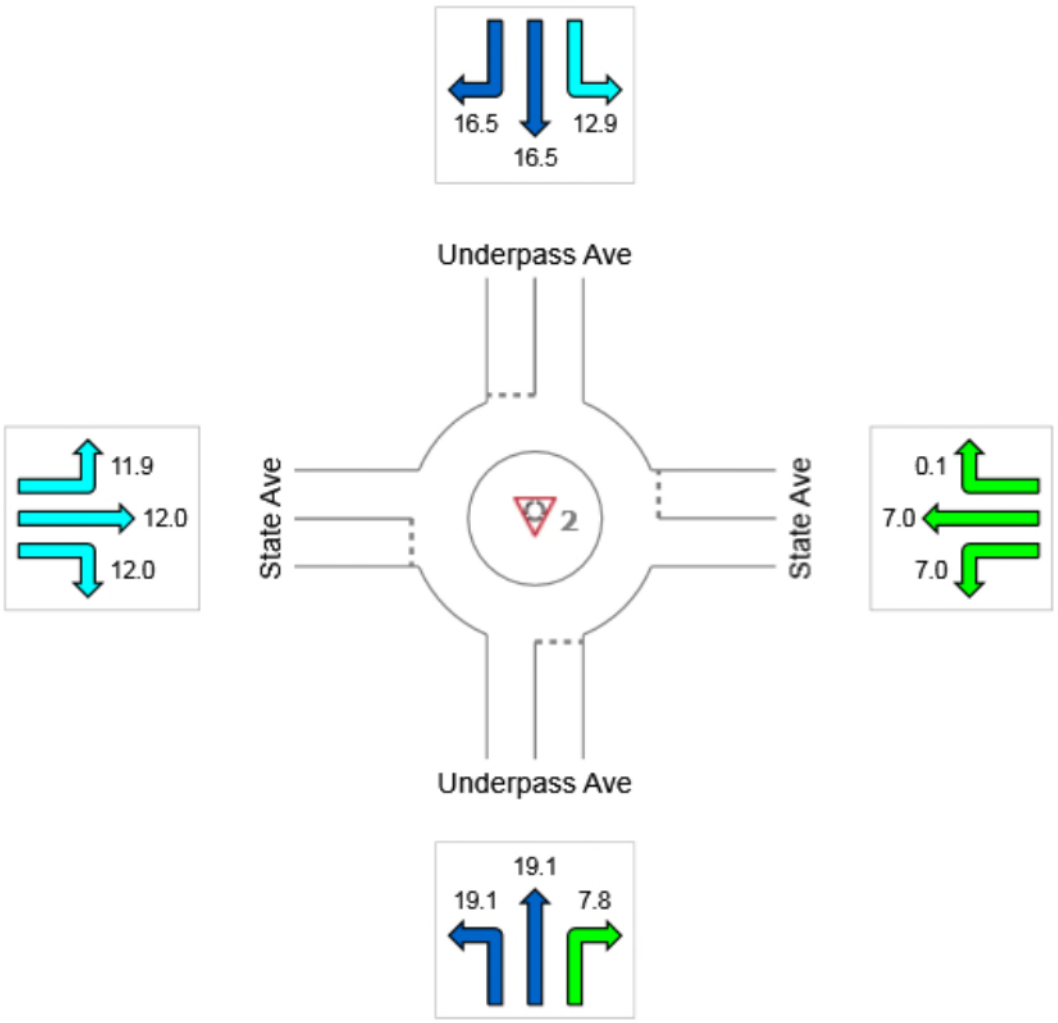
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 2 [2018 PM State Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	16.8	2.5	14.9	11.9	10.8
LOS	C	A	B	B	B



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

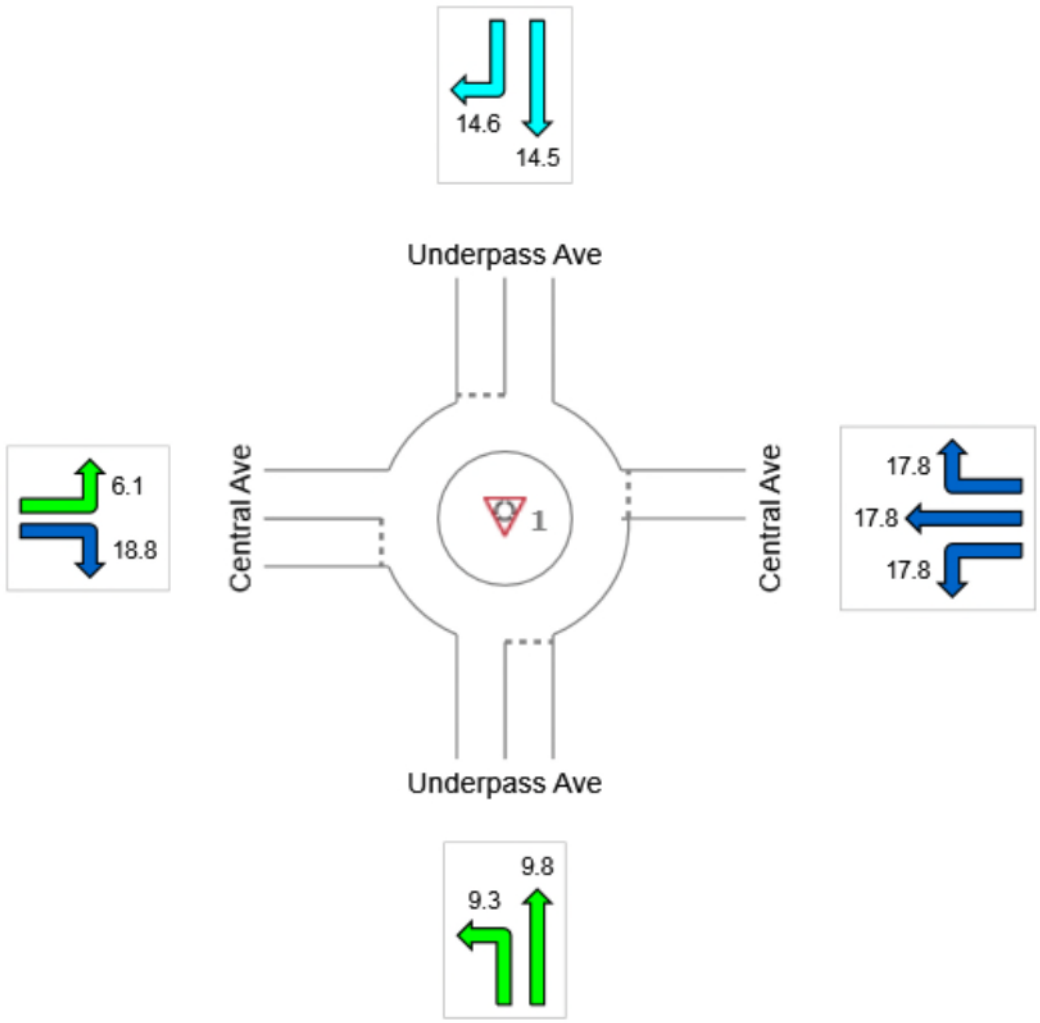
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 1 [2038 AM Central Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	9.5	17.8	14.5	16.8	13.7
LOS	A	C	B	C	B



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

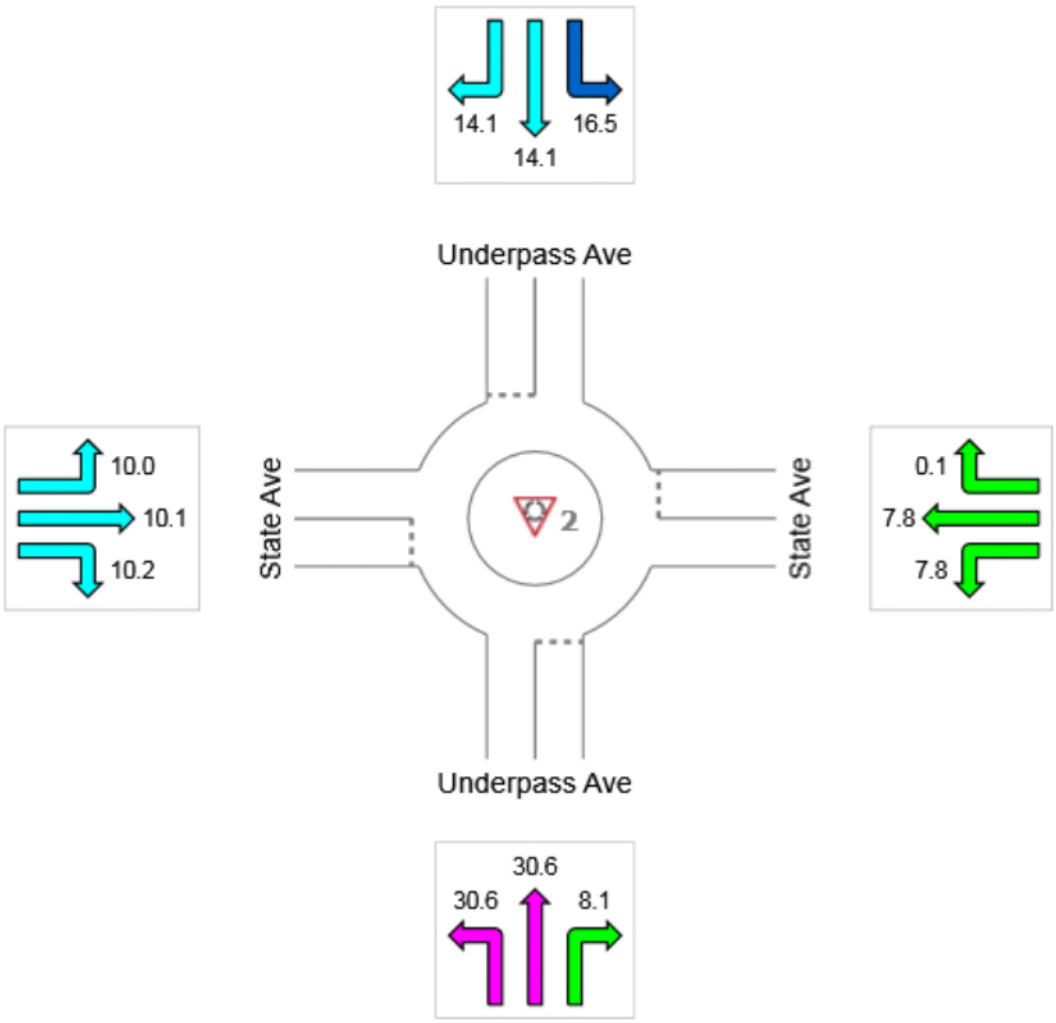
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 2 [2038 AM State Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	26.7	2.9	15.3	10.1	13.3
LOS	D	A	C	B	B



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

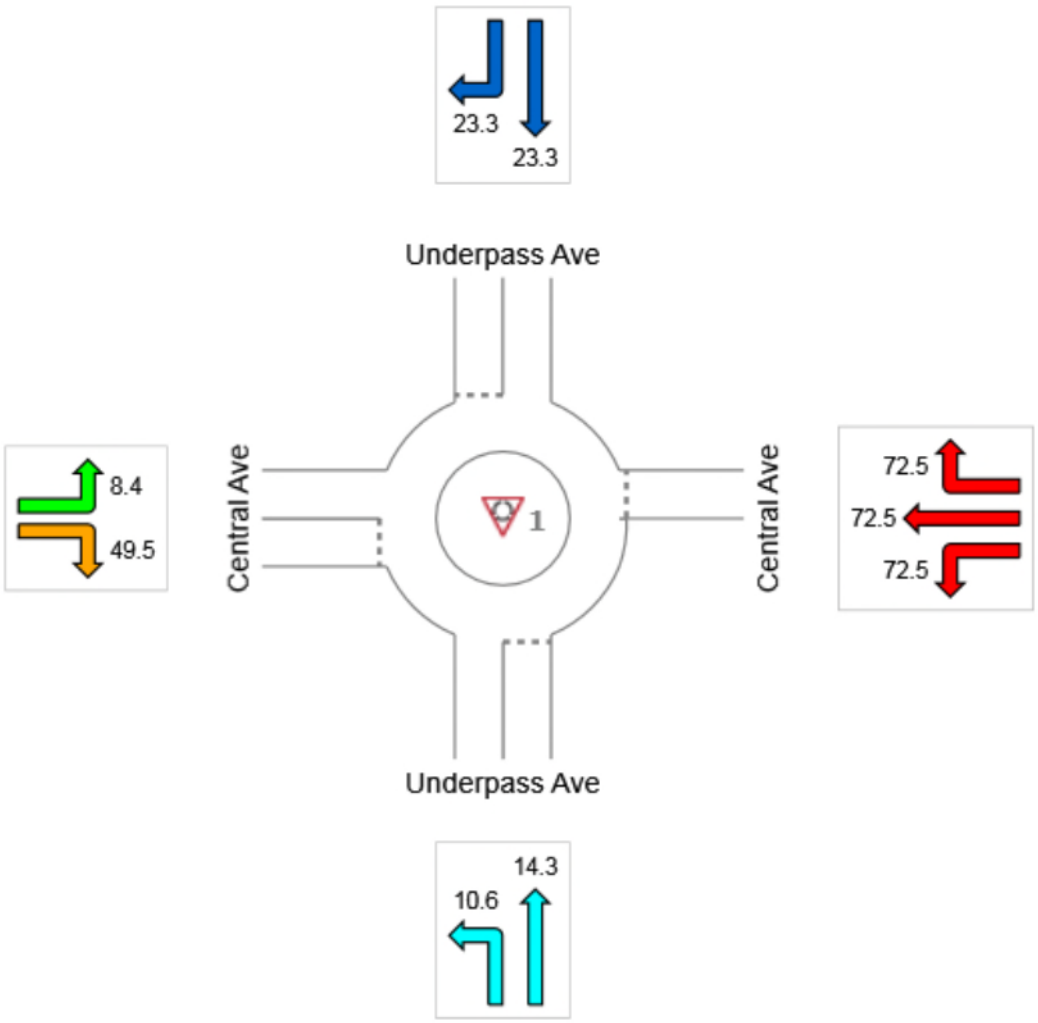
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 1 [2038 PM Central Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	12.6	72.5	23.3	41.0	36.2
LOS	B	F	C	E	E



Colour code based on Level of Service

LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

DELAY (CONTROL)

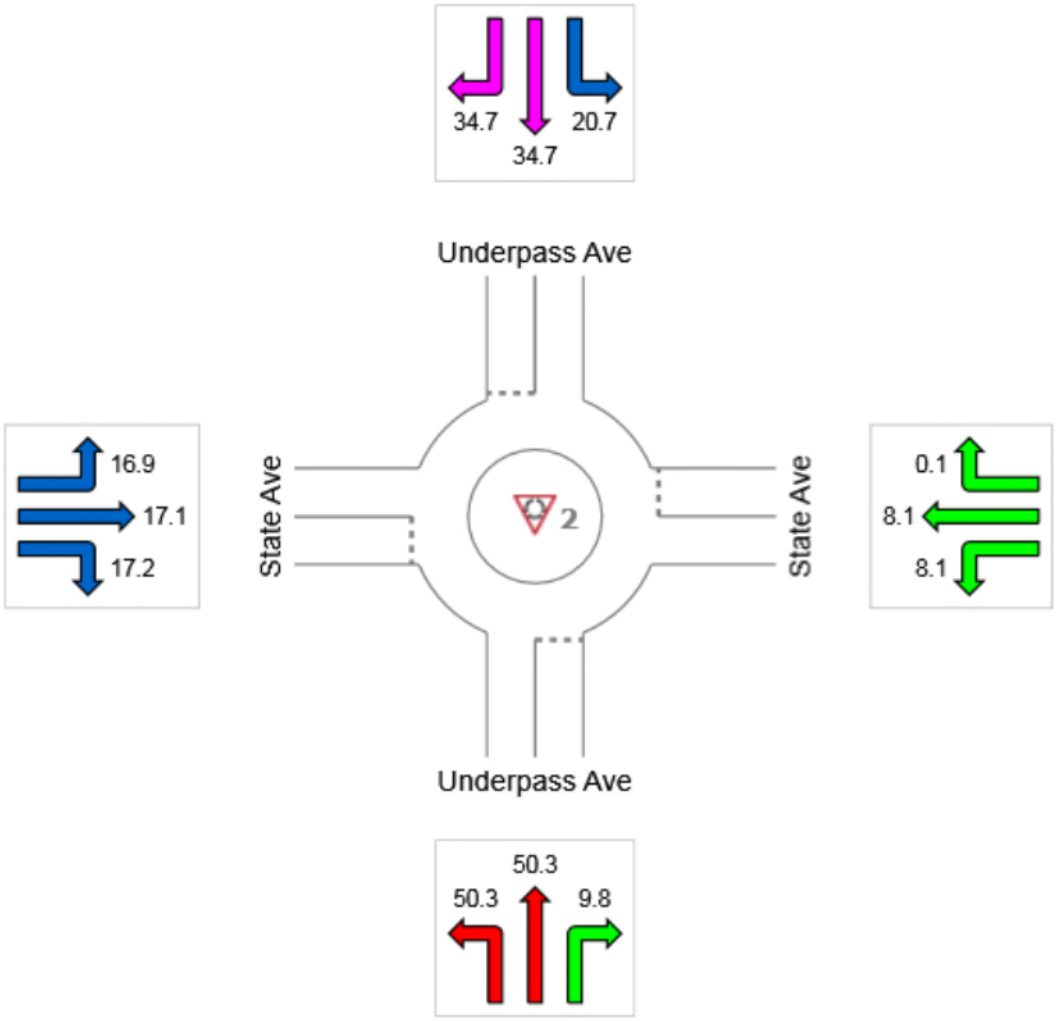
Average control delay per vehicle, or average pedestrian delay (seconds)

Site: 2 [2038 PM State Ave & Underpass Ave]

2038 PM
Roundabout

All Movement Classes

	South	East	North	West	Intersection
Delay (Control)	41.9	2.9	28.3	17.1	21.9
LOS	E	A	D	C	C



Colour code based on Level of Service

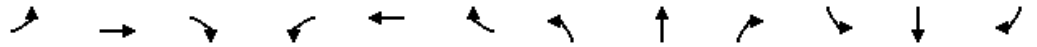
LOS A | LOS B | LOS C | LOS D | LOS E | LOS F

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Roundabout Level of Service Method: Same as Sign Control
HCM Delay Formula option is used. Control Delay does not include Geometric Delay since Exclude Geometric Delay option applies.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	61	0	327	123	255	3	354	379	0	0	289	60
Future Volume (vph)	61	0	327	123	255	3	354	379	0	0	289	60
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		5.4	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		0.97	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.97	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1630		1352	1614	3244		3131	1716			3190	
Flt Permitted	0.57		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (perm)	985		1352	1614	3244		3131	1716			3190	
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	69	0	367	138	287	3	398	426	0	0	325	67
RTOR Reduction (vph)	0	0	126	0	1	0	0	0	0	0	23	0
Lane Group Flow (vph)	69	0	241	138	289	0	398	426	0	0	369	0
Confl. Peds. (#/hr)						2	8					8
Heavy Vehicles (%)	2%	0%	10%	3%	2%	33%	3%	2%	0%	0%	1%	2%
Turn Type	pm+pt		pt+ov	pm+pt	NA		Prot	NA			NA	
Protected Phases	7		4 5	3	8		5	2			6	
Permitted Phases	4			8								
Actuated Green, G (s)	18.5		40.3	22.3	14.7		21.8	42.7			14.6	
Effective Green, g (s)	18.5		40.3	22.3	14.7		21.8	42.7			14.6	
Actuated g/C Ratio	0.23		0.50	0.28	0.18		0.27	0.53			0.18	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	271		681	449	596		853	915			582	
v/s Ratio Prot	0.02		0.18	c0.03	c0.09		0.13	c0.25			c0.12	
v/s Ratio Perm	0.04			0.06								
v/c Ratio	0.25		0.35	0.31	0.49		0.47	0.47			0.63	
Uniform Delay, d1	24.7		12.0	22.8	29.3		24.3	11.6			30.2	
Progression Factor	1.00		1.00	1.00	1.00		0.69	0.86			1.00	
Incremental Delay, d2	0.5		0.3	0.4	0.6		1.5	1.3			2.3	
Delay (s)	25.2		12.3	23.1	29.9		18.3	11.3			32.5	
Level of Service	C		B	C	C		B	B			C	
Approach Delay (s)		14.3			27.7			14.6			32.5	
Approach LOS		B			C			B			C	

Intersection Summary			
HCM 2000 Control Delay	20.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.54		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	23.5
Intersection Capacity Utilization	55.5%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	32	122	5	78	205	480	7	355	76	372	295	72
Future Volume (vph)	32	122	5	78	205	480	7	355	76	372	295	72
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Lane Util. Factor	1.00	0.95		1.00	0.95	1.00		0.95	1.00	0.97	1.00	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Frt	1.00	0.99		1.00	1.00	0.85		1.00	0.85	1.00	0.97	
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1614	3066		1597	3197	1458		3218	1377	2986	1672	
Flt Permitted	0.60	1.00		0.66	1.00	1.00		0.94	1.00	0.95	1.00	
Satd. Flow (perm)	1028	3066		1109	3197	1458		3031	1377	2986	1672	
Peak-hour factor, PHF	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Adj. Flow (vph)	37	140	6	90	236	552	8	408	87	428	339	83
RTOR Reduction (vph)	0	4	0	0	0	132	0	0	72	0	9	0
Lane Group Flow (vph)	37	142	0	90	236	420	0	416	15	428	413	0
Confl. Peds. (#/hr)			1	1			1					
Heavy Vehicles (%)	3%	8%	0%	4%	4%	2%	14%	3%	8%	8%	2%	0%
Turn Type	D.P+P	NA		D.P+P	NA	pm+ov	Perm	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8	1		2		1	6	
Permitted Phases	8			4		8	2		2			
Actuated Green, G (s)	19.5	14.0		18.0	16.5	40.8		13.7	13.7	24.3	43.3	
Effective Green, g (s)	19.5	14.0		18.0	16.5	40.8		13.7	13.7	24.3	43.3	
Actuated g/C Ratio	0.24	0.18		0.22	0.21	0.51		0.17	0.17	0.30	0.54	
Clearance Time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0		3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	272	536		273	659	743		519	235	906	904	
v/s Ratio Prot	0.01	0.05		c0.02	0.07	c0.17				0.14	0.25	
v/s Ratio Perm	0.03			0.06		0.12		c0.14	0.01			
v/c Ratio	0.14	0.26		0.33	0.36	0.56		0.80	0.06	0.47	0.46	
Uniform Delay, d1	23.4	28.5		25.5	27.2	13.5		31.8	27.8	22.6	11.2	
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	0.86	0.88	
Incremental Delay, d2	0.2	0.3		0.7	0.3	1.0		8.7	0.1	1.6	1.5	
Delay (s)	23.6	28.8		26.2	27.5	14.5		40.5	27.9	21.1	11.4	
Level of Service	C	C		C	C	B		D	C	C	B	
Approach Delay (s)		27.8			19.2			38.3			16.3	
Approach LOS		C			B			D			B	

Intersection Summary			
HCM 2000 Control Delay	22.8	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.63		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	24.0
Intersection Capacity Utilization	66.5%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	122	0	449	233	410	3	407	515	0	0	378	58
Future Volume (vph)	122	0	449	233	410	3	407	515	0	0	378	58
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		5.4	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		0.97	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.98	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1662		1473	1662	3321		3162	1750			3246	
Flt Permitted	0.50		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (perm)	874		1473	1662	3321		3162	1750			3246	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	128	0	473	245	432	3	428	542	0	0	398	61
RTOR Reduction (vph)	0	0	80	0	1	0	0	0	0	0	16	0
Lane Group Flow (vph)	128	0	393	245	434	0	428	542	0	0	443	0
Confl. Peds. (#/hr)						2	13					13
Heavy Vehicles (%)	0%	0%	1%	0%	0%	0%	2%	0%	0%	0%	0%	0%
Turn Type	pm+pt		pt+ov	pm+pt	NA		Prot	NA			NA	
Protected Phases	7		4 5	3	8		5	2			6	
Permitted Phases	4			8								
Actuated Green, G (s)	22.4		39.1	26.4	19.0		16.4	38.7			16.0	
Effective Green, g (s)	22.4		39.1	26.4	19.0		16.4	38.7			16.0	
Actuated g/C Ratio	0.28		0.49	0.33	0.24		0.20	0.48			0.20	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	294		719	548	788		648	846			649	
v/s Ratio Prot	0.03		c0.27	c0.04	c0.13		0.14	c0.31			0.14	
v/s Ratio Perm	0.09			0.11								
v/c Ratio	0.44		0.55	0.45	0.55		0.66	0.64			0.68	
Uniform Delay, d1	22.5		14.3	21.1	26.8		29.2	15.4			29.6	
Progression Factor	1.00		1.00	1.00	1.00		0.74	1.01			1.00	
Incremental Delay, d2	1.0		0.9	0.6	0.8		3.9	2.8			3.0	
Delay (s)	23.5		15.1	21.6	27.6		25.6	18.3			32.6	
Level of Service	C		B	C	C		C	B			C	
Approach Delay (s)		16.9			25.5			21.5			32.6	
Approach LOS		B			C			C			C	

Intersection Summary			
HCM 2000 Control Delay	23.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.69		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	23.5
Intersection Capacity Utilization	72.5%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	57	244	7	82	249	606	3	393	104	483	509	68
Future Volume (vph)	57	244	7	82	249	606	3	393	104	483	509	68
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Lane Util. Factor	1.00	0.95		1.00	0.95	1.00		0.95	1.00	0.97	1.00	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Frt	1.00	1.00		1.00	1.00	0.85		1.00	0.85	1.00	0.98	
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1662	3204		1581	3197	1473		3291	1458	3162	1700	
Flt Permitted	0.57	1.00		0.59	1.00	1.00		0.95	1.00	0.95	1.00	
Satd. Flow (perm)	992	3204		980	3197	1473		3123	1458	3162	1700	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	60	257	7	86	262	638	3	414	109	508	536	72
RTOR Reduction (vph)	0	2	0	0	0	119	0	0	90	0	5	0
Lane Group Flow (vph)	60	262	0	86	262	519	0	417	19	508	603	0
Confl. Peds. (#/hr)			2	2			12					
Heavy Vehicles (%)	0%	3%	14%	5%	4%	1%	0%	1%	2%	2%	1%	2%
Turn Type	D.P+P	NA		D.P+P	NA	pm+ov	Perm	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8	1		2		1	6	
Permitted Phases	8			4		8	2		2			
Actuated Green, G (s)	19.0	13.5		17.5	15.0	39.9		13.6	13.6	24.9	43.8	
Effective Green, g (s)	19.0	13.5		17.5	15.0	39.9		13.6	13.6	24.9	43.8	
Actuated g/C Ratio	0.24	0.17		0.22	0.19	0.50		0.17	0.17	0.31	0.55	
Clearance Time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0		3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	269	540		244	599	734		530	247	984	930	
v/s Ratio Prot	0.01	0.08		c0.02	0.08	c0.22				0.16	c0.35	
v/s Ratio Perm	0.04			0.06		0.13		c0.13	0.01			
v/c Ratio	0.22	0.48		0.35	0.44	0.71		0.79	0.08	0.52	0.65	
Uniform Delay, d1	24.1	30.1		25.8	28.8	15.5		31.8	27.9	22.6	12.7	
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	0.90	1.17	
Incremental Delay, d2	0.4	0.7		0.9	0.5	3.1		7.6	0.1	1.6	3.0	
Delay (s)	24.6	30.8		26.7	29.3	18.7		39.4	28.0	21.9	17.8	
Level of Service	C	C		C	C	B		D	C	C	B	
Approach Delay (s)		29.6			22.2			37.0			19.7	
Approach LOS		C			C			D			B	

Intersection Summary			
HCM 2000 Control Delay	24.7	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.72		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	24.0
Intersection Capacity Utilization	80.0%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	78	0	411	156	324	4	450	482	0	0	371	78
Future Volume (vph)	78	0	411	156	324	4	450	482	0	0	371	78
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		5.4	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		0.97	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.97	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1630		1352	1614	3243		3131	1716			3185	
Flt Permitted	0.47		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (perm)	814		1352	1614	3243		3131	1716			3185	
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	88	0	462	175	364	4	506	542	0	0	417	88
RTOR Reduction (vph)	0	0	101	0	1	0	0	0	0	0	15	0
Lane Group Flow (vph)	88	0	361	175	367	0	506	542	0	0	490	0
Confl. Peds. (#/hr)						2	8					8
Heavy Vehicles (%)	2%	0%	10%	3%	2%	33%	3%	2%	0%	0%	1%	2%
Turn Type	pm+pt		pt+ov	pm+pt	NA		Prot	NA			NA	
Protected Phases	7		4 5	3	8		5	2			6	
Permitted Phases	4			8								
Actuated Green, G (s)	30.6		66.1	35.6	23.1		39.8	70.0			23.9	
Effective Green, g (s)	30.6		66.1	35.6	23.1		39.8	70.0			23.9	
Actuated g/C Ratio	0.26		0.55	0.30	0.19		0.33	0.58			0.20	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	273		744	478	624		1038	1001			634	
v/s Ratio Prot	0.03		0.27	c0.04	c0.11		0.16	c0.32			c0.15	
v/s Ratio Perm	0.06			0.07								
v/c Ratio	0.32		0.49	0.37	0.59		0.49	0.54			0.77	
Uniform Delay, d1	35.2		16.5	33.3	44.1		32.0	15.2			45.5	
Progression Factor	1.00		1.00	1.00	1.00		0.75	0.86			1.00	
Incremental Delay, d2	0.7		0.5	0.5	1.4		1.3	1.6			5.8	
Delay (s)	35.9		17.0	33.8	45.5		25.1	14.7			51.3	
Level of Service	D		B	C	D		C	B			D	
Approach Delay (s)		20.1			41.7			19.8			51.3	
Approach LOS		C			D			B			D	

Intersection Summary			
HCM 2000 Control Delay	30.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.62		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	23.5
Intersection Capacity Utilization	65.5%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	36	135	5	86	227	530	9	451	96	472	375	91
Future Volume (vph)	36	135	5	86	227	530	9	451	96	472	375	91
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Lane Util. Factor	1.00	0.95		1.00	0.95	1.00		0.95	1.00	0.97	1.00	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Frt	1.00	0.99		1.00	1.00	0.85		1.00	0.85	1.00	0.97	
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1614	3067		1596	3197	1458		3219	1377	2986	1672	
Flt Permitted	0.48	1.00		0.65	1.00	1.00		0.94	1.00	0.95	1.00	
Satd. Flow (perm)	819	3067		1092	3197	1458		3027	1377	2986	1672	
Peak-hour factor, PHF	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Adj. Flow (vph)	41	155	6	99	261	609	10	518	110	543	431	105
RTOR Reduction (vph)	0	3	0	0	0	80	0	0	86	0	7	0
Lane Group Flow (vph)	41	158	0	99	261	529	0	528	24	543	529	0
Confl. Peds. (#/hr)			1	1			1					
Heavy Vehicles (%)	3%	8%	0%	4%	4%	2%	14%	3%	8%	8%	2%	0%
Turn Type	D.P+P	NA		D.P+P	NA	pm+ov	Perm	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8	1		2		1	6	
Permitted Phases	8			4		8	2		2			
Actuated Green, G (s)	24.9	15.2		23.4	19.2	65.5		26.3	26.3	46.3	77.9	
Effective Green, g (s)	24.9	15.2		23.4	19.2	65.5		26.3	26.3	46.3	77.9	
Actuated g/C Ratio	0.21	0.13		0.19	0.16	0.55		0.22	0.22	0.39	0.65	
Clearance Time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0		3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	207	388		247	511	795		663	301	1152	1085	
v/s Ratio Prot	0.01	0.05		c0.03	0.08	c0.26				0.18	0.32	
v/s Ratio Perm	0.03			0.05		0.11		c0.17	0.02			
v/c Ratio	0.20	0.41		0.40	0.51	0.67		0.80	0.08	0.47	0.49	
Uniform Delay, d1	38.7	48.3		41.5	46.1	19.4		44.3	37.2	27.7	10.8	
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	0.88	0.54	
Incremental Delay, d2	0.5	0.7		1.1	0.9	2.1		6.6	0.1	1.2	1.4	
Delay (s)	39.2	49.0		42.5	47.0	21.6		50.9	37.4	25.6	7.2	
Level of Service	D	D		D	D	C		D	D	C	A	
Approach Delay (s)		47.0			30.5			48.6			16.4	
Approach LOS		D			C			D			B	

Intersection Summary			
HCM 2000 Control Delay	30.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.71		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	24.0
Intersection Capacity Utilization	75.8%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	155	0	597	311	521	4	517	654	0	0	438	64
Future Volume (vph)	155	0	597	311	521	4	517	654	0	0	438	64
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.0		5.4	6.3	6.3		5.8	4.9			5.4	
Lane Util. Factor	1.00		1.00	1.00	0.95		0.97	1.00			0.95	
Frpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Flpb, ped/bikes	1.00		1.00	1.00	1.00		1.00	1.00			1.00	
Frt	1.00		0.85	1.00	1.00		1.00	1.00			0.98	
Flt Protected	0.95		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (prot)	1662		1473	1662	3321		3193	1750			3246	
Flt Permitted	0.33		1.00	0.95	1.00		0.95	1.00			1.00	
Satd. Flow (perm)	571		1473	1662	3321		3193	1750			3246	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	163	0	628	327	548	4	544	688	0	0	461	67
RTOR Reduction (vph)	0	0	63	0	1	0	0	0	0	0	10	0
Lane Group Flow (vph)	163	0	565	327	551	0	544	688	0	0	518	0
Confl. Peds. (#/hr)						2	13					13
Heavy Vehicles (%)	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Turn Type	pm+pt		pt+ov	pm+pt	NA		Prot	NA			NA	
Protected Phases	7		4 5	3	8		5	2			6	
Permitted Phases	4			8								
Actuated Green, G (s)	41.0		64.0	45.4	31.5		29.0	59.9			24.6	
Effective Green, g (s)	41.0		64.0	45.4	31.5		29.0	59.9			24.6	
Actuated g/C Ratio	0.34		0.53	0.38	0.26		0.24	0.50			0.21	
Clearance Time (s)	6.0			6.3	6.3		5.8	4.9			5.4	
Vehicle Extension (s)	3.0			3.0	3.0		3.0	3.0			3.0	
Lane Grp Cap (vph)	298		785	628	871		771	873			665	
v/s Ratio Prot	0.05		c0.38	c0.06	c0.17		0.17	c0.39			0.16	
v/s Ratio Perm	0.13			0.14								
v/c Ratio	0.55		0.72	0.52	0.63		0.71	0.79			0.78	
Uniform Delay, d1	29.2		21.2	28.9	39.1		41.6	24.8			45.1	
Progression Factor	1.00		1.00	1.00	1.00		0.81	0.95			1.00	
Incremental Delay, d2	2.1		3.2	0.8	1.5		3.9	5.2			5.7	
Delay (s)	31.2		24.4	29.6	40.6		37.7	28.7			50.9	
Level of Service	C		C	C	D		D	C			D	
Approach Delay (s)		25.8			36.6			32.7			50.9	
Approach LOS		C			D			C			D	

Intersection Summary			
HCM 2000 Control Delay	34.9	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.81		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	23.5
Intersection Capacity Utilization	88.6%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	63	269	8	91	275	670	4	499	132	613	646	87
Future Volume (vph)	63	269	8	91	275	670	4	499	132	613	646	87
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Lane Util. Factor	1.00	0.95		1.00	0.95	1.00		0.95	1.00	0.97	1.00	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00	1.00	
Frt	1.00	1.00		1.00	1.00	0.85		1.00	0.85	1.00	0.98	
Flt Protected	0.95	1.00		0.95	1.00	1.00		1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1662	3203		1581	3197	1473		3291	1458	3162	1700	
Flt Permitted	0.46	1.00		0.48	1.00	1.00		0.95	1.00	0.95	1.00	
Satd. Flow (perm)	800	3203		799	3197	1473		3122	1458	3162	1700	
Peak-hour factor, PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Adj. Flow (vph)	66	283	8	96	289	705	4	525	139	645	680	92
RTOR Reduction (vph)	0	2	0	0	0	66	0	0	109	0	4	0
Lane Group Flow (vph)	66	289	0	96	289	639	0	529	30	645	768	0
Confl. Peds. (#/hr)			2	2			12					
Heavy Vehicles (%)	0%	3%	14%	5%	4%	1%	0%	1%	2%	2%	1%	2%
Turn Type	D.P+P	NA		D.P+P	NA	pm+ov	Perm	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8	1		2		1	6	
Permitted Phases	8			4		8	2		2			
Actuated Green, G (s)	27.1	17.8		25.6	21.1	65.9		25.6	25.6	44.8	75.7	
Effective Green, g (s)	27.1	17.8		25.6	21.1	65.9		25.6	25.6	44.8	75.7	
Actuated g/C Ratio	0.23	0.15		0.21	0.18	0.55		0.21	0.21	0.37	0.63	
Clearance Time (s)	6.6	6.6		6.3	4.8	5.0		6.1	6.1	5.0	5.8	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0		3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	223	475		221	562	808		666	311	1180	1072	
v/s Ratio Prot	0.01	0.09		c0.03	0.09	c0.30				0.20	c0.45	
v/s Ratio Perm	0.05			0.06		0.14		0.17	0.02			
v/c Ratio	0.30	0.61		0.43	0.51	0.79		0.79	0.10	0.55	0.72	
Uniform Delay, d1	37.5	47.8		39.6	44.8	21.6		44.7	37.9	29.6	14.9	
Progression Factor	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.03	0.82	
Incremental Delay, d2	0.7	2.2		1.4	0.8	5.3		6.5	0.1	1.4	3.1	
Delay (s)	38.3	50.1		40.9	45.6	26.9		51.2	38.1	31.8	15.3	
Level of Service	D	D		D	D	C		D	D	C	B	
Approach Delay (s)		47.9			33.1			48.5			22.8	
Approach LOS		D			C			D			C	

Intersection Summary			
HCM 2000 Control Delay	33.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.79		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	24.0
Intersection Capacity Utilization	92.9%	ICU Level of Service	F
Analysis Period (min)	15		

c Critical Lane Group

Appendix D
Signal Warrant Analysis

Growth 1.2%

	Underpass Avenue & Calhoun Lane											
	EB			WB			NB			SB		
15-Min	L	T	R	L	T	R	L	T	R	L	T	R
0:00 - 0:15	0	6	0	5	3	0	0	0	6			
0:15 - 0:30	0	6	1	0	6	0	0	0	1			
0:30 - 0:45	0	5	0	3	3	0	0	0	0			
0:45 - 1:00	0	1	0	2	7	0	0	0	3			
1:00 - 1:15	0	4	0	4	3	0	0	0	1			
1:15 - 1:30	0	4	0	0	3	0	0	0	3			
1:30 - 1:45	0	6	0	2	3	0	0	0	1			
1:45 - 2:00	0	4	0	1	6	0	0	0	1			
2:00 - 2:15	0	6	0	1	1	0	0	0	0			
2:15 - 2:30	0	2	0	0	4	0	0	0	1			
2:30 - 2:45	0	1	0	1	5	0	1	0	2			
2:45 - 3:00	0	3	0	0	3	0	1	0	1			
3:00 - 3:15	0	5	0	0	2	0	0	0	2			
3:15 - 3:30	0	2	0	3	1	0	0	0	1			
3:30 - 3:45	0	3	0	2	5	0	2	0	2			
3:45 - 4:00	0	2	0	1	4	0	1	0	0			
4:00 - 4:15	0	4	0	5	2	0	0	0	2			
4:15 - 4:30	0	5	0	10	5	0	0	0	0			
4:30 - 4:45	0	5	0	5	4	0	0	0	1			
4:45 - 5:00	0	8	0	2	9	0	0	0	5			
5:00 - 5:15	0	8	1	2	2	0	0	0	0			
5:15 - 5:30	0	16	0	2	6	0	0	0	1			
5:30 - 5:45	0	13	0	2	11	0	1	0	5			
5:45 - 6:00	0	10	2	4	26	0	1	0	5			
6:00 - 6:15	0	12	1	4	13	0	1	0	5			
6:15 - 6:30	0	19	0	9	19	0	0	0	13			
6:30 - 6:45	0	42	0	5	22	0	0	0	10			
6:45 - 7:00	0	26	2	8	44	0	2	0	21			
7:00 - 7:15	0	40	1	14	62	0	1	0	21			
7:15 - 7:30	0	54	1	16	64	0	0	0	23			
7:30 - 7:45	0	81	1	18	85	0	0	0	40			
7:45 - 8:00	0	81	4	28	77	0	0	0	38			
8:00 - 8:15	0	70	3	26	68	0	0	0	38			
8:15 - 8:30	0	61	1	23	47	0	1	0	20			
8:30 - 8:45	0	51	1	26	29	0	3	0	30			
8:45 - 9:00	0	65	1	18	49	0	2	0	17			
9:00 - 9:15	0	52	1	21	39	0	3	0	27			
9:15 - 9:30	0	51	1	20	34	0	0	0	24			
9:30 - 9:45	0	46	4	29	43	0	0	0	24			
9:45 - 10:00	0	43	1	17	46	0	0	0	22			
10:00 - 10:15	0	57	0	12	36	0	0	0	17			
10:15 - 10:30	0	52	4	25	46	0	2	0	15			
10:30 - 10:45	0	35	0	28	37	0	1	0	26			
10:45 - 11:00	0	51	4	28	52	0	1	0	18			
11:00 - 11:15	0	41	5	25	51	0	1	0	25			
11:15 - 11:30	0	60	1	25	40	0	0	0	25			
11:30 - 11:45	0	62	3	27	47	0	1	0	24			
11:45 - 12:00	0	65	8	30	62	0	1	0	28			
12:00 - 12:15	0	65	3	29	69	0	0	0	27			
12:15 - 12:30	0	55	1	35	50	0	5	0	25			
12:30 - 12:45	0	59	1	37	65	0	1	0	27			
12:45 - 1:00	0	85	5	25	55	0	4	0	30			
1:00 - 1:15	0	76	2	26	58	0	4	0	24			
1:15 - 1:30	0	69	3	29	59	0	0	0	29			
1:30 - 1:45	0	58	2	42	48	0	2	0	22			
1:45 - 2:00	0	77	1	29	49	0	4	0	27			
2:00 - 2:15	0	71	4	33	59	0	3	0	47			
2:15 - 2:30	0	76	3	30	45	0	1	0	25			
2:30 - 2:45	0	78	2	47	71	0	2	0	30			
2:45 - 3:00	0	63	6	30	66	0	0	0	38			
3:00 - 3:15	0	58	5	47	68	0	3	0	32			
3:15 - 3:30	0	70	3	59	82	0	1	0	38			
3:30 - 3:45	0	72	6	34	67	0	1	0	48			
3:45 - 4:00	0	72	10	53	61	0	3	0	27			
4:00 - 4:15	0	81	3	56	63	0	1	0	28			
4:15 - 4:30	0	79	1	53	63	0	1	0	23			
4:30 - 4:45	0	102	5	54	77	0	1	0	22			
4:45 - 5:00	0	84	4	59	76	0	0	0	38			
5:00 - 5:15	0	109	3	70	80	0	0	0	20			
5:15 - 5:30	0	70	6	78	83	0	1	0	36			
5:30 - 5:45	0	73	3	52	82	0	1	0	36			
5:45 - 6:00	0	59	1	34	64	0	0	0	25			
6:00 - 6:15	0	61	5	32	60	0	4	0	27			
6:15 - 6:30	0	45	2	41	33	0	0	0	27			
6:30 - 6:45	0	48	3	35	35	0	1	0	30			
6:45 - 7:00	0	37	2	23	30	0	0	0	26			
7:00 - 7:15	0	33	2	23	33	0	0	0	18			
7:15 - 7:30	0	54	0	26	37	0	1	0	23			
7:30 - 7:45	0	39	3	26	40	0	1	0	26			
7:45 - 8:00	0	25	4	15	40	0	2	0	19			
8:00 - 8:15	0	36	2	21	32	0	0	0	16			
8:15 - 8:30	0	22	3	17	32	0	0	0	17			
8:30 - 8:45	0	33	2	16	37	0	0	0	13			
8:45 - 9:00	0	30	2	25	21	0	0	0	13			
9:00 - 9:15	0	31	1	23	31	0	0	0	17			
9:15 - 9:30	0	27	3	16	16	0	0	0	19			
9:30 - 9:45	0	12	2	9	15	0	1	0	10			
9:45 - 10:00	0	14	1	7	12	0	0	0	10			
10:00 - 10:15	0	14	2	9	16	0	0	0	2			
10:15 - 10:30	0	14	2	8	12	0	2	0	5			
10:30 - 10:45	0	9	0	6	12	0	0	0	9			
10:45 - 11:00	0	13	1	2	6	0	0	0	3			
11:00 - 11:15	0	8	0	6	8	0	0	0	8			
11:15 - 11:30	0	12	1	2	5	0	0	0	6			
11:30 - 11:45	0	10	0	6	14	0	1	0	2			
11:45 - 12:00	0	10	0	3	6	0	2	0	3			

8-Hour Warrant					
2015		2018		2038	
1-hr		1-hr		1-hr	
EBTR	WBL	EBTR	WBL	EBTR	WBL
19	10	20	10	25	13
17	9	18	9	22	12
14	9	15	9	18	12
15	8	16	8	20	11
18	7	19	7	24	9
20	4	21	4	26	5
18	4	19	4	24	5
13	3	13	3	17	4
12	2	12	2	16	3
11	1	11	1	14	1
11	4	11	4	14	5
13	5	13	5	17	7
12	6	12	6	16	8
11	11	11	11	14	14
14	18	15	19	18	24
16	21	17	22	21	28
22	22	23	23	29	29
27	19	28	20	36	25
38	11	39	11	50	14
46	8	48	8	61	11
50	10	52	10	66	13
54	12	56	12	71	16
57	19	59	20	75	25
86	22	89	23	113	29
102	26	106	27	134	34
130	36	135	37	171	47
166	43	172	45	218	57
206	56	214	58	271	74
263	76	273	79	346	100
295	88	306	91	388	116
302	95	313	98	397	125
272	103	282	107	358	136
253	93	262	96	333	122
233	88	241	91	307	116
223	85	231	88	293	112
221	88	229	91	291	116
199	87	206	90	262	114
203	78	210	81	267	103
207	83	215	86	272	109
192	82	199	85	253	108
203	93	210	96	267	122
192	106	199	110	253	139
197	106	204	110	259	139
227	105	235	109	299	138
245	107	254	111	322	141
267	111	277	115	351	146
262	121	272	125	345	159
257	131	266	136	338	172
274	126	284	131	360	166
284	123	294	127	374	162
300	117	311	121	395	154
300	122	311	126	395	161
288	126	298	131	379	166
285	133	295	138	375	175
292	134	303	139	384	176
312	139	323	144	410	183
303	140	314	145	399	184
291	154	302	160	383	203
285	183	295	190	375	241
283	170	293	176	372	224
296	193	307	200	389	254
317	202	329	209	417	266
324	196	336	203	426	258
353	216	366	224	464	284
359	222	372	230	472	292
387	236	401	245	509	311
383	261	397	271	504	343
352	259	365	268	463	341
324	234	336	243	426	308
278	196	288	203	366	258
249	159	258	165	328	209
224	142	232	147	295	187
203	131	210	136	267	172
172	122	178	126	226	161
179	107	186	111	236	141
170	98	176	102	224	129
160	90	166	93	211	118
163	88	169	91	214	116
134	79	139	82	176	104
127	69	132	72	167	91
130	79	135	82	171	104
124	81	129	84	163	107
129	80	134	83	170	105
108	73	112	76	142	96
91	55	94	57	120	72
75	41	78	42	99	54
61	33	63	34	80	43
56	30	58	31	74	39
55	25	57	26	72	33
47	22	49	23	62	29
44	16	46	17	58	21
45	16	47	17	59	21
41	17	42	18	54	22
33	11	34	11	43	14
20	9	21	9	26	12
10	3	10	3	13	4

4-Hour Warrant					
2015		2018		2038	
1-hr		1-hr		1-hr	
EBTR	WBL	EBTR	WBL	EBTR	WBL
19	10	20	10	25	13
18	7	19	7	24	9
12	2	12	2	16	3
12	6	12	6	16	8
22	22	23	23	29	29
50	10	52	10	66	13
102	26	106	27	134	34
263	76	273	79	346	100
253	93	262	96	333	122
199	87	206	90	262	114
203	93	210	96	267	122
245	107	254	111	322	141
274	126	284	131	360	166
288	126	298	131	379	166
303	140	314	145	399	184
296	193	307	200	389	254
359	222	372	230	472	292
324	234	336	243	426	308
203	131	210	136	267	172
160	90	166	93	211	118
130	79	135	82	171	104
91	55	94	57	120	72
55	25	57	26	72	33
41	17	42	18	54	22

Warrant 1: Eight-Hour Volume

Condition A

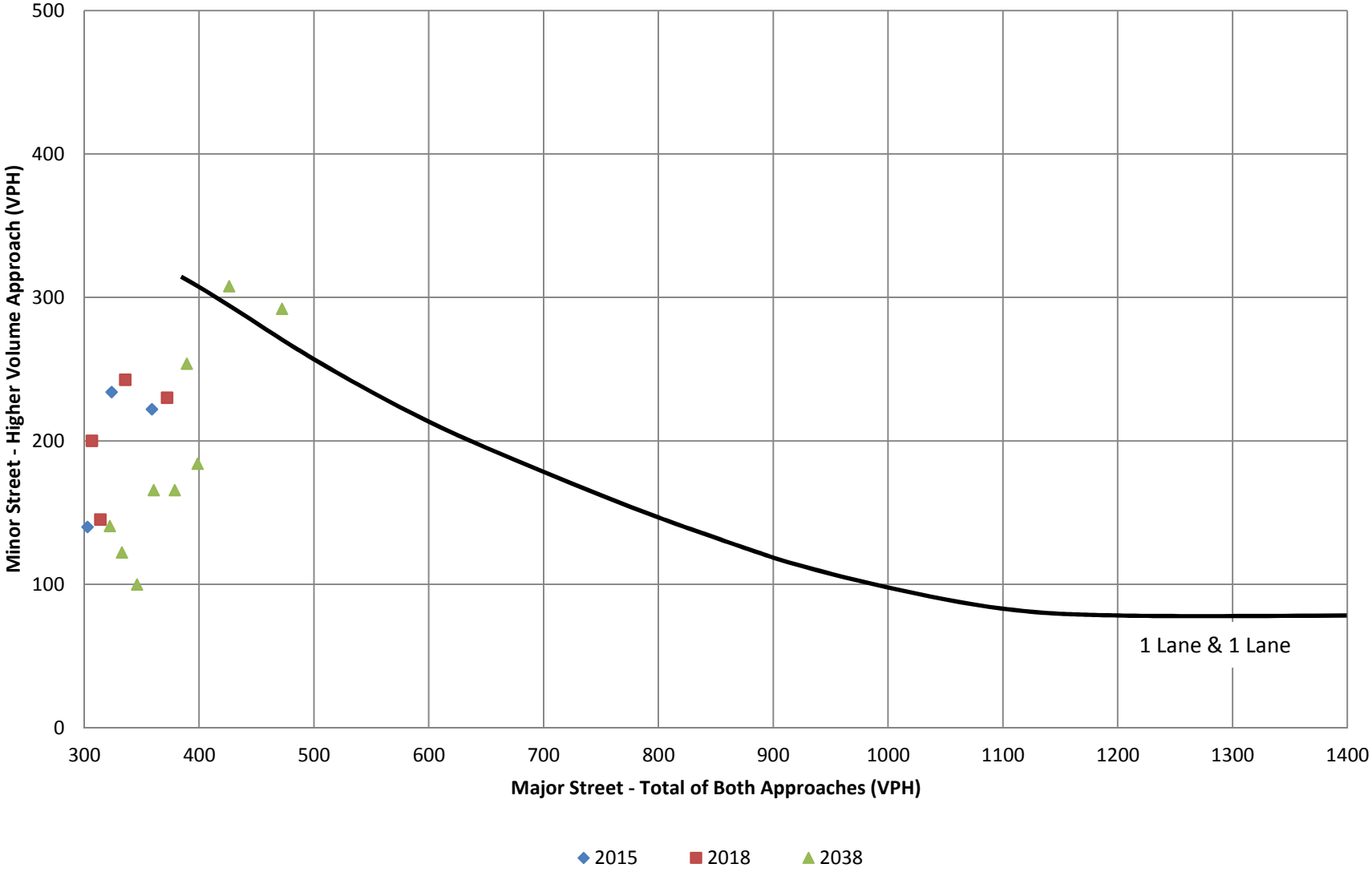
Lanes		Major VPH	Minor VPH
Major St	Minor St	100%	100%
1	1	500	150

Condition B

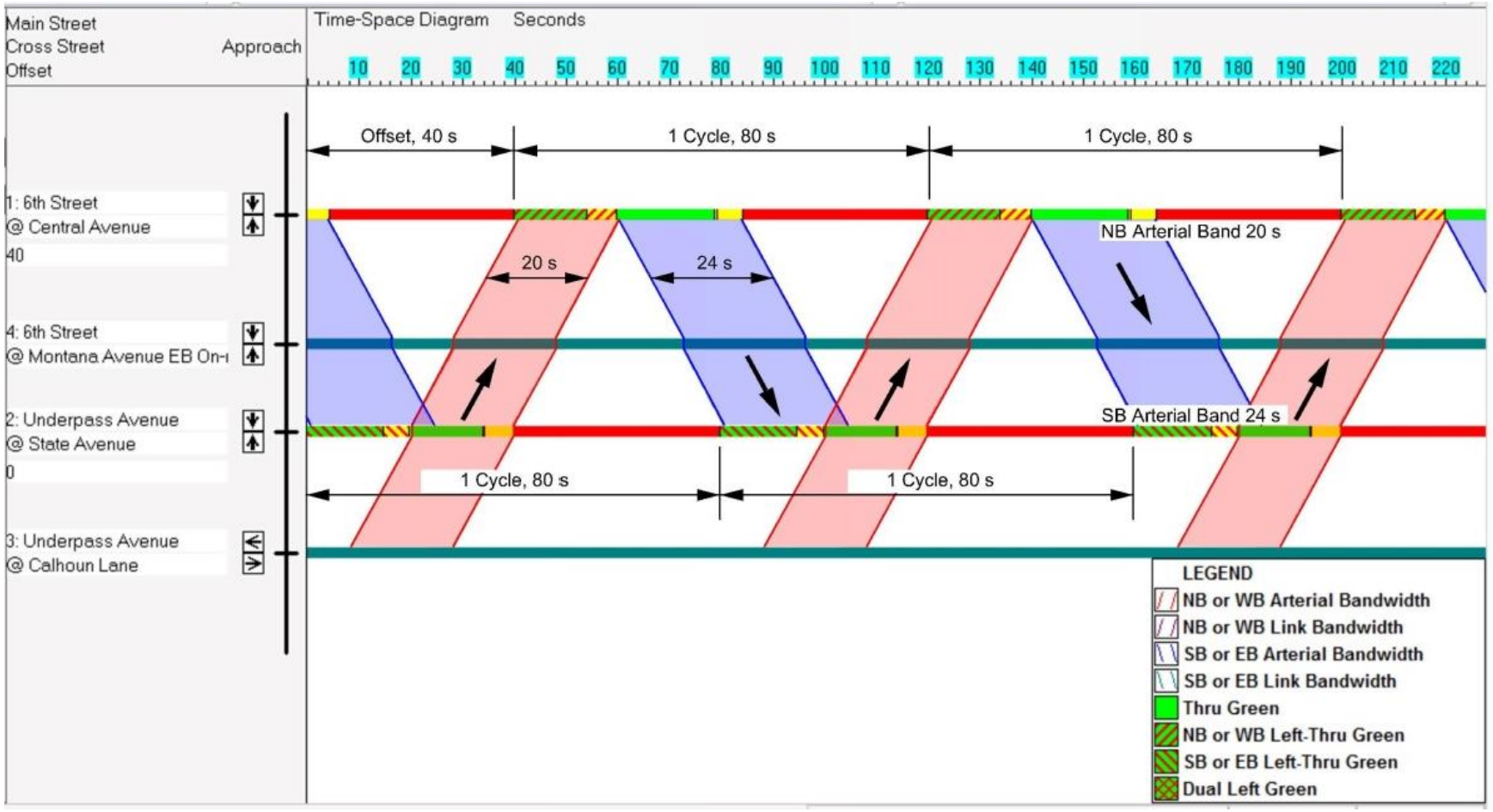
Lanes		Major VPH	Minor VPH
Major St	Minor St	100%	100%
1	1	750	75

	2015				2018				2038			
	Condition A		Condition B		Condition A		Condition B		Condition A		Condition B	
Hour	Met Major?	Met Minor?	Met Major?	Met Minor?	Met Major?	Met Minor?	Met Major?	Met Minor?	Met Major?	Met Minor?	Met Major?	Met Minor?
0:00 - 0:15	No	No	No	No	No	No	No	No	No	No	No	No
0:15 - 0:30	No	No	No	No	No	No	No	No	No	No	No	No
0:30 - 0:45	No	No	No	No	No	No	No	No	No	No	No	No
0:45 - 1:00	No	No	No	No	No	No	No	No	No	No	No	No
1:00 - 1:15	No	No	No	No	No	No	No	No	No	No	No	No
1:15 - 1:30	No	No	No	No	No	No	No	No	No	No	No	No
1:30 - 1:45	No	No	No	No	No	No	No	No	No	No	No	No
1:45 - 2:00	No	No	No	No	No	No	No	No	No	No	No	No
2:00 - 2:15	No	No	No	No	No	No	No	No	No	No	No	No
2:15 - 2:30	No	No	No	No	No	No	No	No	No	No	No	No
2:30 - 2:45	No	No	No	No	No	No	No	No	No	No	No	No
2:45 - 3:00	No	No	No	No	No	No	No	No	No	No	No	No
3:00 - 3:15	No	No	No	No	No	No	No	No	No	No	No	No
3:15 - 3:30	No	No	No	No	No	No	No	No	No	No	No	No
3:30 - 3:45	No	No	No	No	No	No	No	No	No	No	No	No
3:45 - 4:00	No	No	No	No	No	No	No	No	No	No	No	No
4:00 - 4:15	No	No	No	No	No	No	No	No	No	No	No	No
4:15 - 4:30	No	No	No	No	No	No	No	No	No	No	No	No
4:30 - 4:45	No	No	No	No	No	No	No	No	No	No	No	No
4:45 - 5:00	No	No	No	No	No	No	No	No	No	No	No	No
5:00 - 5:15	No	No	No	No	No	No	No	No	No	No	No	No
5:15 - 5:30	No	No	No	No	No	No	No	No	No	No	No	No
5:30 - 5:45	No	No	No	No	No	No	No	No	No	No	No	No
5:45 - 6:00	No	No	No	No	No	No	No	No	No	No	No	No
6:00 - 6:15	No	No	No	No	No	No	No	No	No	No	No	No
6:15 - 6:30	No	No	No	No	No	No	No	No	No	No	No	No
6:30 - 6:45	No	No	No	No	No	No	No	No	No	No	No	No
6:45 - 7:00	No	No	No	No	No	No	No	No	No	No	No	No
7:00 - 7:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
7:15 - 7:30	No	No	No		No	No	No		No	No	No	Yes
7:30 - 7:45	No	No	No		No	No	No		No	No	No	
7:45 - 8:00	No	No	No		No	No	No		No	No	No	
8:00 - 8:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
8:15 - 8:30	No	No	No		No	No	No		No	No	No	Yes
8:30 - 8:45	No	No	No		No	No	No		No	No	No	
8:45 - 9:00	No	No	No		No	No	No		No	No	No	
9:00 - 9:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
9:15 - 9:30	No	No	No		No	No	No		No	No	No	Yes
9:30 - 9:45	No	No	No		No	No	No		No	No	No	
9:45 - 10:00	No	No	No		No	No	No		No	No	No	
10:00 - 10:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
10:15 - 10:30	No	No	No		No	No	No		No	No	No	Yes
10:30 - 10:45	No	No	No		No	No	No		No	No	No	
10:45 - 11:00	No	No	No		No	No	No		No	No	No	
11:00 - 11:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
11:15 - 11:30	No	No	No		No	No	No		No	No	No	Yes
11:30 - 11:45	No	No	No		No	No	No		No		No	
11:45 - 12:00	No	No	No		No	No	No		No		No	
12:00 - 12:15	No	No	No	Yes	No	No	No	Yes	No		No	
12:15 - 12:30	No	No	No		No	No	No		No	Yes	No	Yes
12:30 - 12:45	No	No	No		No	No	No		No		No	
12:45 - 1:00	No	No	No		No	No	No		No		No	
1:00 - 1:15	No	No	No	Yes	No	No	No	Yes	No		No	
1:15 - 1:30	No	No	No		No	No	No		No	Yes	No	Yes
1:30 - 1:45	No	No	No		No	No	No		No		No	
1:45 - 2:00	No	No	No		No	No	No		No		No	
2:00 - 2:15	No	No	No	Yes	No	No	No	Yes	No		No	
2:15 - 2:30	No		No		No		No		No	Yes	No	Yes
2:30 - 2:45	No		No		No		No		No		No	
2:45 - 3:00	No		No		No		No		No		No	
3:00 - 3:15	No	Yes	No	Yes	No	Yes	No	Yes	No		No	
3:15 - 3:30	No		No		No		No		No	Yes	No	Yes
3:30 - 3:45	No		No		No		No		No		No	
3:45 - 4:00	No		No		No		No		No		No	
4:00 - 4:15	No	Yes	No	Yes	No	Yes	No	Yes	No		No	
4:15 - 4:30	No		No		No		No		Yes	Yes	No	Yes
4:30 - 4:45	No		No		No		No				No	
4:45 - 5:00	No		No		No		No		No		No	
5:00 - 5:15	No	Yes	No	Yes	No	Yes	No	Yes	No		No	
5:15 - 5:30	No		No		No		No		No	Yes	No	Yes
5:30 - 5:45	No		No		No		No		No		No	
5:45 - 6:00	No	No	No		No	No	No		No		No	
6:00 - 6:15	No	No	No	Yes	No	No	No	Yes	No		No	
6:15 - 6:30	No	No	No		No	No	No		No	Yes	No	Yes
6:30 - 6:45	No	No	No		No	No	No		No	No	No	
6:45 - 7:00	No	No	No		No	No	No		No	No	No	
7:00 - 7:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
7:15 - 7:30	No	No	No		No	No	No		No	No	No	Yes
7:30 - 7:45	No	No	No		No	No	No		No	No	No	
7:45 - 8:00	No	No	No	No	No	No	No	No	No	No	No	
8:00 - 8:15	No	No	No	Yes	No	No	No	Yes	No	No	No	
8:15 - 8:30	No	No	No		No	No	No		No	No	No	Yes
8:30 - 8:45	No	No	No		No	No	No		No	No	No	
8:45 - 9:00	No	No	No	No	No	No	No		No	No	No	
9:00 - 9:15	No	No	No	No	No	No	No	No	No	No	No	No
9:15 - 9:30	No	No	No	No	No	No	No	No	No	No	No	No
9:30 - 9:45	No	No	No	No	No	No	No	No	No	No	No	No
9:45 - 10:00	No	No	No	No	No	No	No	No	No	No	No	No
10:00 - 10:15	No	No	No	No	No	No	No	No	No	No	No	No
10:15 - 10:30	No	No	No	No	No	No	No	No	No	No	No	No
10:30 - 10:45	No	No	No	No	No	No	No	No	No	No	No	No
10:45 - 11:00	No	No	No	No	No	No	No	No	No	No	No	No
11:00 - 11:15	No	No	No	No	No	No	No	No	No	No	No	No
11:15 - 11:30	No	No	No	No	No	No	No	No	No	No	No	No
11:30 - 11:45	No	No	No	No	No	No	No	No	No	No	No	No
11:45 - 12:00	No	No	No	No	No	No	No	No	No	No	No	No
	2015				2018				2038			
# Yes	A	0	B	0	A	0	B	0	A	1	B	0

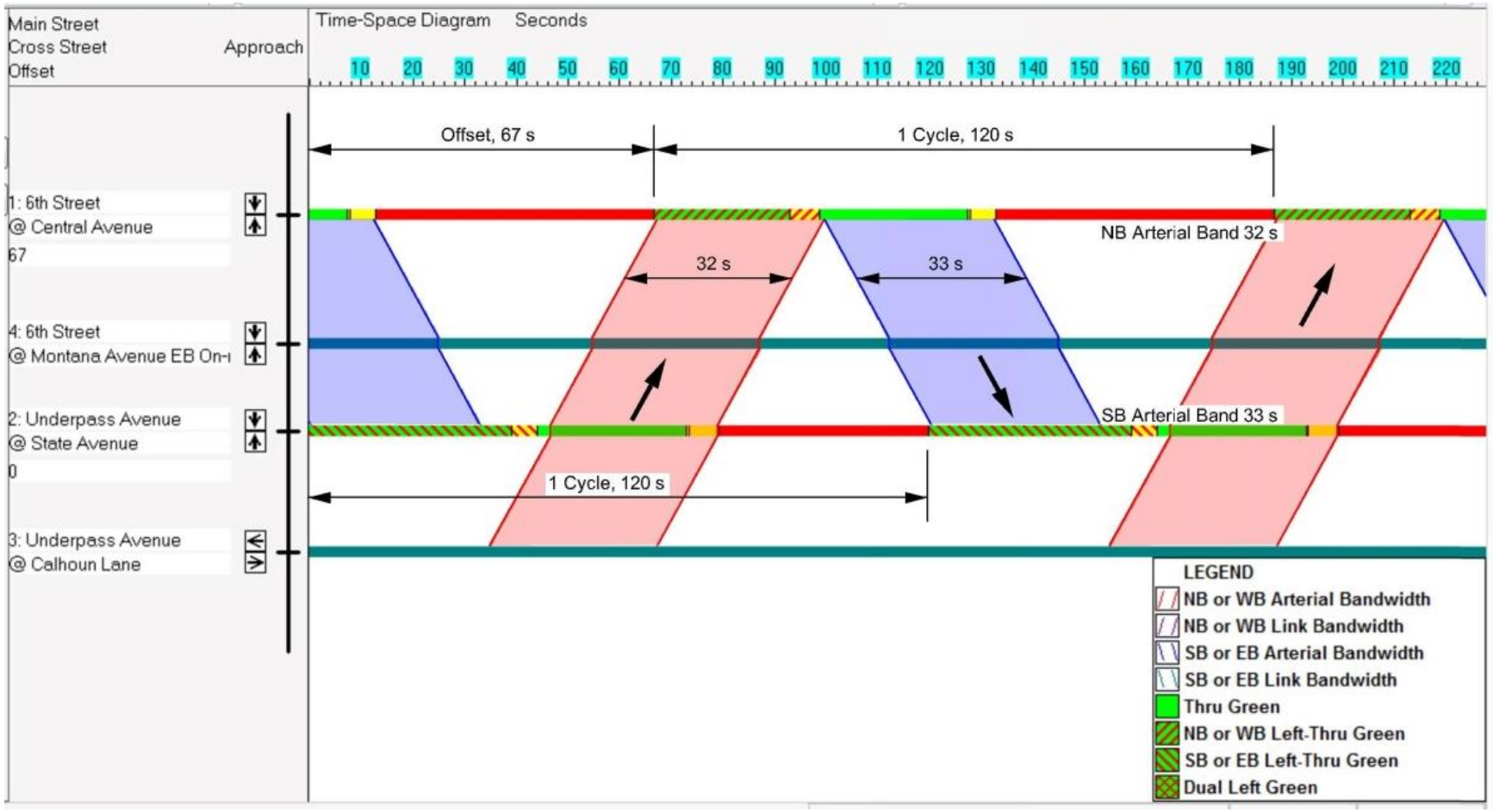
Underpass Ave/Calhoun Lane: Warrant 2, Four-Hour Volume



Appendix E
Signal Coordination



2018 Bandwidth



2038 Bandwidth

Lane Group	EBL	EBR	WBL	WBT	NBL	NBT	SBT	Ø4
Lane Configurations								
Traffic Volume (vph)	122	449	233	410	407	515	378	
Future Volume (vph)	122	449	233	410	407	515	378	
Turn Type	pm+pt	pt+ov	pm+pt	NA	Prot	NA	NA	
Protected Phases	7	4 5	3	8	5	2	6	4
Permitted Phases	4		8					
Detector Phase	7	4 5	3	8	5	2	6	
Switch Phase								
Minimum Initial (s)	5.0		5.0	10.0	5.0	10.0	5.0	5.0
Minimum Split (s)	11.0		11.3	23.3	10.8	15.4	24.3	24.3
Total Split (s)	11.0		11.4	24.7	20.0	44.3	24.3	24.3
Total Split (%)	13.8%		14.3%	30.9%	25.0%	55.4%	30.4%	30%
Yellow Time (s)	3.2		3.6	3.6	3.0	3.0	3.0	3.5
All-Red Time (s)	2.8		2.7	2.7	2.8	1.9	2.4	1.9
Lost Time Adjust (s)	-2.0		-2.3	-2.3	-1.8	-0.9	-1.4	
Total Lost Time (s)	4.0		4.0	4.0	4.0	4.0	4.0	
Lead/Lag	Lead		Lead	Lag	Lead		Lag	Lag
Lead-Lag Optimize?	Yes		Yes	Yes			Yes	Yes
Recall Mode	None		None	None	C-Min	C-Min	None	Min

Intersection Summary

Cycle Length: 80
Actuated Cycle Length: 80
Offset: 40 (50%), Referenced to phase 2:NBT and 5:NBL, Start of Green
Natural Cycle: 75
Control Type: Actuated-Coordinated

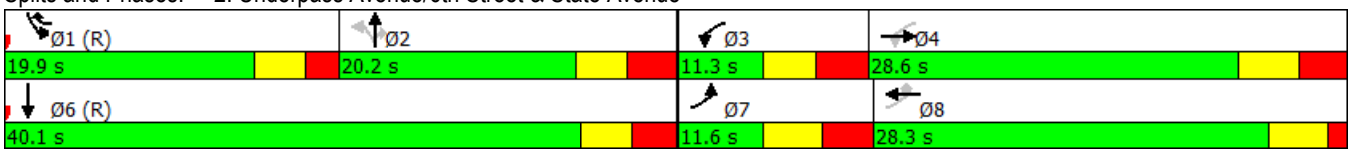
Splits and Phases: 1: 6th Street & Central Avenue

Lane Group	EBL	EBT	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations										
Traffic Volume (vph)	57	244	82	249	606	3	393	104	483	509
Future Volume (vph)	57	244	82	249	606	3	393	104	483	509
Turn Type	D.P+P	NA	D.P+P	NA	pm+ov	Perm	NA	Perm	Prot	NA
Protected Phases	7	4	3	8	1		2		1	6
Permitted Phases	8		4		8	2		2		
Detector Phase	7	4	3	8	1	2	2	2	1	6
Switch Phase										
Minimum Initial (s)	5.0	10.0	5.0	10.0	5.0	10.0	10.0	10.0	5.0	10.0
Minimum Split (s)	11.6	28.6	11.3	14.8	10.0	16.1	16.1	16.1	10.0	32.8
Total Split (s)	11.6	28.6	11.3	28.3	19.9	20.2	20.2	20.2	19.9	40.1
Total Split (%)	14.5%	35.8%	14.1%	35.4%	24.9%	25.3%	25.3%	25.3%	24.9%	50.1%
Yellow Time (s)	3.6	3.6	3.2	3.6	3.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	3.0	3.0	3.1	1.2	2.0	3.1	3.1	3.1	2.0	2.8
Lost Time Adjust (s)	-2.6	-2.6	-2.3	-0.8	-1.0		-2.1	-2.1	-1.0	-1.8
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0	4.0	4.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lag	Lag	Lead	
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Recall Mode	None	None	None	None	C-Min	None	None	None	C-Min	C-Min

Intersection Summary

Cycle Length: 80
Actuated Cycle Length: 80
Offset: 0 (0%), Referenced to phase 1:SBL and 6:SBT, Start of Green, Master Intersection
Natural Cycle: 75
Control Type: Actuated-Coordinated

Splits and Phases: 2: Underpass Avenue/6th Street & State Avenue

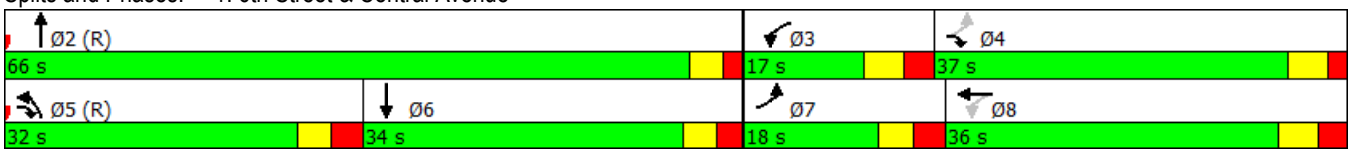


Lane Group	EBL	EBR	WBL	WBT	NBL	NBT	SBT	Ø4
Lane Configurations								
Traffic Volume (vph)	155	597	311	521	517	654	438	
Future Volume (vph)	155	597	311	521	517	654	438	
Turn Type	pm+pt	pt+ov	pm+pt	NA	Prot	NA	NA	
Protected Phases	7	4 5	3	8	5	2	6	4
Permitted Phases	4		8					
Detector Phase	7	4 5	3	8	5	2	6	
Switch Phase								
Minimum Initial (s)	5.0		5.0	10.0	5.0	10.0	5.0	5.0
Minimum Split (s)	11.0		11.3	23.3	10.8	15.4	24.3	24.3
Total Split (s)	18.0		17.0	36.0	32.0	66.0	34.0	37.0
Total Split (%)	15.0%		14.2%	30.0%	26.7%	55.0%	28.3%	31%
Yellow Time (s)	3.2		3.6	3.6	3.0	3.0	3.0	3.5
All-Red Time (s)	2.8		2.7	2.7	2.8	1.9	2.4	1.9
Lost Time Adjust (s)	-2.0		-2.3	-2.3	-1.8	-0.9	-1.4	
Total Lost Time (s)	4.0		4.0	4.0	4.0	4.0	4.0	
Lead/Lag	Lead		Lead	Lag	Lead		Lag	Lag
Lead-Lag Optimize?	Yes		Yes	Yes			Yes	Yes
Recall Mode	None		None	None	C-Min	C-Min	None	Min

Intersection Summary

Cycle Length: 120
Actuated Cycle Length: 120
Offset: 67 (56%), Referenced to phase 2:NBT and 5:NBL, Start of Green
Natural Cycle: 80
Control Type: Actuated-Coordinated

Splits and Phases: 1: 6th Street & Central Avenue



Lane Group	EBL	EBT	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations										
Traffic Volume (vph)	63	269	91	275	670	4	499	132	613	646
Future Volume (vph)	63	269	91	275	670	4	499	132	613	646
Turn Type	D.P+P	NA	D.P+P	NA	pm+ov	Perm	NA	Perm	Prot	NA
Protected Phases	7	4	3	8	1		2		1	6
Permitted Phases	8		4		8	2		2		
Detector Phase	7	4	3	8	1	2	2	2	1	6
Switch Phase										
Minimum Initial (s)	5.0	10.0	5.0	10.0	5.0	10.0	10.0	10.0	5.0	10.0
Minimum Split (s)	11.6	28.6	11.3	14.8	10.0	16.1	16.1	16.1	10.0	32.8
Total Split (s)	13.0	28.6	12.0	27.6	44.4	35.0	35.0	35.0	44.4	79.4
Total Split (%)	10.8%	23.8%	10.0%	23.0%	37.0%	29.2%	29.2%	29.2%	37.0%	66.2%
Yellow Time (s)	3.6	3.6	3.2	3.6	3.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	3.0	3.0	3.1	1.2	2.0	3.1	3.1	3.1	2.0	2.8
Lost Time Adjust (s)	-2.6	-2.6	-2.3	-0.8	-1.0		-2.1	-2.1	-1.0	-1.8
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0	4.0	4.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lag	Lag	Lead	
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Recall Mode	None	None	None	None	C-Min	None	None	None	C-Min	C-Min

Intersection Summary

Cycle Length: 120
Actuated Cycle Length: 120
Offset: 0 (0%), Referenced to phase 1:SBL and 6:SBT, Start of Green, Master Intersection
Natural Cycle: 90
Control Type: Actuated-Coordinated

Splits and Phases: 2: Underpass Avenue/6th Street & State Avenue