BILLINGS BYPASS EIS
NCPD 56(55)CN 4199

Combined Traffic Reports

Billings Bypass

August 2013

NCPD 56 (55) Control Number 4199

Section 1 - Preliminary Traffic Study
Section 2 - Geometric Design Report
Section 3 - Traffic Signal Warrant Study
Section 4 - Lighting Warrant Study
Section 5 - FEIS Traffic Study Report




MONTANA MDT
DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

BILLINGS BYPASS EIS
NCPD 56(55)CN 4199

SECTION 1
Preliminary Traffic Study Report

Billings Bypass

April 2012

MONTANA MDT DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

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INTRODUCTION

This report was prepared in fulfillment of Activity 112 (Preliminary Traffic) for the Billings Bypass Project NCPD 56(55) CN 4199. General descriptions of the preliminary project alignments and potentially impacted existing street system are presented within this report. Summaries of the existing street system are provided as baseline traffic conditions. Future design year (2035) traffic projections for the No-build and preliminary alignment alternatives are presented along with traffic analysis results associated with existing and proposed alternative roadways and intersections.

An extensive number of alternative alignments and intersections were screened within the project's Environmental Impact Statement (EIS) process. This report presents a summary of the traffic operations that would be associated with each of the alternatives that have been advanced through to the final screening process. All of the design alternatives presented within this report would provide acceptable traffic operating conditions in the design year. Since there are a number of considerations other than traffic operations that need to be considered in final design, this report summarizes the potential safety and efficiency associated with each alternative, but does not make recommendations to identify preferred alternatives.

PROJECT BACKGROUND

The project was originally intended to be a bypass route north of Billings between Interstate 90 (I-90) and Montana Route 3 (MT 3) and was to be part of the Camino Real International Trade Corridor route from Canada to Mexico. The bypass was to skirt congested urban routes within Billings and provide a direct connection between MT 3 and I-90. Funding constraints eventually resulted in a re-scoping of the project to focus on the eastern segment of the proposed project between the interstate and Old Hwy 312. A review of the transportation needs in the eastern portion of Billings, coupled with input from local plans and documents, revealed that physical barriers (Yellowstone River, MRL Railroad, Rimrocks, and Interstate 90) limit access and connectivity within and through the area for both local travel and truck/commercial vehicles. MDT coordinated with local, state, and federal agencies and the public on revising the project purpose and need to address these transportation issues. The project purpose and need, as detailed in the EIS, were used as prime screening criteria in development of the alternative alignments that were analyzed and summarized within this report.

PROJECT LOCATION AREA DESCRIPTION

The City of Billings has an extensive system of internal streets and has eight highways that enter the urban area. These highways include: Interstates 90 and 94; Primary Highways MT 3, US 87, old US 87 to Hardin, and old US 312; and a Secondary Highway to Pryor, south of Billings. This regional highway system is important in terms of commercial and through traffic within the Billings urban area. Also, smaller towns in the region tend to act as bedroom communities with substantial numbers of persons working in Billings and living in the outlying areas.

Key physical characteristics of Billings include the “Rimrocks”, which are 300’ high sandstone bluffs which rise on the northern boundary of Billings Proper. Billings Heights, which contains approximately 25% to 30% of the urban population, is located on bench-land north and northeast of the Rimrocks. Access between Billings and Billings Heights is confined to one of three routes:
Main Street, which provides a narrow passage around the east edge of the Rimrocks just west of the Yellowstone River; North 27th Street, which is a roadway cut diagonally into the face of the Rimrocks north of downtown (CBD); and Zimmerman Trail, which is a steep winding roadway that follows a natural drainage way on the west end of Billings. All of these routes eventually converge at a point between the Rimrocks and the Yellowstone River, where Main Street is forced to carry all north-south external area traffic and a large portion of the urban area traffic.

The Yellowstone River is another physical feature of the Billings area that has determined the location and function of transportation systems in Billings. Lockwood and the South Hills are the two major urbanized areas located on the south side of the Yellowstone River. There are only three crossings of the Yellowstone within the concentrated urban area: US 87 at the Lockwood (I-90) Interchange; the I-90 River Bridge west of Lockwood; and the South Billings Boulevard River Bridge, located south of the Billings CBD.

These two important physical characteristics create a great deal of traffic demand on urban arterial streets by forcing traffic with external origins and destinations to utilize local urban streets. External traffic on all routes northeast of Billings has no other option than to utilize portions of Main Street.

Interstate 90, which runs east–west along the southern boundary of the urbanized area, is the major carrier of external area traffic. Interstate 94 begins at an intersection with I-90 on the eastern edge of the urbanized area at the Pinehills Interchange. US 87 begins at an intersection with I-90, on the western edge of Lockwood and heads north to access communities north and east of Billings. Old Highway 312 parallels the alignment of I-94 on the north side of the Yellowstone River and provides access to a number of bedroom communities northeast of Billings, including the town of Huntley, which is also served by an interchange with Interstate 94.

A number of street and highway routes were identified as having the greatest potential for changes in traffic demand associated with the proposed arterial road river crossing. Traffic modeling efforts completed as a part of this project were instrumental in the identification of key corridors which would be sensitive to the proposed project alignments. Figure 1 provides an illustration of the select system routes for which existing traffic conditions have been compiled and evaluated within this report.

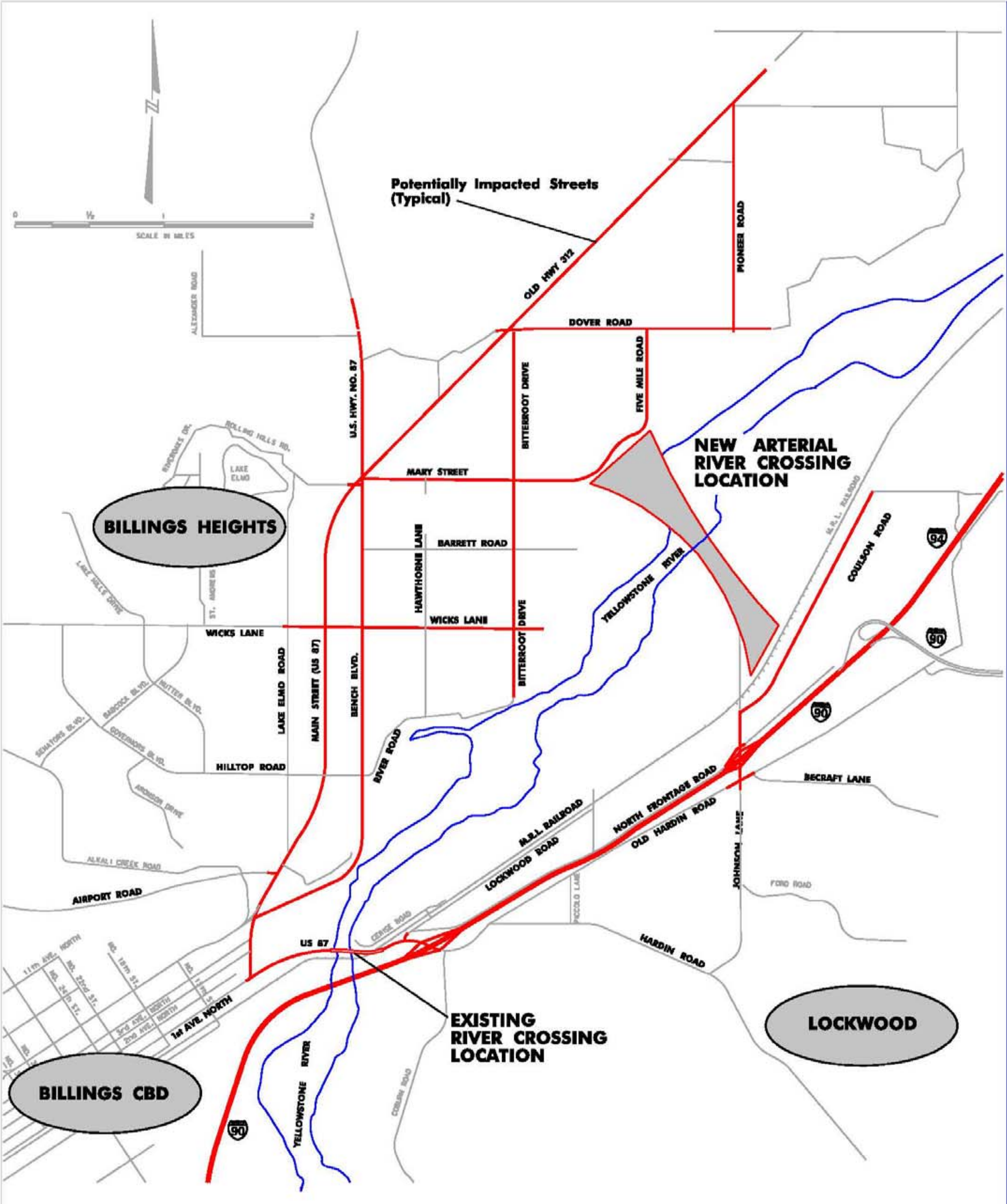


Figure 1. Project Location /Existing Road & Street System Map

The principal roads and streets that have the potential for impacts resulting from the construction of a new arterial roadway between Billings Heights and Lockwood would be Main Street (US 87), Bench Boulevard, Old Highway 312, US 87 River Crossing between Main Street, Interstate 90, and Interstate 94.

Main Street is a principal arterial street within the City of Billings that is coincident with US 87 between 1st Avenue North, on its southern terminus, and the US 87/Old Highway 312 junction, on its northern terminus. Main Street is approximately 90 feet in width, carries three thru-lanes in each direction, and has a raised median with left-turn lanes along its entire length. Constructed in 1965, Main Street has numerous driveways and median openings to commercial businesses between 1st Avenue North and Wicks Lane. The segment of Main Street north of Wicks Lane was reconstructed in 1983 and has fewer driveway approaches and median openings with much greater access control. Main Street has the highest traffic volumes of any roadway in the state of Montana, with approximately 50,000 vehicles per day just north of a junction with Airport Road. It is at this point that most of the traffic between Billings Proper, Lockwood and Billings Heights is funneled, due to physical barriers (the Rimrocks, the Yellowstone River, and the railroad). There are a total of 10 signalized intersections on Main Street, with one additional traffic signal being planned at the present time. For the purposes of impact evaluation within this study, four of these intersections are considered to be key intersections that are most representative of overall operations on Main Street. Those intersections are at 1st Avenue North, Airport Road, Wicks Lane, and US 87/HWY 312.

Bench Boulevard is a principal arterial street that parallels Main Street between US 87/HWY 312 and Lake Elmo Drive south of Hilltop Road. Bench is currently a 24 foot wide, two-lane roadway that was the original US 10 highway to Miles City. When Main Street was constructed in 1965, it reverted to being a county road, and in the late 1980s it became a City of Billings street when the Billings Heights was annexed into the City of Billings. Bench Boulevard is surrounded by residential development along its length and there is limited access to Main Street. Where those access streets do exist, some commercial development exists on side street lots east of Main Street. There are numerous driveways that access Bench Boulevard along its length, and the majority of traffic is localized with origins and destinations on Bench Boulevard or on side streets east of Bench Boulevard. At the time this report was written, a construction project was completed that extended Bench Boulevard from Lake Elmo Road over a new Alkali Creek bridge to 6th Avenue North at Main Street. In addition, two subsequent MDT projects that will improve Bench Boulevard from the north end of the new Alkali Creek Bridge to US 87/HWY 312 are currently undergoing final design. Those projects will create a new three lane roadway with improved horizontal geometry and access control. One of the purposes of those projects is to create a facility that would take some of the operational pressure off on Main Street. Bench Boulevard's function as a parallel facility to Main Street would be realized by a third project that involves a grade separation between Main Street and the Bench Boulevard/6th Avenue North roadway.

Old Highway 312 was previously the primary highway connection between Billings and Miles City, but was reclassified as a Secondary state highway after Interstate 94 was constructed in the 1960's. It provides access to residential subdivisions and small communities northeast of Billings, and its terminus is I-94 near Pompey's Pillar. It is currently classified as a Yellowstone County road and is maintained by Yellowstone County. It is approximately 28 feet wide for the majority of its length. Approximately four years ago, MDT reconstructed Old Highway 312 from its junction with US 87/Main Street to a point approximately one mile northeast of Dover Road. The newly constructed portion of Old Highway 312 has a width that varies between 64 feet and 80 feet and provides two travel lanes in each direction and a two-way-left-turn-lane along the majority of its length.

The segment of ***US 87*** that runs between the Lockwood I-90 interchange and the Main Street/First Avenue North intersection ranges in width between 68 feet and 80 feet. There are only two street accesses within this segment of US 87. There is an access to the City of Billings' sewage treatment facility and METRA Park fairgrounds to the North, and another northern access to Lockwood Road/North Frontage Road near the Lockwood Interchange. This segment of US 87 features an elevated crossing of both the Yellowstone River and the Montana Rail Link Railroad. It is the main entry to Billings for traffic with origins and destinations east of Billings on I-90 and I-94. It is also the only direct access between Billings and Lockwood, and between Billings Heights and Lockwood. The only other river crossing between Billings Heights and Lockwood is approximately ten miles northeast at the Huntley-Interstate 94 (I-94) Interchange. This segment also serves as a connection between Billings Heights and large commercial attractions on the extreme west end of Billings. In addition, this US 87 segment carries all external and through traffic from US 87, north of Billings to and from Old US 87, I-90, and I-94.

Interstate 90 skirts the southern edge of Billings, south of the Yellowstone River, west of US 87, and crosses the Yellowstone River west of the Lockwood Interchange. I-90 was constructed south of the industrial area along the Yellowstone River and south of what was in 1966 sparse residential areas in Lockwood. It now bisects the community of Lockwood from the Yellowstone River Bridge to its junction with I-94, at a small community known as Pinehills, on the eastern edge of Lockwood. The I-90/I-94 junction is commonly known as the Pinehills Interchange. The Pinehills Interchange is a Trumpet style interchange that requires eastbound I-90 traffic to exit on a single lane ramp. Its geometrics are considered to be substandard, according to current AASHTO geometric criteria and guidelines.

Two I-90 interchanges would potentially be impacted by this project. The ***Johnson Lane Interchange*** is located approximately 1.3 miles southwest of the Pinehills Interchange and 2.5 miles northeast of the Lockwood Interchange. This interchange provides access to Johnson lane, which is a principal north-south arterial roadway in Lockwood. Johnson Lane begins at an intersection with old US 87 on the south and extends through the community of Lockwood, under I-90, crosses the MRL railroad, and dead-ends near the Yellowstone River. Jus south of the railroad tracks, Johnson Lane intersects Coulson Road. Coulson Road is a rural roadway south of and parallel to the railroad tracks. It accesses properties to the northeast, and provides a secondary access to the Pinehills community. Johnson Lane also intersects with the I-90 North Frontage Road immediately north of the I-90 westbound interchange ramps. North Frontage road begins at an intersection with Lockwood Road near the Lockwood Interchange and parallels I-90 to its intersection with Johnson Lane. North frontage continues one mile northeast of Johnson Lane and terminates at an access to private property near the Pinehills Interchange. The North Frontage Road intersection with Johnson Lane currently operates with stop control on the North Frontage Road.

The Johnson Lane Interchange is a standard diamond interchange. The eastbound and westbound ramp intersections with Johnson Lane are separated by a distance of approximately 750 feet. The westbound ramps intersection is stop controlled while the eastbound ramps are controlled by a traffic signal. There are two traffic lanes on the eastbound off-ramp approach to Johnson lane. All other ramps have single lanes. Johnson Lane has single through lanes and marked left-turn lanes at intersections with the I-90 ramps.

South of the eastbound I-90 ramps, Johnson Lane intersects Old Hardin Road, which is a principal arterial street located south of and parallel to I-90. Old Hardin Road extends from its western terminus at an intersection with Old US 87, near the Lockwood Interchange, to its eastern terminus within the community of Pinehills. The intersection of Old Hardin Road and Johnson Lane has multiple approach lanes and operations are controlled by a traffic signal.

The Johnson Lane Interchange was constructed in 1984 to serve the eastern portion of Lockwood and was the first project in Montana that was constructed using a combination of local and federal funds. The Lockwood Transportation District was created to provide the local share of Interstate matching funds necessary to create the federal project. Growth in Lockwood and associated traffic volumes have increased substantially since its construction such that operational problems have begun to develop on the Johnson Lane crossroad.

The ***Lockwood Interchange*** was constructed as a part of the original I-90 construction project in 1965. The Lockwood interchange provides access to the Billings CBD from origins and destinations east of Billings. It also is the primary access for traffic to and from the Billings Heights area and for external traffic on US 87 and Highway 3. Prior to the Johnson Lane Interchange construction, it was the only access to the entire community of Lockwood. The interchange is standard diamond type with single lane ramps and a five lane crossroad (US 87). The US 87 roadway has two traffic lanes in each direction and left turns lanes within a raised median section at the ramp intersections. Both eastbound and westbound ramps were signalized approximately ten years ago and a right-turn lane was added to the eastbound off-ramp in 2010. A third traffic signal at the Lockwood Road intersection, west of I-90 operates in coordination with the ramp signals. Current traffic volumes on the US 87 crossroad create periodic congestion due to vehicle queues exceeding available storage.

EXISTING ROADS & STREETS OPERATIONS

Traffic Volumes

Existing (2010) traffic count data was requested from and supplied by MDT, the City of Billings, and Yellowstone County. In addition, data was extracted from the Lockwood Transportation Plan. In order to supplement data that was incomplete or out-dated, additional peak hour traffic movement counts were taken at a number of intersections in 2010 and 2011. Traffic count data was composed of road tube data summarized by hourly volume variations, and peak hour turning movement data summarized by 15 minute count periods. Average Daily Traffic (ADT) counts were calculated by factoring 24 hour count data by day of the week and month of the year where 24-hour count data was available. At locations where 24 hour count data was not available, turning movement counts were used to estimate ADT based on average hourly variations for the type and location of each facility. MDT has a number of permanent traffic count stations in the Billings area that record one-hour volumes continuously on a number of different facilities. Statistics gathered from those permanent count stations are published on the MDT Web Site. Appendix A in this report presents the daily and monthly variation factors used to estimate ADT volumes. Other statistics in the MDT reports were used to determine peak design hour traffic volumes.

There were three specific locations where turning movement counts were collected at successive intersections on different days and in some cases different months. As a result, departure traffic volumes from one intersection did not match approach traffic volumes at the next intersection. Those locations involved four intersections at both the Lockwood and Johnson Lane interchanges and on Main Street, between 1st Avenue North and Airport Road. In order to resolve the differences and present a more accurate accounting of traffic volumes at these locations, a traffic balancing spreadsheet was created to ensure that traffic demand at individual intersections agreed with the daily and peak hour traffic passing through each individual corridor.

Figure 2 illustrates the existing (2010) traffic volumes for Average Daily Traffic (ADT) and peak PM hour design traffic. Throughout the study process, it was determined that the PM peak hour traffic volumes are considerably higher than the AM hour volumes and that operational measures of efficiency are worse during the PM hour. Therefore, the PM design hour volumes were used for evaluation of operational differences within this study.

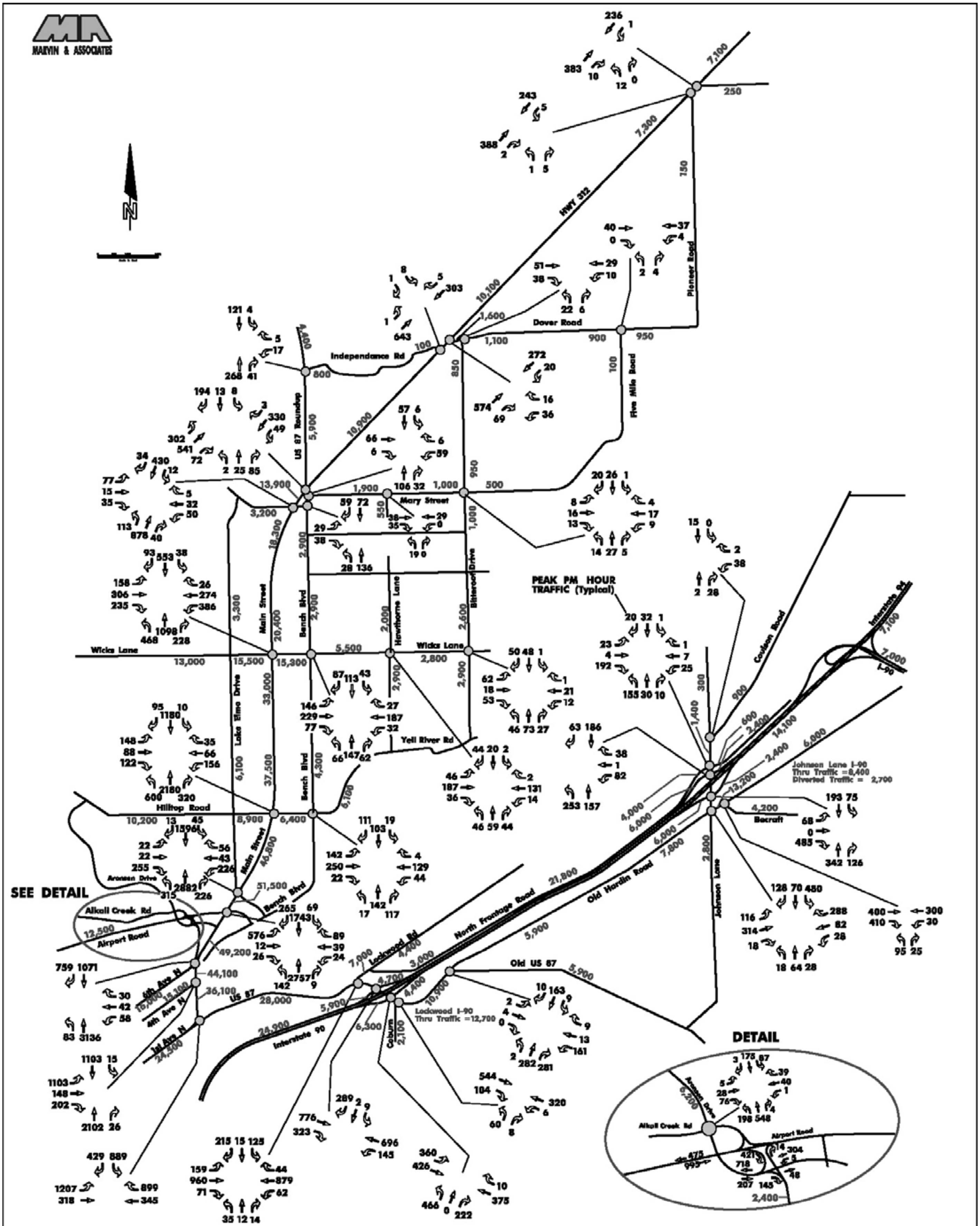


Figure 2. Existing (2010) Traffic Volumes on Potentially Impacted System

Trucks and Through Traffic

In addition to ADT for all vehicles, commercial vehicle traffic (trucks) data was extracted from MDT's "Traffic by Section" report for 2010, previous traffic classification counts by Marvin & Associates, and extrapolations between segments. Table 1 includes a summary of the existing system road and street segments; the segment length, year 2010 ADT, commercial (truck) ADT, and percentage of total ADT that includes trucks. The highest volume and percentage of trucks are on the Interstate 90 and 94 corridors, ranging from 14.6% on I-94 to 22.1% on I-90 east of Johnson Lane. Truck traffic on Johnson Lane, within the interchange area, also has a high percentage of trucks that ranges between 11.7% and 16.3% because of two large truck plazas that exist on each side of I-90 at that interchange.

Both Main Street and US 87 carry a substantial volume of commercial vehicle traffic, which ranges between 300 and 550 ADT. Because Main Street has such a high volumes of overall traffic, the relative percentage of trucks is actually less than 1% of total ADT. On US 87 north of the Old Highway 312 junction, the relative percentage of trucks is 5.2% of ADT. One hour counts were taken at the intersections of US 87/HWY 312/Main Street, Main Street/Airport Road, and 1st Avenue N/Main/US 87 to determine the percentage of trucks that were local or short-haul trucks as opposed to interstate or long-haul trucks. It was determined that the percentage of total trucks that were local ranged between 65% and 85%. Thus, it appears that on the average, 75% of truck traffic on the Main Street/US 87 corridor is local or short- haul vehicles while the remaining 25% of truck traffic is represented by interstate or long- haul vehicles.

The lowest volume of truck traffic occurs on the east-west roads and streets that feed into the Main Street or I-90 corridors. The county roads, represented by Dover Road, Five Mile Road and Pioneer Road, are primarily rural with a small number of farm trucks and, in the case of Dover Road, gravel trucks. Because the total volume of traffic on those roads is so small, the percentage of truck traffic appears to be high.

Through traffic demand (external to external origins and destinations) data and estimates used within this study are based on an Origin-Destination Study completed in the year 2000 as a part of the North Bypass Feasibility Study. Figures 3 and 4 illustrate the percentage of external trips to and from external and internal origins and destinations, based on origin-destination (OD) studies on Highway 3 and US 87. Figure 3 is a summary for all vehicles and Figure 4 presents percent distributions for commercial traffic (trucks). While the study is ten years old, the percentages of total traffic could be applied to the year 2010 traffic volumes to reflect current conditions.

Table 1. Commercial Truck Traffic on Existing (2010) Road & Street System

	EXISTING STREET LINK SEGMENTS			Length	2010	Commercial Traffic	
	ROUTE NAME	from	to	(miles)	ADT	ADT	% Total
I-94	Interstate 94	Pinehill Interchange	Huntley Interchange	6.21	7000	1020	14.6%
I-90	Interstate 90	Johnson Lane	Lockwood	1.27	21400	3150	14.7%
	Interstate 90	Pinehill Interchange	Johnson Lane	2.45	14000	3100	22.1%
County	Johnson Lane	I-90 Interchange	Coulson Road	0.29	4600	750	16.3%
U-1032	Johnson Lane	Old Hardin Road	I-90 Interchange	0.17	12000	1400	11.7%
U-1028	(Old US 87)	Lockwood Interchange	Jct Old Hardin Road	0.58	10700	450	4.2%
US 87 N-16	Highway 87	I-90 Lockwood Interchng	1st Avenue N	1.25	27500	550	2.0%
	Main Street	1st Avenue N	6th Avenue N	0.35	39300	500	1.3%
	Main Street	6th Avenue N	Airport Road	0.37	48500	450	0.9%
	Main Street	Airport Road	Hilltop Road	0.64	50400	300	0.6%
	Main Street	Hilltop Road	Wicks Lane	1.02	35000	300	0.9%
	Main Street	Wicks Lane	HWY 312/Bench	1.00	19300	300	1.6%
	Highway 87	HWY 312/Bench	Independence Road	0.96	5800	300	5.2%
U-1012	Wicks Lane	Lake Elmo	Main Street	0.24	15200	20	0.1%
	Wicks Lane	Main Street	Bench Boulevard	0.24	15000	50	0.3%
	Wicks Lane	Bench Boulevard	Bitterroot Drive	1.00	2800	10	0.4%
City	Mary Street	Bench Boulevard	Five Mile Road	1.67	1500	10	0.7%
CO56788	Highway 312	US 87 (N16)	Dover Road	1.32	10700	100	0.9%
	Highway 312	Dover Road	Pioneer Road	2.20	7100	50	0.7%
	Highway 312	Pioneer Road	S-522 Huntley	5.43	6000	50	0.8%
U-1036	Bench Boulevard	Wicks Lane U-1012	US 87 (N16)	1.03	2900	5	0.2%
County	Dover Road	HWY 312 CO56788	Pioneer Road	1.56	1200	50	4.2%
County	Bitterroot Drive	Wicks (U-1012)	Mary Street	1.00	1300	5	0.4%
	Bitterroot Drive	Mary Street	Dover Road	0.96	1000	5	0.5%
County	5 Mile Road	Mary Street	Dover Road	0.65	150	10	6.7%
County	Pioneer Road	Dover Road	HWY 312 CO56788	1.50	200	15	7.5%
S-522	Huntley Main Street	I-94 Huntley Interchange	CO56788 (HWY 312)	2.37	3700	50	1.4%
			Total =	37.73	13491	481	3.6%
					Avg	Avg	Avg

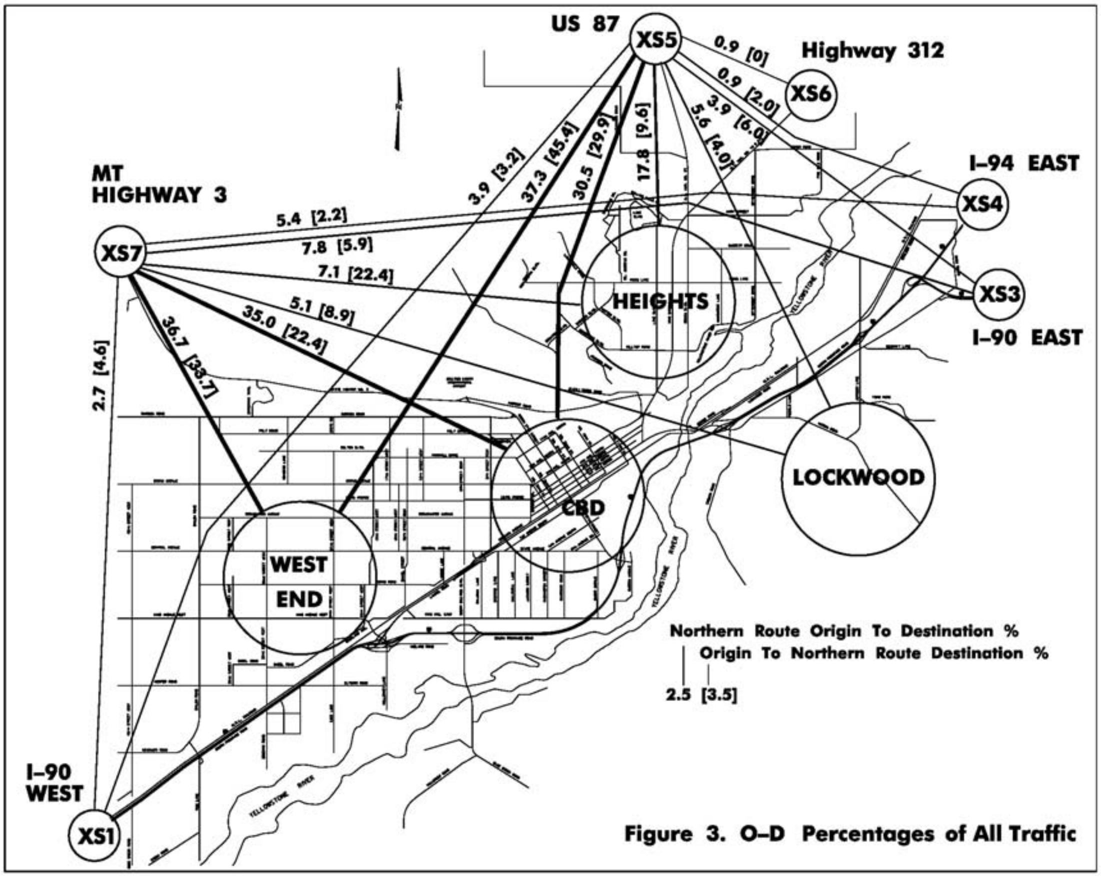


Figure 3. O-D Percentages of All Traffic

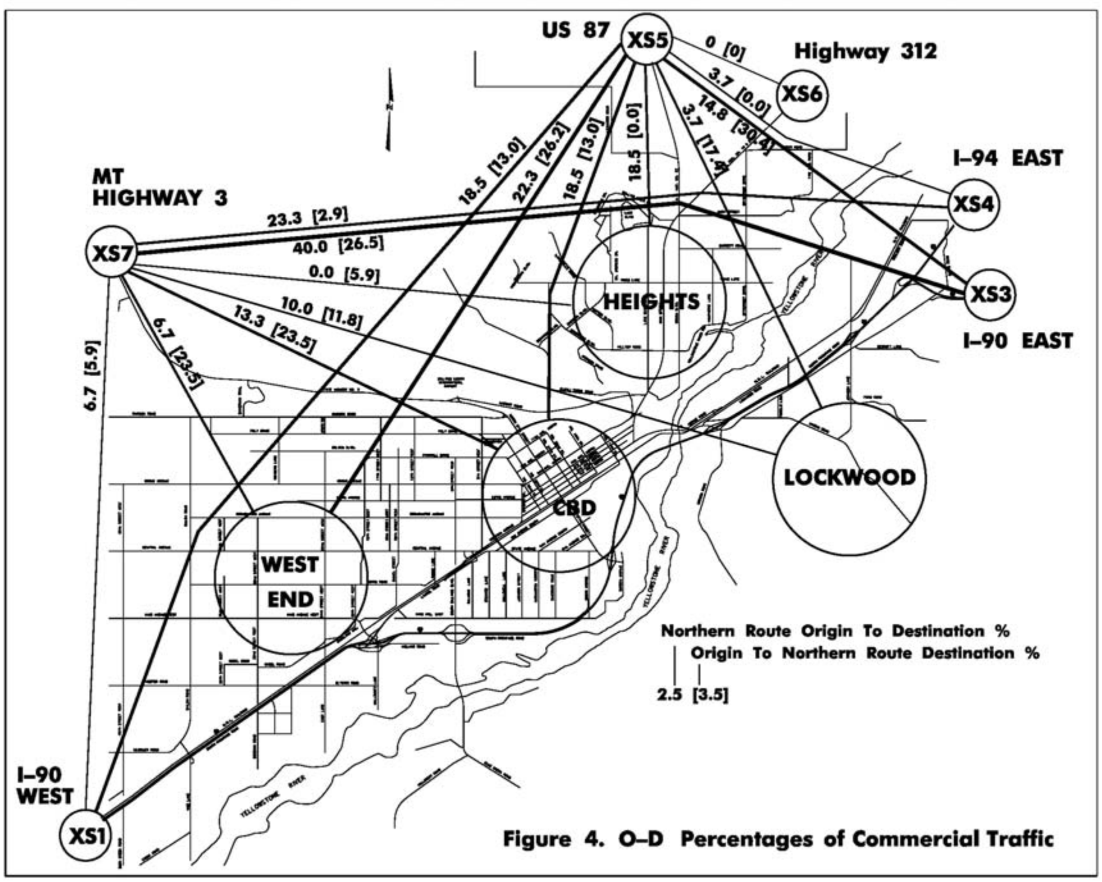


Figure 4. O-D Percentages of Commercial Traffic

For the OD study on Highway 3, it was determined that approximately 15% of all traffic was through traffic, with an origin and destination external to the Billings area. The remaining traffic (85%) either originated in Billings or was destined to stop in Billings. On US 87, only 10.5% of the total traffic could be classified as through traffic. The percentage of through traffic for commercial (truck) traffic was substantially different, with through traffic accounting for approximately 53% of Highway 3 traffic, and 40% of US 87 traffic.

Capacity and Level of Service

Operational data for key intersections along the existing roads and streets that have the most probable impacts was gathered, and capacity analysis for existing (year 2010) conditions was performed for 18 separate intersections. In addition, capacity analysis was performed on three sections of Interstate-90 and the ramps at the Lockwood and the Johnson Lane Interchanges. All of the Interstate segments and ramps currently operate at Level-of-Service (LOS) "C" or better. The traffic analysis summaries can be found in Appendix B of this report.

Table 2. Existing (2010) Intersection Capacity Summary

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
Highway 312 & Dover	C	15					A	9
Dover & Bitterroot	A	10					A	7
Dover & Five Mile Road	A	9					A	7
Mary & Bitterroot	B	11	A	10	A	7	A	7
Mary & Hawthorne	A	10					A	8
Mary & Bench			A	8	B	12	B	12
US87/Main/HWY 312/Bench	E	38	C	22	A	9	A	9
Main & Wicks Lane	D	44	D	35	E	58	D	44
Main & Airport Road	D	38	B	15	E	70	F	114
Main/1st Ave N/US 87			B	16	C	33	C	35
Lockwood US87/WB Ramps			C	33	C	24	B	12
Lockwood US87/EB Ramps	B	18			B	18	C	29
Johnson Lane EB Ramps	B	19	B	14	C	27		
Johnson Lane WB Ramps	A	9					F	51
Johnson Lane & N Frontage	A	8	A	7	B	11	C	22
Johnson Lane & Coulson Road			A	7			A	9
Johnson Lane & Old Hardin Rd	C	34	B	15	C	25	B	20
Old Hardin Rd & Becraft	E	41					B	11

= LOS D & E   = LOS F

Table 2 presents a summary of LOS and delay, in terms of seconds per vehicle, for each intersection approach. Only five of the 18 intersections have approaches that operate below a LOS “C”. The northbound approach to the US 87/HWY 312/Main/Bench intersection currently operates at LOS “E” with 38 seconds per vehicle delay in the PM design hour. Signalization of that intersection is currently under design.

Two key intersections on Main Street have approaches that operate at a LOS less than “C”. The NB and SB approaches at Wicks Lane operate at LOS “D”, while the EB approach has the most delay and operates at LOS “E”. At the Airport Road intersection with Main Street, the NB movement operates at LOS “D” while accommodating in excess of 3,000 vehicles during the peak PM hour period. However, the lower volume Airport Road approaches suffers more delay with a LOS “E” on the EB approach and LOS “F” on the WB approach. Because Main Street is operating on a coordinated system and the majority of traffic flows in the northbound direction during the PM hour, there is more side street delay during that time. Operations at these intersections are much better at off-peak hours of the day.

The Johnson Lane WB Off-ramp operates at LOS “F” during the PM design hour due mainly to the high volume of truck movements on the ramp and on Johnson Lane, and the number of turning movements within the intersection. Fortunately the ramps’ volumes are so low that only four or five vehicles are in the storage queues.

The intersection of Becraft Lane and Old Hardin Road is located within 300 feet of the Johnson Lane and Old Hardin Road intersection. The NB Becraft Lane approach to the intersection is stop controlled and currently operates at LOS “E” with 41 seconds per vehicle delay during the PM design hour traffic. While the approach volume is fairly low (200 vehicles) in the PM hour, it is double that in the AM hour. Thus, the Becraft approach operations are poor during most heavy traffic periods of the day. Signalizing this intersection would be difficult since its operations would then interfere with the existing signal at Johnson Lane and Old Hardin Road. The Lockwood Transportation Plan presents a method of relocating Becraft to enable coordinated operations on Old Hardin Road. However, there are no projects currently being planned at this intersection.

Crash History

The MDT Traffic Safety Section provided collision data for the select system routes for a five-year time period between January 1, 2006 and December 31, 2010. The collision data was divided into a number route segments and statistics were compiled for each route segment. Table 3, on the following page, presents a summary of collision statistics. As a comparison, the 2006 to 2010 statewide average crash rates for Urban Interstate routes was 1.18 crashes per million vehicle miles of travel (mvm) and the average severity rate was 2.11/mvm. For NHS routes & primary highways within city limits the average crash rate was 4.86 crashes/mvm and the average severity rate was 8.16/mvm. No other statewide urban crash statistics are available for city streets.

Table 3. Crash Statistics on Existing (2010) Road & Street System - 1/1/2006 to 12/31/2010

	EXISTING STREET LINK SEGMENTS					CRASH HISTORY PAST 5 YEARS							
				Length	2009	No.	Crash	Injury	No.	Fatal	No.	Crash Severity	
	ROUTE NAME	from	to	(miles)	ADT	Acc.	Rate	Crash	Inury	Crash	Fatal	Index	Rate
I-94	Interstate 94	Pinehill Interchange	Huntley Interchange	6.21	7000	79	1.00	18	23	0	0	1.41	1.40
I-90	Interstate 90	Johnson Lane	Lockwood	1.27	21400	74	1.49	20	32	0	0	1.49	2.22
	Interstate 90	Pinehill Interchange	Johnson Lane	2.45	14000	7	0.11	1	1	0	0	1.26	0.14
County	Johnson Lane	I-90 Interchange	Coulson Road	0.29	4600	20	8.22	3	5	0	0	1.27	10.43
U-1032	Johnson Lane	Old Hardin Road	I-90 Interchange	0.17	12000	10	2.69	2	5	0	0	1.36	3.65
U-1028	(Old US 87)	Lockwood Interchange	Jct Old Hardin Road	0.58	10700	17	1.50	8	15	0	0	1.85	2.77
US 87 N-16	Highway 87	I-90 Lockwood Interchng	1st Avenue N	1.25	27500	176	2.81	50	73	0	0	1.51	4.24
	Main Street	1st Avenue N	6th Avenue N	0.35	39300	146	5.82	45	65	0	0	1.55	9.04
	Main Street	6th Avenue N	Airport Road	0.37	48500	107	3.27	34	56	0	0	1.57	5.14
	Main Street	Airport Road	Hilltop Road	0.64	50400	335	5.69	115	186	0	0	1.62	9.21
	Main Street	Hilltop Road	Wicks Lane	1.02	35000	290	4.45	110	170	2	2	2.02	8.99
	Main Street	Wicks Lane	HWY 312/Bench	1.00	19300	146	4.15	31	0	0	0	1.38	5.73
	Highway 87	HWY 312/Bench	Independence Road	0.96	5800	35	3.44	8	13	0	0	1.41	4.86
U-1012	Wicks Lane	Lake Elmo	Main Street	0.24	15200	19	2.85	4	4	0	0	1.38	3.94
	Wicks Lane	Main Street	Bench Boulevard	0.24	15000	45	6.85	16	19	0	0	1.64	11.23
	Wicks Lane	Bench Boulevard	Bitterroot Drive	1.00	2800	33	6.46	6	9	0	0	1.33	8.57
City	Mary Street	Bench Boulevard	Five Mile Road	1.67	1500	9	1.97	0	0	0	0	1.00	1.97
CO56788	Highway 312	US 87 (N16)	Dover Road	1.32	10700	20	0.78	3	3	1	1	3.72	2.89
	Highway 312	Dover Road	Pioneer Road	2.20	7100	51	1.79	21	31	1	1	2.70	4.83
	Highway 312	Pioneer Road	S-522 Huntley	5.43	6000	96	1.61	38	63	1	1	2.22	3.59
U-1036	Bench Boulevard	Wicks Lane U-1012	US 87 (N16)	1.03	2900	60	11.01	21	27	0	0	1.63	17.94
County	Dover Road	HWY 312 CO56788	Pioneer Road	1.56	1200	6	1.76	1	1	0	0	1.30	2.28
County	Bitterroot Drive	Wicks (U-1012)	Mary Street	1.00	1300	17	7.17	3	5	0	0	1.32	9.44
	Bitterroot Drive	Mary Street	Dover Road	0.96	1000	0	0.00	0	0	0	0	0.00	0.00
County	5 Mile Road	Mary Street	Dover Road	0.65	150	1	5.62	1	1	0	0	2.80	15.74
County	Pioneer Road	Dover Road	HWY 312 CO56788	1.50	200	5	9.13	3	3	0	0	2.08	19.00
S-522	Huntley Main Street	I-94 Huntley Interchange	CO56788 (HWY 312)	2.37	3700	29	1.81	14	16	0	0	1.87	3.39
	Totals =			**37.73**	**13491**	**1833**	**3.83**	**576**	**826**	**5**	**5**	**1.66**	**6.39**
					Avg		Avg					Avg	Avg

There were a total of 1,833 reported crashes on 37.73 miles of roads and streets during the 5 year reporting period. These crashes produced 826 injuries and 5 fatalities, while 1,002 crashes involved property damage only. The average crash rate on all roadway segments was approximately 3.83 crashes per million vehicle miles of travel (mvm) and the average severity rate was 6.39/mvm.

The highest crash rate on any one route segment was 11.01/mvm on Bench Boulevard between Main Street and Wicks Lane. However, it should be noted that the majority of those crashes occurred at either the US 87 intersection or at the Wicks Lane intersection located on either end of the route segment. The second highest crash rate (9.13) was on Pioneer Road, which has a very low volume of traffic and the five crashes on that route elevate the crash rate, though it is suspected that most of the crashes involved the nearby intersection with Highway 312. This segment also had the highest severity rate (19.0) with three of the five crashes resulting in injuries. The third highest crash rate (8.22) was on Johnson Lane between the I-90 interchange and Coulson Road. Since the crash rate on the south side of the interchange is substantially lower, it is possible that some of the crashes may have been located on the south side rather than the north. The high volumes and restrictive geometry at the Johnson Lane interchange, along with heavy truck traffic and major turning movements, tend to make this interchange area congested and may overload drivers' perception skills.

Some crash trends relative to the route class can also be seen. The interstate segments experienced the lowest overall crash rates, ranging between 0.11 and 1.49 crashes/mvm. Crash rates on the Highway 312 corridor were also fairly low, ranging between 0.78 and 1.79. However, it should be noted that the section of Highway 312 east of US 87 was recently rebuilt to provide multiple lanes and wide shoulders. The value of the reconstruction project can be seen when comparing the 0.78 crash rate in that section to the 1.79 rate east of the new project.

The average collision rate on urban arterial segments of the select system routes averaged about 5.0/mvm. However, it should be noted that the collision rates on urban arterials can be somewhat skewed to the higher end because of the number of intersections which involve side street traffic in the collision numbers, yet side street traffic volumes are not always in the calculation.

The crash rate on the rural county roads (Pioneer Road, 5 Mile Road, and Bitterroot Drive) were the highest, probably because of increasing traffic on older substandard roadways.

COMMITTED FUTURE PROJECTS

Future transportation improvement projects that have been committed for within the Billings Urban Area Transportation Plan that would interact with the Billings Bypass Project are: the 6th Avenue North – Bench Boulevard grade separation at Main Street, and the Billings Inner Belt Loop connecting Wicks Lane to Highway 3. Although both of these projects would decrease dependence on Main Street to satisfy travel demand, each project targets different areas of Billings Heights and thusly, would have distinct differences with regard to interaction with the study project.

The **6th Avenue North – Bench Boulevard Grade Separation Project** is considered to be Phase 2 of the Bench Boulevard – 4th and 6th Avenues North connection project that was recently constructed (not currently in operation). That project connected Bench Boulevard, at its current Lake Elmo Drive termini, directly to Main Street via a new bridge over Alkali Creek. The new roadway passes adjacent to and north of the METRA Park Rimrock Auto Arena, and will serve as the main access to the building's parking lots. The connection to Main Street was made at an existing signalized intersection at 6th Avenue North and Main Street. The newly constructed intersection features a slip ramp for northbound vehicles on Main Street. This ramp will allow access to Bench Boulevard for all northbound vehicles, and all eastbound vehicles entering Main Street on 4th Avenue North that have destinations in Billings Heights east of Main Street. Southbound traffic on Bench Boulevard would stop at the Main Street traffic signal. Because southbound traffic on Bench Boulevard would compete for green time at the signal with traffic on Main Street, it is anticipated that northbound traffic on the Bench Boulevard connection road will far exceed southbound traffic volumes. The Phase 2 grade separation project is expected to equalize the directional disparity when it is implemented. For the purposes of this study, it was assumed that the Phase 2 project would be in-place and operating by the year 2035 design year.

The **Billings Inner Belt-Loop Project** involves a new connector route that would begin at a point near the existing termini of Wicks Lane west of Main Street, intersect with Alkali Creek Road, and connect to Highway 3 west of the Billings Logan Airport near Zimmerman Trail. Contained in various transportation planning documents for a number of decades, this segment of the Inner Belt-Loop would complete a connection between Interstate 90 at Shiloh Road and US 87 (Main Street). Preliminary design of this segment of roadway was undertaken by the City of Billings in 2010 and construction of the first two-lane phase recently was delayed until the year 2013 or 2014. The project would provide an alternate route between Billings Heights and the west end of Billings. This route would satisfy travel demand in the western and northern portions of Billings Heights. For purposes of this project, it was assumed that the Inner Belt-Loop would be in-place in the design year 2035. It was also assumed that the Inner Belt-Loop would reduce traffic demand on Wicks Lane west of Main Street to a measured degree, and that a coordinated system of future streets in the outlying northern area would reduce traffic demand on US 87, just north of Main Street.

PROPOSED ALTERNATIVE ALIGNMENTS

After an extensive screening process, multiple alternative project alignments were screened out and three alternatives are being carried forward in the Environmental Impact Statement (EIS) process. This study addresses specific traffic operations associated with alignment design operations and impacts on the potentially impacted street system. Descriptions of the three alternative alignments can be found in the EIS Alternatives Report and in the following narratives and illustrations.

A connection to the Johnson Lane Interchange and a segment of the alignment south of the Yellowstone River is common to all alternative alignments. This segment is approximately 2.4 miles long and extends through land zoned for industrial and agricultural use. The Johnson Lane connection to I-90 would require reconstruction of the existing interchange to accommodate the anticipated traffic patterns.

The alignment would proceed north from I-90 along Johnson Lane and follow the existing Coulson Road alignment northeast for approximately 0.3 miles. At this point, the alignment would veer off of that existing road alignment and continue northeast roughly along the boundaries of parcels with industrial use. The alignment would proceed north and then west over Coulson Road and the Montana Rail Link railroad toward the Yellowstone River traversing agricultural land.

This alignment would include an at-grade connection with Coulson Road approximately 0.35 miles northeast of Johnson Lane. The existing segment of Coulson Road between Johnson Lane and this new connection would be removed.

Mary Street Alignment Option 1

This alignment would provide a 2.51-mile long connection from Old Hwy 312 across the Yellowstone River through land zoned for residential, agricultural, and commercial use. The connection to Old Hwy 312 would be located near the intersection of Old Hwy 312 and Mary Street, requiring the reconstruction of the existing at-grade intersection.

The alignment would proceed east directly north of Mary Street for approximately 1.6 miles, and would be bordered by land with agricultural and residential uses along this section. The alignment would veer south across Mary Street and proceed southeast across an undeveloped parcel before crossing the Yellowstone River.

This alignment would include at-grade connections to Mary Street at four locations; Bench Boulevard, Hawthorne Lane, Bitterroot Drive, and approximately 1.6 miles east of Old Hwy 312 where the alignment would cross Mary Street. Mary Street would be used as a frontage road for local resident access.

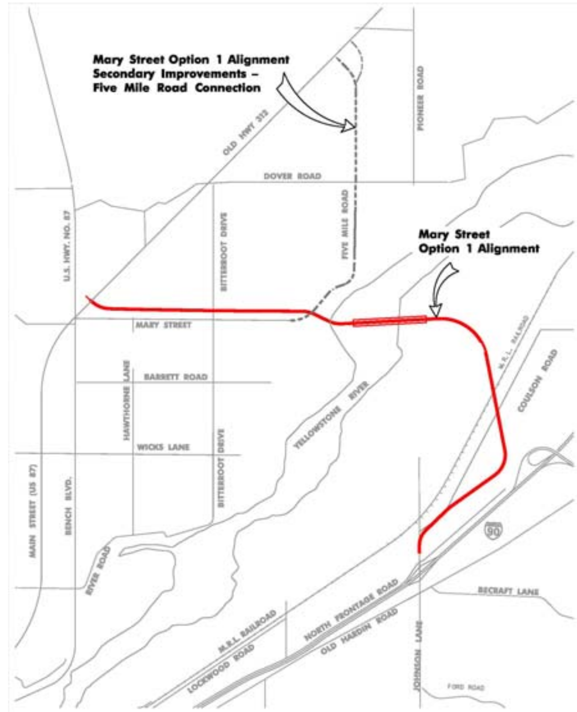


Figure 5. Mary Street Option 1 Alignment

Mary Street Alignment Option 2

This alignment would provide a 2.76-mile long connection from Old Hwy 312 across the Yellowstone River through land zoned for residential, agricultural, and commercial use, as well as a tract of future park land.

This alignment would be identical to the Mary Street Alignment - Option 1 from Old Hwy 312 to approximately 0.5 miles before the Yellowstone River. At this point, it would veer to the north across Five Mile Creek and Five Mile Road. The alignment would then proceed southeast through a tract of future park land and continue across the Yellowstone River.

This alignment would include connections to Mary Street at three locations: Bench Boulevard, Hawthorne Lane, and Bitterroot Drive. The alignment would also connect with Five Mile Road north of Five Mile

Figure 6. Mary Street Option 2 Alignment

Creek. Mary Street would be used as a frontage road for local resident access.

Five Mile Road Alignment

For this alternative, there are two connection location options at Old Hwy 312. Depending on the location of its connection with Old Hwy 312, the Five Mile Road alignment would provide either a 2.13 or 2.23-mile long connection from Old Hwy 312 across the Yellowstone River. It would cross land zoned for agricultural, commercial, and residential use, as well as a tract of future park land.

Either connection to Old Hwy 312 would be located approximately 1 mile north of Dover Road, requiring the construction of a new at-grade intersection. The alignment would proceed south to the existing intersection of Five Mile Road and Dover Road. From that location, the alignment would continue south along the Five Mile Road alignment before veering southeast through planned future park land and crossing the Yellowstone River.

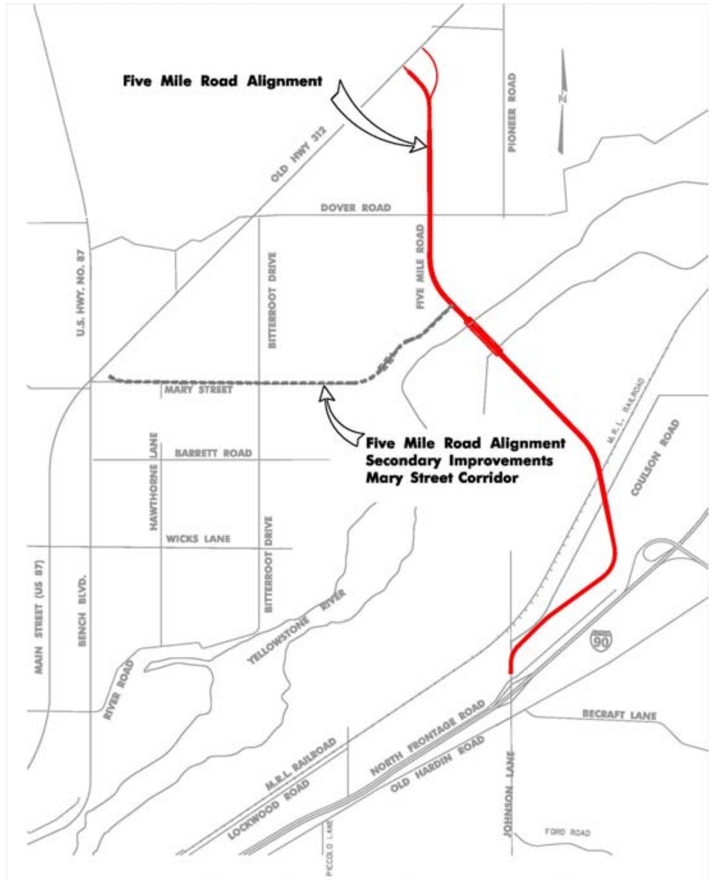


Figure 7. Five Mile Road Alternative Alignment

FUTURE TRAFFIC PROJECTION METHODS

Traffic projections for future design year volumes were based upon an approved methodology established specifically for this project. As with all transportation models, the traffic projection methods employed do not result in volumes that can be stated with any discrete level of accuracy, but have produced reasonable traffic volume estimates necessary to make informed planning decisions and also provide a realistic representation of traffic demand that was used to develop concept geometry and traffic controls for the alternative alignments.

The proposed traffic projection methodology is based on the following assumptions.

- The existing Billings traffic model was created for system-wide planning level projections within the urban area, while the proposed Bypass alternative alignment projections were based on a corridor level analysis.
- The Bypass corridor would provide an alternate route to serve both initial and future travel demand between Billings Heights and Lockwood. The corridor would also serve external travel demands by using the Bypass corridor as an alternate route to existing street system routing.
- The Bypass corridor alternatives will intersect and connect to a number of existing streets between the two termini connections in Billing Heights and Lockwood.
- Bypass corridor traffic projections were made by redistributing existing and future road system traffic based on shortest travel time routing.
- There was sufficient existing and easily obtained traffic data available to perform calculations required for redistribution of existing traffic.
- Future traffic projections were completed by using projected land use growth scenarios contained within the Billings Urban Area Transportation Plan 2009 Update.
- For the purposes of estimating future trips, Billings Heights and Lockwood were considered to be production centers, while other portions of the urban area such as the CBD and the west end commercial areas are considered to be trip attractors. It was assumed that the number of trips produced in each area having external origins and destinations will be in the proportion to the existing ratio of internal/external traffic.
- Origin-destination results from the Origin-Destination Study completed in 2000 are still valid with current and future land uses.

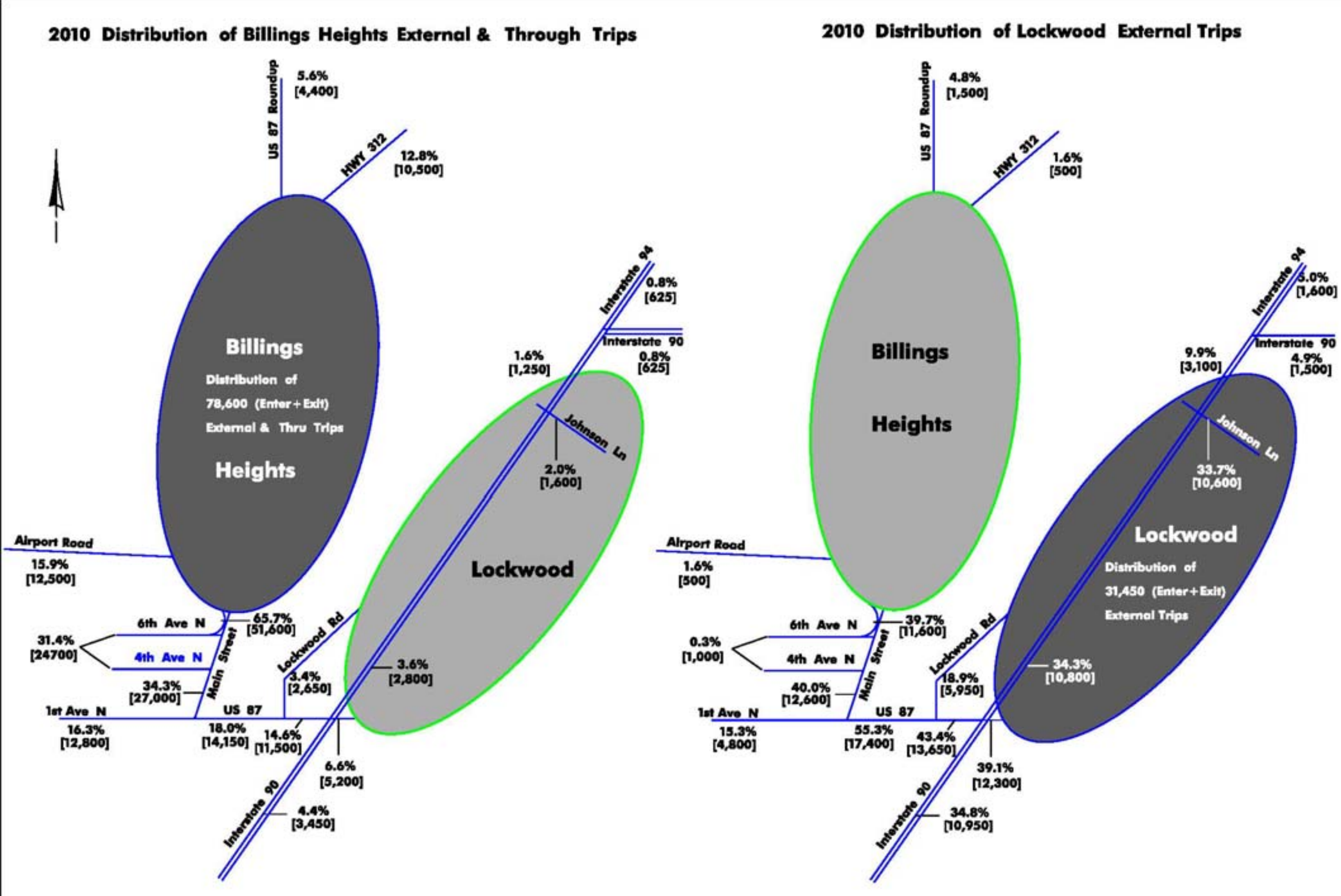


Figure 8. Distribution of Existing (2010) Trips – Billings Heights & Lockwood

Figure 8 illustrates the relative boundaries of the Billings Heights and Lockwood communities and the roadway system entering and exiting each community. The only substantial external accesses to and from Billings Heights are Airport Road, Main Street, US 87, and Highway 312. The only external accesses to Lockwood are US 87 and I-90, and the only reasonable connection between the two communities is the US 87 Yellowstone River Crossing. Thus, in terms of travel demand, the Bypass corridor is essentially an alternate river crossing and the demand for travel on the route can be calculated by examining the directional traffic demand on the existing US 87 river crossing.

Figure 8 also shows the 2010 average daily traffic (ADT) volumes at key count stations and the relative percentage of external trips produced in Billings Heights and Lockwood, plus external traffic passing through each community. Through trip data was obtained by applying the Origin-Destination Study data detailed in Figures 3 and 4. The number of trips generated in each area that enter or leave the area's boundaries is determined by adding all of the cordon count station volumes and subtracting the external to external through traffic. It is important to note that the number of external trips produced in the Billings Heights area represents approximately 40% of the total number of trips produced within that area, while the number of external trips produced in Lockwood represents approximately 65% of the total trip production in Lockwood. This disparity illustrates the fact that Billings Heights has developed a higher level of diversity in terms of residential and commercial land use, whereas Lockwood has a land use mix with a higher proportion of residential uses. Thus, one component of the traffic projections involves redistribution of trips between Lockwood and the west end of Billings to the Billings Heights commercial areas, since a new connection would reduce travel times for commercial trip purposes.

Data from the previous O-D study was used to determine external-external traffic, including commercial (truck) traffic that would use the new arterial route. In addition, the new arterial route would have an impact on traffic that currently uses the Huntley I-94 interchange to connect the residential developments and small communities northeast of the project site along Old Highway 312. Travel times savings associated with the new alignment would divert a portion of the traffic that currently uses the Huntley Interchange and traffic flow on a portion of Highway 312 would be reversed, thus reducing traffic on I-94 and I-90 east of the Johnson Lane Interchange.

An analysis of travel times was completed for the alternative alignments based upon average travel speeds along route segments and average intersection delays using the average HCM delays associated with existing intersection movement levels-of-service (LOS). It was determined that the areas of Billings for which the new alternative alignments would reduce travel time are Billings Heights East & West, Outlying North, Outlying Northeast, and the West End Commercial Areas. It was determined that none of the alternative alignments would reduce travel time to and from the CBD, Central Billings, or large areas of the Billings West end that are not immediately adjacent to I-90.

The data from this study was used to develop travel time contour mapping in order to delineate the specific areas of Billings Heights and Lockwood that would experience a travel time advantage by using each Bypass alternative. Demographic data within these smaller areas combined with the percentage of external trips on each route was used to determine the number of trips to and from each area for each alternative alignment. Table 4 presents the land use growth projections, extracted from the 2009 Update to the Billings Area Urban Transportation Plan, that were used to project growth within the travel time contour areas.

Table 4. Project Specific Demographic Areas - Years 2002 to 2035 From 2009 Plan Update

	Year 2002		Year 3035		2035 - 2002 Difference	
ZONE NAME	**D U s**	**Employment**	**D U s**	**Employment**	**D U s**	**Employment**
Outlying North	834	20	3000	500	2166	480
Heights West	5957	2988	10457	5488	4500	2500
West End	6074	4264	8574	11764	2500	7500
Outlying Northeast	356	111	476	361	120	250
Lockwood	1717	2011	2917	3511	1200	1500
Heights East	2040	265	3640	1015	1600	750
Totals =	**16978**	**9659**	**29064**	**22639**	**12086**	**12980**
Population Estimates	**42445**		**72660**		**30215**	

The zones listed in Table 4 are associated with distinct areas contained in the Billings Urban Area Transportation plan. The Outlying North area is a large area that is north of the US 87/Old HWY 312 intersection and straddles US 87. The Outlying Northeast area encompasses land the fans out from the US 87/Old Hwy 312 intersection and it bisected by Old Hwy 312. The Height East and West areas encompass the developed areas of Billings Heights that are located on either side of Main Street. The Lockwood area encompasses all of the land south of the Yellowstone River between the Lockwood Interchange and Pinehills (including the Pinehills Community). The West End area encompasses a large area of land that includes residential and commercial developments within the western portion of Billings' City Limits.

NO-BUILD ALTERNATIVE SYSTEM IMPACTS

This section of the study report deals with year 2035 traffic projections and resultant traffic operations that could be expected on the existing plus committed (E+C) street system, if this project were not built. The existing system consists of the streets and roadways indicated in Figure 1 and as described in subsequent narratives. The committed system consists of the projects described in the "Committed Future Projects" section of this report.

Traffic Volume Projections

Figure 9 presents a summary of year 2035 ADT volumes on the study's road and street system. Traffic projections were based upon the relative land use changes described in the "Future Traffic Projections" section of this report and by calculating future traffic volumes using historic records on facilities with a substantial volume of traffic external to the study area, such as the Interstate roadway system. It was determined that the majority of roadways would have ADT increases of approximately 50% in excess of the current year 2010. Committed projects, such as the Bench Boulevard – 6th Avenue North grade separation and Bench Boulevard reconstruction projects, were also factored into the estimates. The Inner Belt-loop project would result in reduced traffic on Wicks Lane west of Main Street and on Airport Road. In addition, the Inner Belt-loop Road would also reduce the overall traffic demand on US 87 north of Main Street, when local streets are constructed in a configuration that would encourage use of the Belt-loop.

Figure 10 presents the No-build Alternative year 2035 PM design hour traffic volumes at critical intersections along the E+C street system. These volumes reflect the ADT traffic growth based on existing peak hour traffic counts and redistribution of traffic due to land use changes and committed project influences. The peak hour volumes shown in Figure 10 represent the baseline conditions used for alternative alignment projections and are used in capacity calculations to determine measures of effectiveness (MOEs) and crash projections.

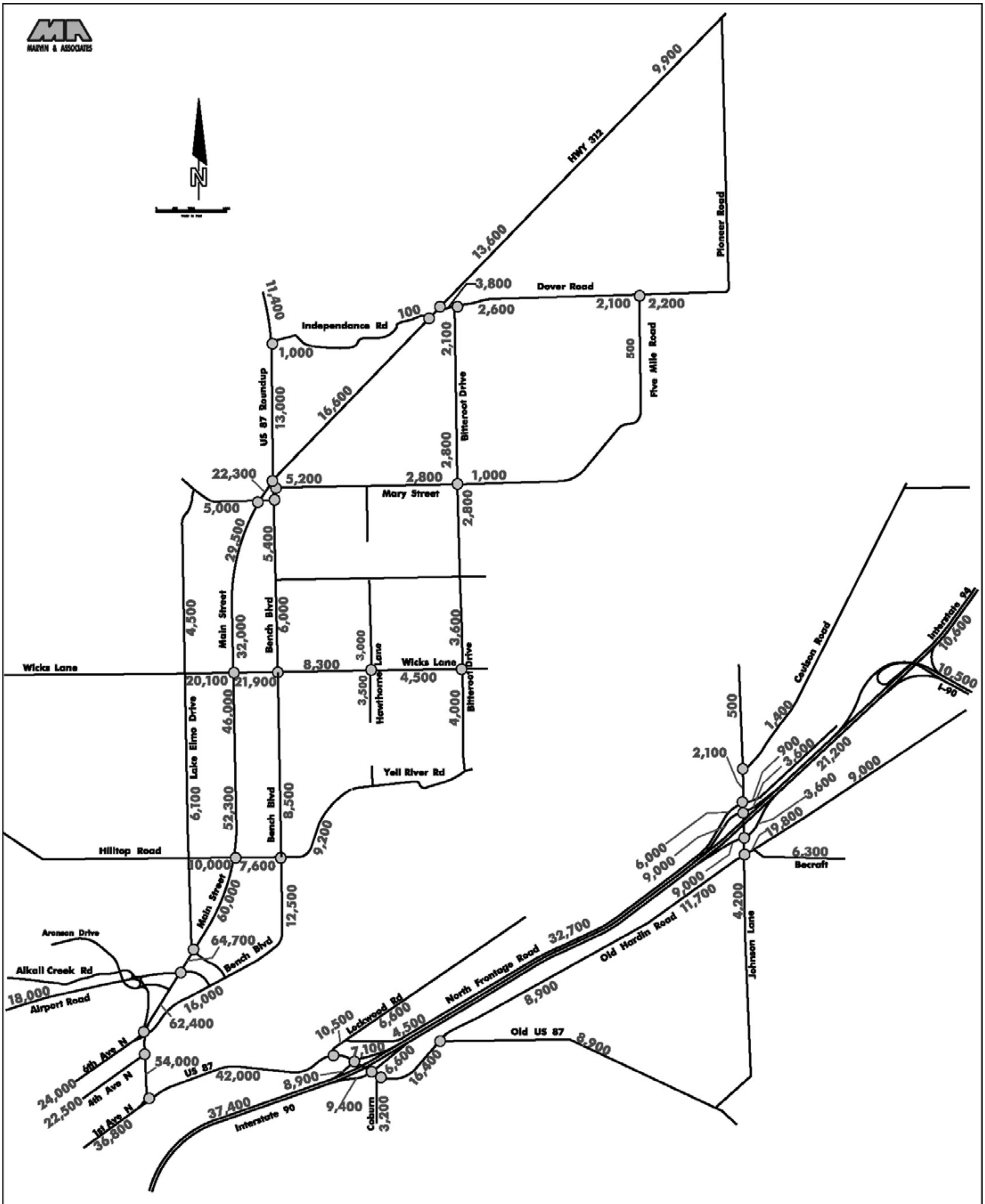


Figure 9. Year 2035 ADT Volumes on No–Build System

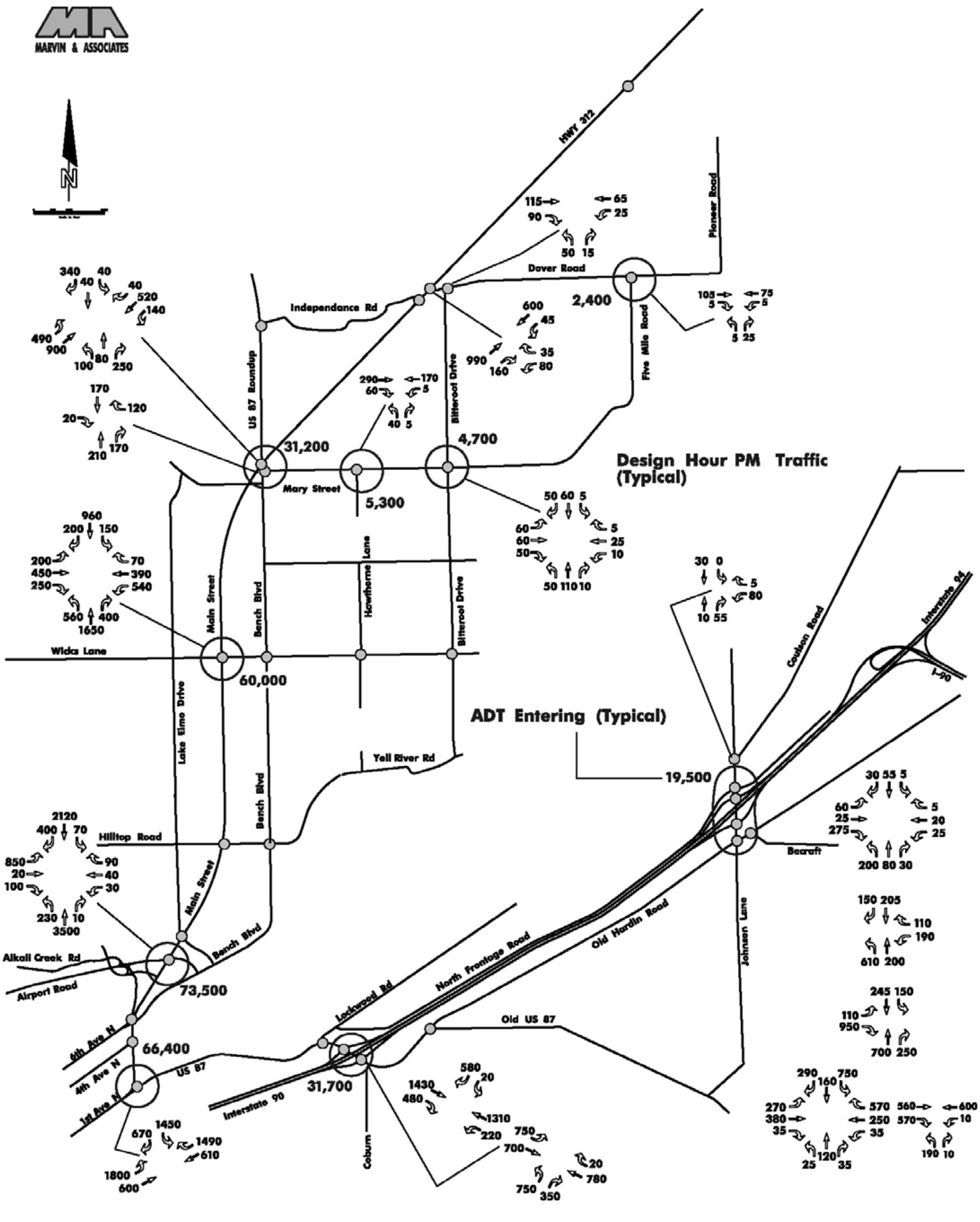


Figure 10. No–Build Alternative Year 2035 Traffic at Critical Intersections

Capacity and Level of Service

Capacity calculations along existing roads and streets were completed for the No-Build system based upon the year 2035 traffic at critical intersections illustrated in Figure 10. In addition, capacity analysis was performed on three sections of Interstate-90 and on all ramps at the Lockwood and the Johnson Lane Interchanges. All I-90 freeway segments and interchange ramps would still operate at LOS "C" or better in the year 2035. The capacity analysis calculations for each location can be found in Appendix C of this report.

Table 5 presents a summary of level-of-service (LOS) and delay (sec/vehicle) for each intersection approach. Only one of the 17 intersections would have all approaches that operate at LOS "C" or better. Ten of the intersections would have at least one approach that would operate at LOS "F". It should be noted that the eastbound approach to the US 87/HWY 312/Main/Bench intersection would only operate at LOS "F" when pedestrian crossings occur, which is currently a rare occurrence.

Table 5. No-Build Alternative (2035) Intersection Capacity Summary

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
Highway 312 & Dover	F	194					B	13
Dover & Bitterroot	B	12					A	8
Dover & Five Mile Road	A	9					A	8
Mary & Bitterroot	C	19	B	13	A	7	A	8
Mary & Hawthrone	B	14					A	8
US87/Main/HWY 312/Bench	B	18	B	18	F	110	D	40
Main & Wicks Lane	F	115	D	40	F	148	F	116
Main & Airport Road	F	175	D	45	F	109	F	148
Main/1st Ave N/US 87			D	42	F	100	F	203
Lockwood US87/WB Ramps			F	209	F	101	C	26
Lockwood US87/EB Ramps	F	157			F	222	D	43
Johnson Lane EB Ramps	F	89	F	357	D	37		
Johnson Lane WB Ramps	B	12					F	2421
Johnson Lane & N Frontage	A	8	A	8	C	16	D	35
Johnson Lane & Coulson Road			A	8			A	10
Johnson Lane & Old Hardin Rd	F	137	D	44	D	40	D	54
Old Hardin Rd & Becraft	F	1141					B	14

= LOS D & E   = LOS F

Crash Projections

Table 6 represents a projection of future crash statistics that would be associated with the No-Build alternative if current crash and severity rates were applicable in the design year 2035. It is recognized that a number of improvements could be made to the existing system during the next 24 years and there are a number of driver and vehicle variables that could occur during that period of time, however existing baseline conditions extrapolated into future conditions provides a common baseline in comparisons between the No-Build and the project alignment conditions. The values shown in Table 6 represent the best estimates that can be made given the limitations of available information and uncertain future conditions.

Table 6. No-build Alternative Crash Projections on Existing Road & Street System Year 2035

EXISTING STREET LINK SEGMENTS					Annual Crash Projections				
ROUTE NAME	from	to	Length (miles)	2035 ADT	No. Crash	Injury Crash	No. Inury	Fatal Crash	No. Fatals
Interstate 94	Pinehill Interchange	Huntley Interchange	6.21	10600	23.6	5.4	6.9	0.0	0.0
Interstate 90	Johnson Lane	Lockwood	1.27	32700	22.2	6.0	9.6	0.0	0.0
Interstate 90	Pinehill Interchange	Johnson Lane	2.45	21200	2.1	0.3	0.3	0.0	0.0
Johnson Lane	I-90 Interchange	Coulson Road	0.29	6900	6.0	0.9	1.5	0.0	0.0
Johnson Lane	Old Hardin Road	I-90 Interchange	0.17	18000	3.0	0.6	1.5	0.0	0.0
(Old US 87)	Lockwood Interchange	Jct Old Hardin Road	0.58	16400	5.1	2.4	4.5	0.0	0.0
Highway 87	I-90 Lockwood Interchng	1st Avenue N	1.25	42000	53.8	15.3	22.3	0.0	0.0
Main Street	1st Avenue N	6th Avenue N	0.35	54000	40.1	12.4	17.9	0.0	0.0
Main Street	6th Avenue N	Airport Road	0.37	62400	27.5	8.7	14.4	0.0	0.0
Main Street	Airport Road	Hilltop Road	0.64	62400	83.0	28.5	46.1	0.0	0.0
Main Street	Hilltop Road	Wicks Lane	1.02	49100	81.4	30.9	47.7	0.6	0.6
Main Street	Wicks Lane	HWY 312/Bench	1.00	30700	46.4	9.9	0.0	0.0	0.0
Highway 87	HWY 312/Bench	Independence Road	0.96	13000	15.7	3.6	5.8	0.0	0.0
Wicks Lane	Lake Elmo	Main Street	0.24	21000	5.3	1.1	1.1	0.0	0.0
Wicks Lane	Main Street	Bench Boulevard	0.24	21900	13.1	4.7	5.5	0.0	0.0
Wicks Lane	Bench Boulevard	Bitterroot Drive	1.00	6400	15.1	2.7	4.1	0.0	0.0
Mary Street	Bench Boulevard	Five Mile Road	1.67	4500	5.4	0.0	0.0	0.0	0.0
Highway 312	US 87 (N16)	Dover Road	1.32	16600	6.2	0.9	0.9	0.3	0.3
Highway 312	Dover Road	Pioneer Road	2.20	13600	19.5	8.0	11.9	0.4	0.4
Highway 312	Pioneer Road	S-522 Huntley	5.43	9000	28.8	11.4	18.9	0.3	0.3
Bench Boulevard	Wicks Lane U-1012	US 87 (N16)	1.03	5800	24.0	8.4	10.8	0.0	0.0
Dover Road	HWY 312 CO56788	Pioneer Road	1.56	2300	2.3	0.4	0.4	0.0	0.0
Bitterroot Drive	Wicks (U-1012)	Mary Street	1.00	4000	10.5	1.8	3.1	0.0	0.0
Bitterroot Drive	Mary Street	Dover Road	0.96	2500	0.0	0.0	0.0	0.0	0.0
5 Mile Road	Mary Street	Dover Road	0.65	500	0.7	0.7	0.7	0.0	0.0
Pioneer Road	Dover Road	HWY 312 CO56788	1.50	400	2.0	1.2	1.2	0.0	0.0
Huntley Main Street	I-94 Huntley Interchange	CO56788 (HWY 312)	2.37	5500	8.6	4.2	4.8	0.0	0.0
Totals =			**37.7**	**19756** Avg	**551.3**	**170.3**	**241.8**	**1.6**	**1.6**

To compare the projected crash statistics in Table 6 to the existing conditions in Table 3, they must be converted to an annual rate. Thus, the existing number of crashes (1,539) on the road and street system is divided by five (years) to arrive at 307.8 annual average crashes. Year 2035 No-build projections in Table 6 are 443.4, or approximately 135 more crashes per year than on the existing system. Similar increases in the number of injury crashes, number of injuries, and number of fatalities would increase in a similar manner, since existing crash rates and severity rates were used to project future statistics. The only variable that would change in the year 2035 would be the traffic volumes on each street segment.

BUILD ALTERNATIVE ALIGNMENTS' SYSTEM IMPACTS

This section of the traffic study report presents the traffic volume projections for the three alternative alignments carried forward in the EIS. Year 2035 capacity and LOS for the existing system roads and streets are summarized. Crash projections for each alternative alignment are calculated in a similar manner as completed for the No-build alternative and comparisons between all alternatives are made. Individual intersections along the new alignments are not addressed within this section. Subsequent report sections address individual intersection design recommendations. At some of the alignment intersections, there are a number of design options that would provide acceptable operations for year 2035 conditions, and each option is evaluated and summarized.

Year 2035 Alternative Alignment Traffic Projections

Traffic projection methodologies (previously detailed) were utilized for each of the alternative alignments. Initial traffic projections revealed that traffic demand from and to various areas of Billings Heights would result in substantial traffic demand on connecting roadways. In particular, Pioneer Road would have significant traffic increases due to reduced travel times from outlying northeast areas along Old Highway 312 and redistribution of I-94 Huntley Interchange traffic. This condition was found to exist for both of the Mary Street alignments. Since it was determined that there were a number of conditions on Pioneer Road, such as: multiple approach legs at Old Highway 312; a 90 degree curve between Pioneer Road and Dover Road; an elementary school complex located within the curve area; and substandard roadway geometrics, it was evident that impact mitigation on Pioneer Road would be very difficult. Traffic projections determined that an extension of the Five Mile Road alignment would better serve outlying northeast travel demand than Pioneer Road. Traffic demand to and from the Billings Heights and Outlying North areas would also use the existing Mary Street corridor to access the new river crossing associated with the Five Mile Road alternative. In that case, improvements would also be needed to Mary Street as a part of the Five Mile alignment implementation. The screening process led to the conclusion that each of the three alignments would require additional secondary improvements. An extension of Five Mile Road to Old Highway 312 from Dover Road would be necessary for both of the Mary Street Alignment alternatives, and the Five Mile Alignment alternative would require reconstruction of Mary Street.

The traffic model was revised to include the Five Mile Road connection for both of the Mary Street Alignments and to reflect improved geometry on Mary Street as a part of the Five Mile Road Alignment alternative. Figures 11 through 16, on the following pages, present a summary of year 2035 ADT and PM design hour traffic volumes on the existing system and at proposed intersections along each alternative alignment. Comparisons between No-Build ADT and alternative alignment ADT indicate that substantial traffic reductions on Main Street, US 87 between Main Street and I-90, and on I-90 could be realized.

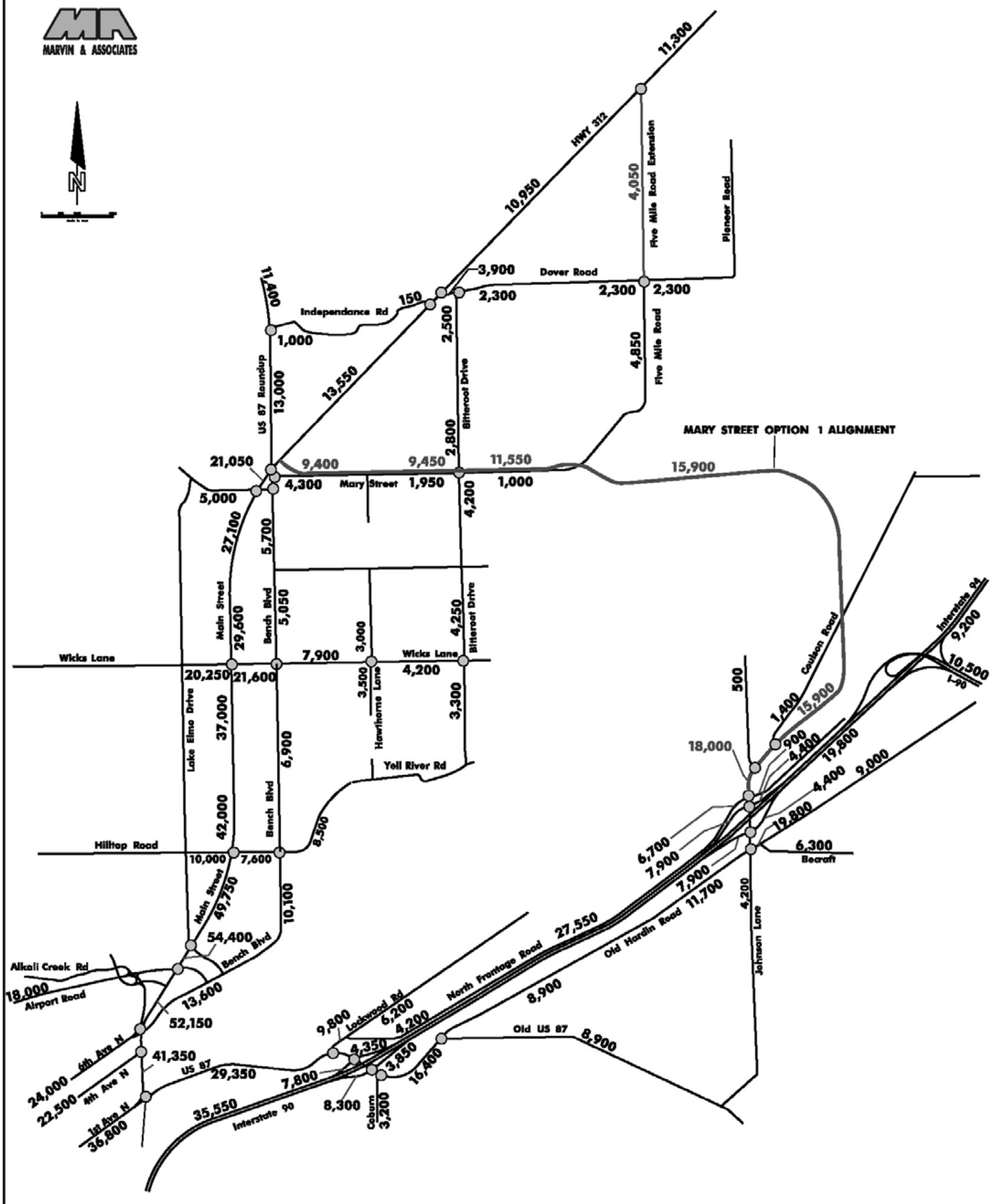


Figure 11. Mary Street Option 1 Alignment – Year 2035 ADT Volumes

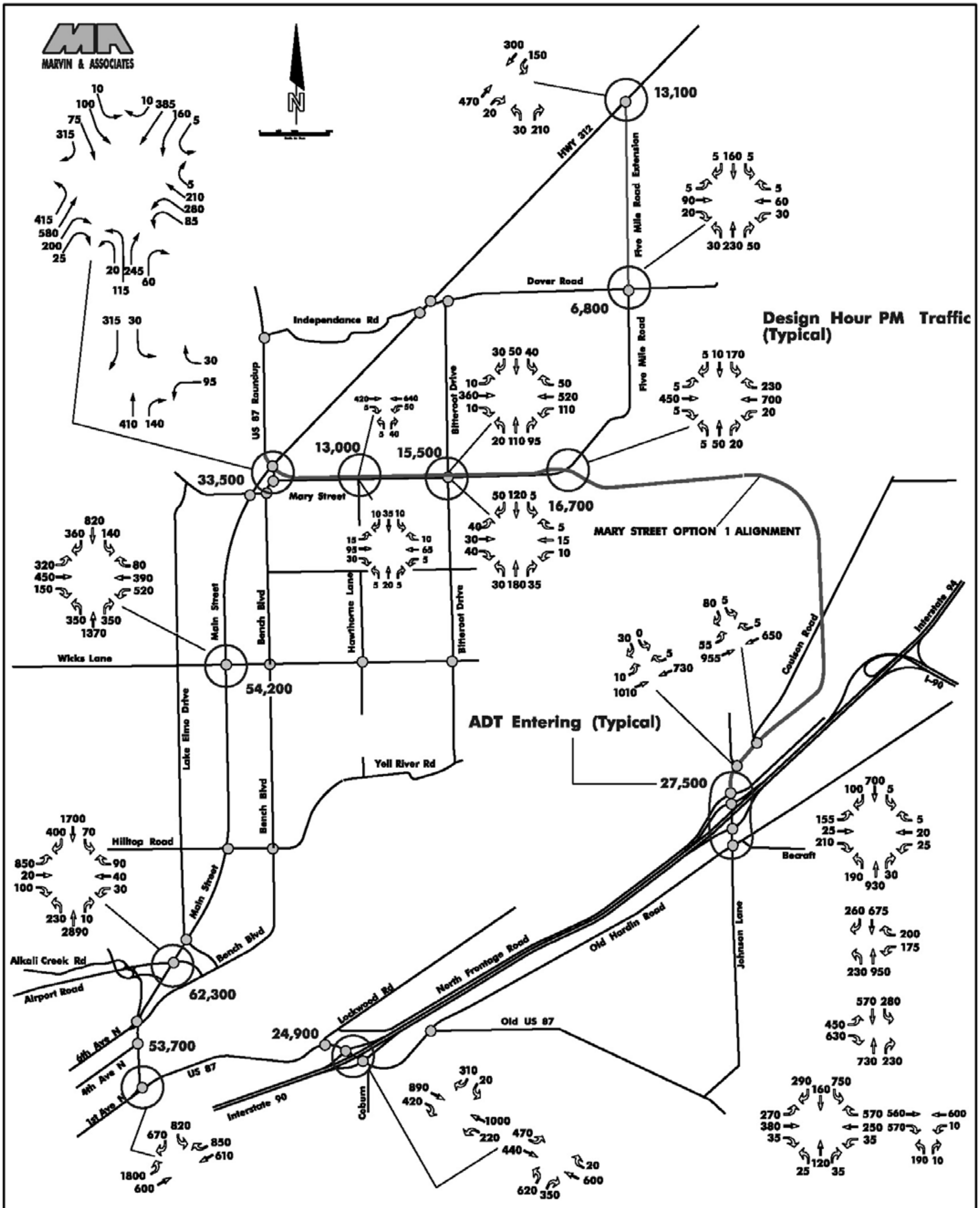


Figure 12. Mary Street Option 1 Alignment – Year 2035 PM Design Hour Traffic

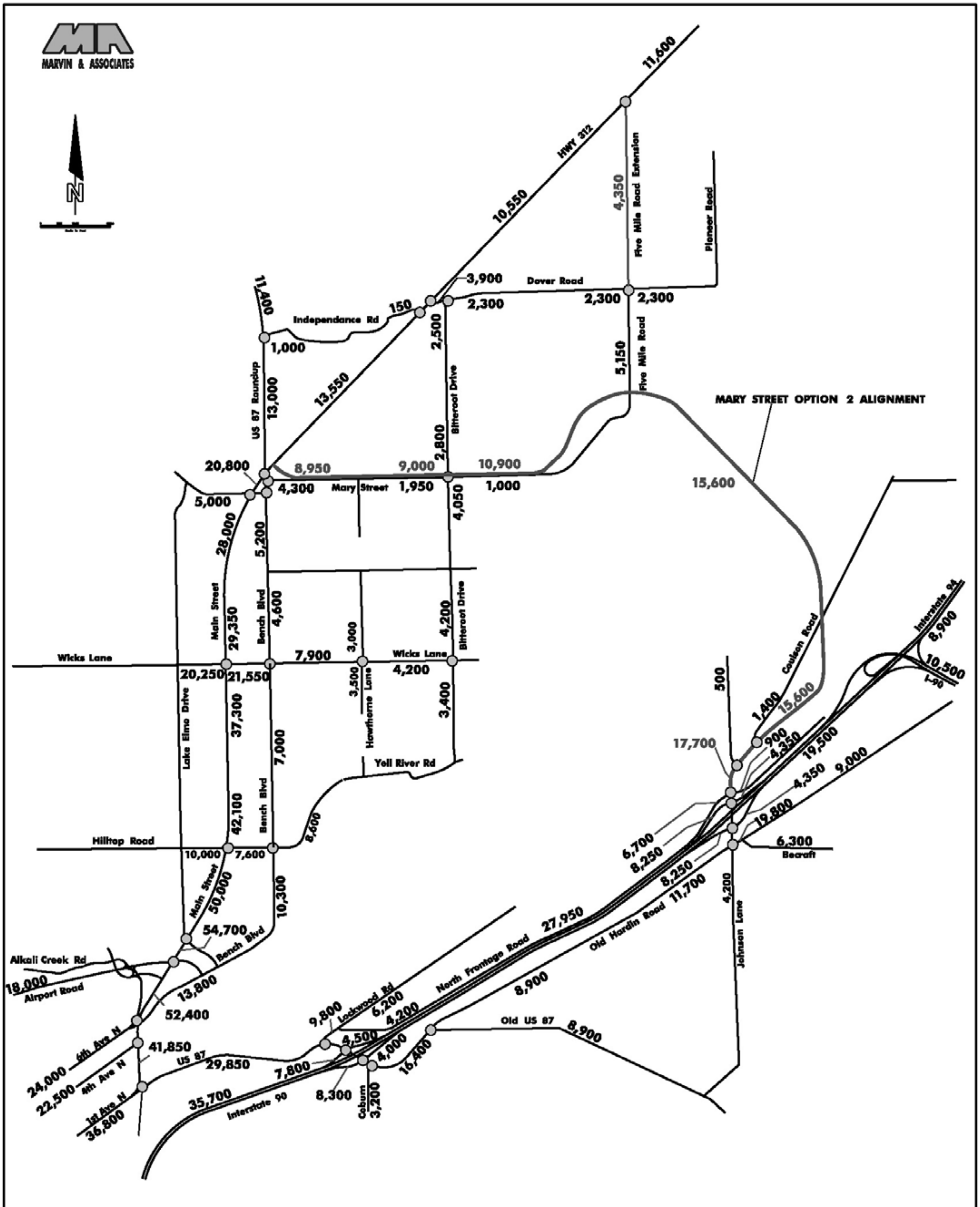


Figure 13. Mary Street Option 2 Alignment – Year 2035 ADT Volumes

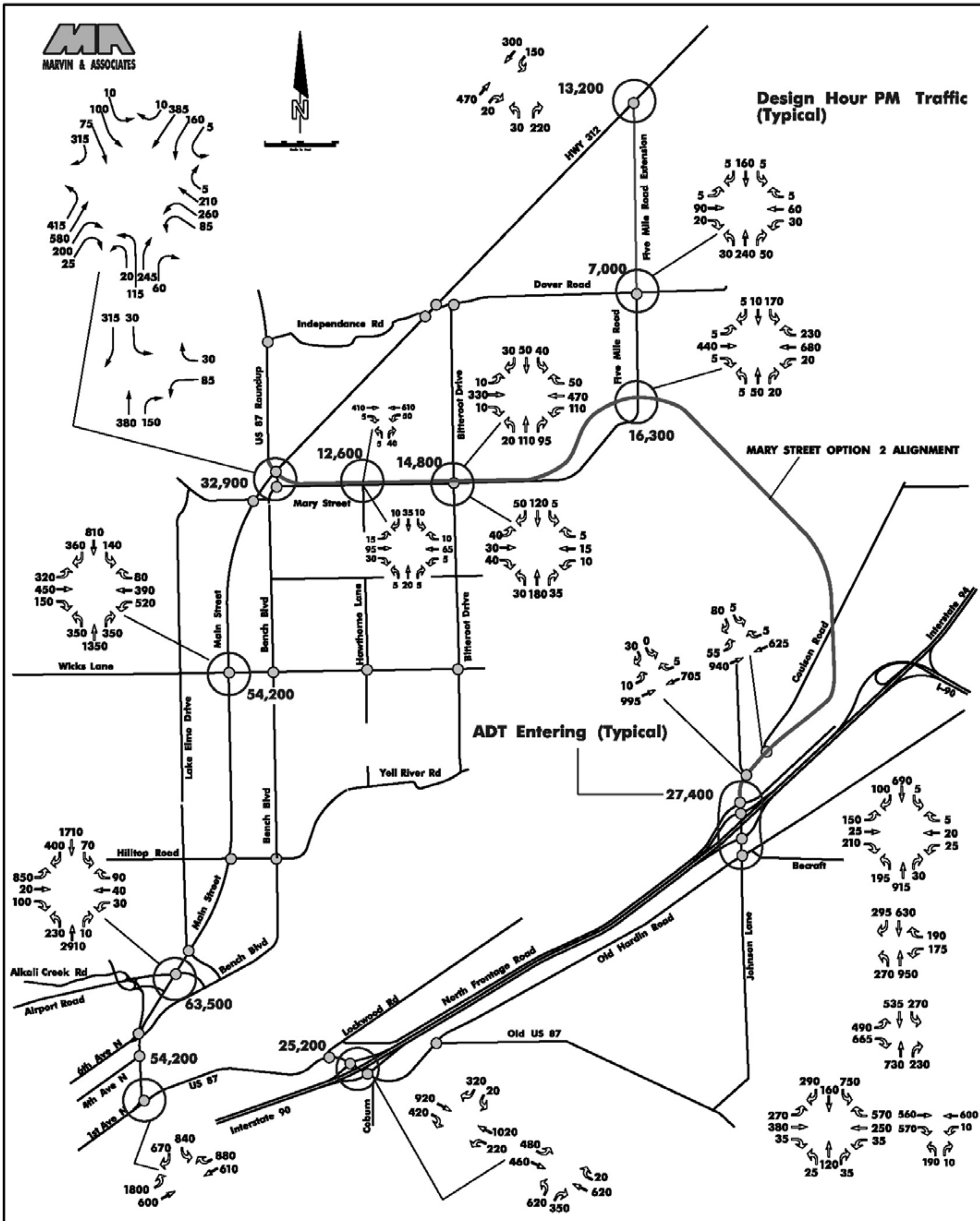


Figure 14. Mary Street Option 2 Alignment – Year 2035 PM Design Hour Traffic

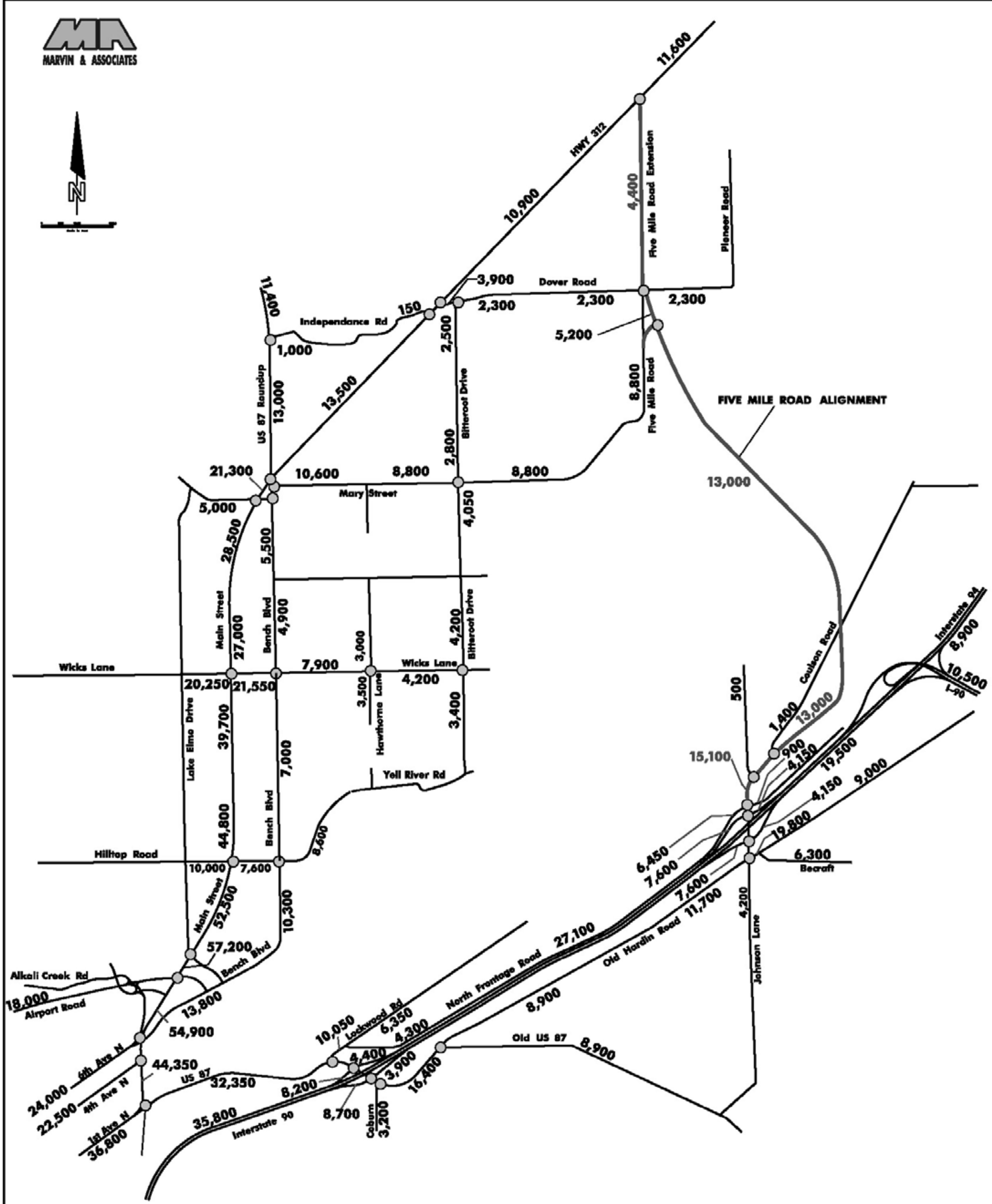


Figure 15. Five Mile Road Alignment – Year 2035 ADT Volumes

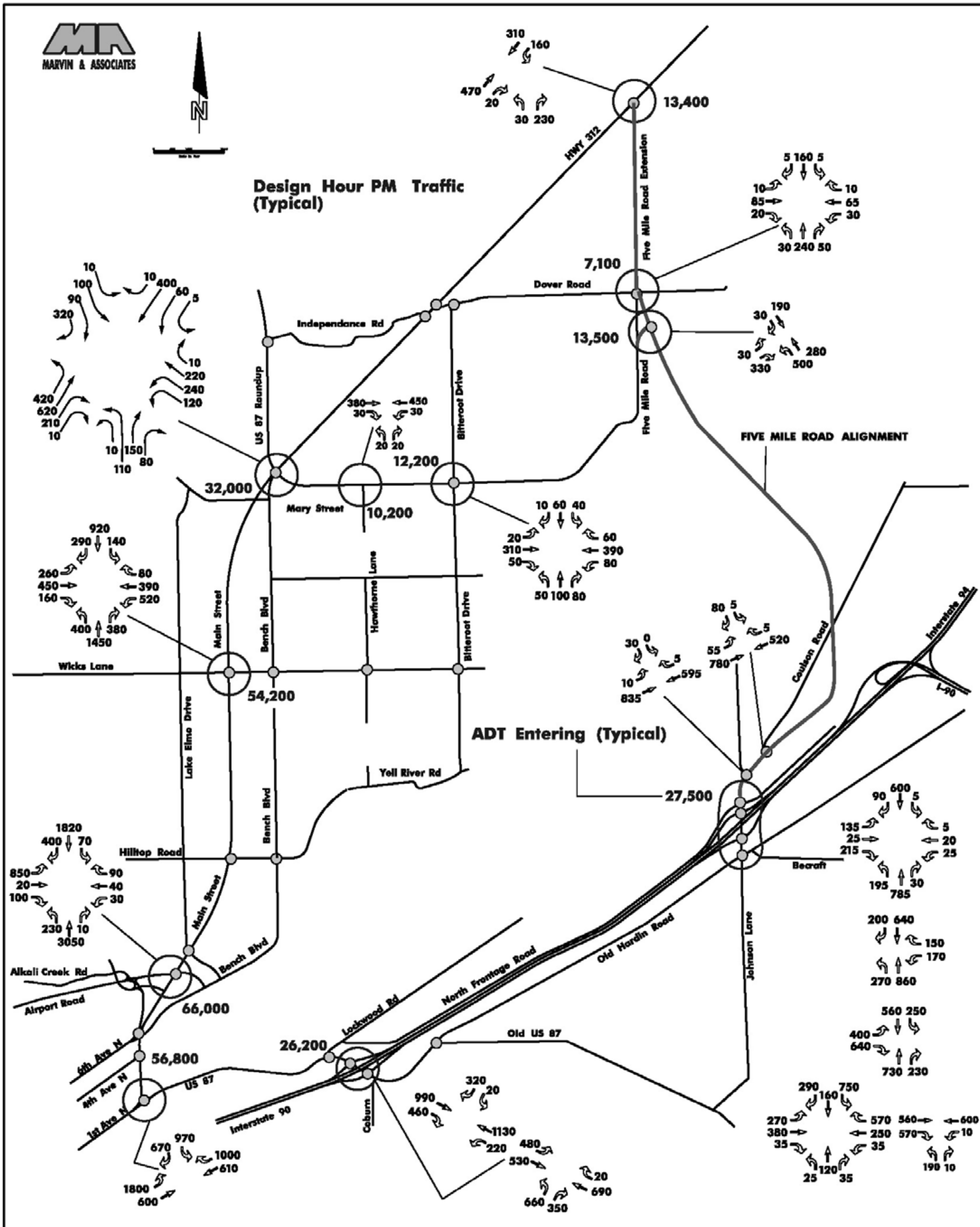


Figure 16. Five Mile Road Alignment – Year 2035 PM Design Hour Traffic

Year 2035 Alternative Alignments Vehicle Miles Travel

Table 7 presents a summary of vehicle miles travel (VMT) for each of the alternative alignments, including the No-Build alternative. VMT are based on ADTs projected for each alternative route segment. The No-Build alternative would experience approximately 667,000 VMT in the year 2035, while each of the Build alternative alignments would have higher VMT totals. The reason why the alternative alignments have a higher VMT is because the alternative alignments have shorter travel times and while there are more miles traveled, the overall vehicle hours of travel (VHT) are less.

It is important to note that the Mary Street Option 1 Alignment would have the highest ADT, but the total VMT for that alternative would be less than the Five Mile Road Alignment. The smallest increase in VMT would be for Mary Street Option 2 Alignment with approximately 3,500 VMT more than the No-Build alternative.

The most significant values shown in Table 7 are the VMT savings on Main Street, US 87, and on I-90. Comparing the No-Build Alternative on the Main Street corridor south of Wicks Lane with the Mary Option 1 Alignment, an approximate savings of 25,000 VMT on an average daily basis could be realized. The segment of US 87 between Main Street and the Lockwood Interchange would save 16,000 VMT. Both of these corridors would be highly congested, whereas the new alignment corridors would be relatively free-flow conditions.

It has been determined that the average travel time savings for all traffic that would use the alternative alignments ranges between 4 and 6 minutes. If an average travel time savings of 5 minutes was applied to year 2035 traffic projections for the alternative alignments, the approximate travel time savings for each of the alignments would be:

Mary Street Option 1 Alignment	480,000 VHT Savings
Mary Street Option 2 Alignment	475,000 VHT Savings
Five Mile Road Alignment	395,000 VHT Savings

The above noted VHT savings is significant when the economic value of time is considered. Current federal guidelines value the cost of time in excess of thirteen dollars per hour. Even if a reduced value of ten dollars per hour was used, the annual travel time savings associated with the alternatives would be between four and five million dollars.

Table 7. Alternative Alignment Vehicle Miles Travel Comparison

	Link		Existing	Length	Alternatives' Vehicle Miles Travel			
Route	From	To	ADT	Miles	No-Build	Mary 1	Mary 2	Five Mile
Highway 312	US 87	Dover Road	10900	1.32	21912	17886	17886	17820
	Dover Road	Five Mile Road	8700	1.47	17346	16097	15509	16023
	Five Mile Road	S-522 Huntley	6500	6.16	56056	64680	66528	66528
US 87 North	Highway 312	Independence Lane	5900	0.96	12480	12480	12480	12480
Main Street	1st Avenue N	4th/6th Avenues North	36100	0.32	17280	13232	13392	14192
	4th/6th Avenues North	Airport Road	49200	0.40	24960	20860	20960	21960
	Airport Road	Hilltop Road	42200	0.64	38400	31840	32000	33600
	Hilltop Road	Wicks Lane	35200	1.02	50184	40290	40494	43095
	Wicks Lane	US 87/312	19350	1.00	31300	28350	28650	27750
Bench Boulevard	US 87	Wicks Lane	2900	1.03	5871	5511	5047	5356
	Wicks Lane	Hilltop Road	4300	1.01	8585	6969	7070	7070
	Hilltop Road	Main Street	na	1.36	19380	16116	16388	16388
Bitterroot Drive	Dover Road	Mary Street	900	0.96	2400	2544	2544	2544
	Mary Street	Wicks Lane	1800	1.00	3200	4250	4100	4100
Mary Street	Bench Boulevard	Bitterroot Drive	1450	1.00	4000	3100	3100	9700
	Bitterroot Drive	5 Mile Road	500	1.15	1150	1150	1150	10120
5 Mile Road	Mary Street	Dover Road	100	0.65	325	3153	3348	5720
Dover Road	HWY 312	Bitterroot Drive	1600	0.08	304	312	312	312
	Bitterroot Drive	5 Mile Road	1000	1.00	2400	2300	2300	2300
Wicks Lane	Lake Elmo Road	Main Street	15500	0.24	4824	4860	4860	4860
	Main Street	Bench Boulevard	15300	0.24	5256	5184	5172	5172
	Bench Boulevard	Bitteroot Drive	4100	1.00	6400	6050	6050	6050
Hilltop Road	Lake Elmo Road	Main Street	8900	0.24	2400	2400	2400	2400
	Main Street	Bench Boulevard	6400	0.24	1824	1824	1824	1824
Johnson Lane	Old Hardin Road	Johnson Interchange	12500	0.17	3196	3196	3196	3196
	Johnson Interchange	Coulson Road	1400	0.29	609	5220	5133	4379
US 87	Lockwood Interchange	Old Hardin Road	10900	0.58	9512	9512	9512	9512
	1st Avenue N/Main	Lockwood Interchange	28000	1.25	52500	36688	37313	40438
I-94	Huntley Interchange	Pinehill Interchange	7100	6.21	65826	57132	55269	55269
I-90	S. 27th St. Interchange	Lockwood Interchange	24900	2.76	103224	98118	98532	98808
	Lockwood Interchange	Johnson Ln Interchange	21800	1.27	41529	34989	35497	34417
	Johnson Ln Interchange	Pinehill Interchange	14100	2.45	51940	48510	47775	47775
Mary Street Option 1	Highway 312	Bitterroot Drive	0	0.97	0	9118	0	0
	Bitterroot Drive	Five Mile Road	0	0.65	0	7508	0	0
	Five Mile Road	Johnson Lane	0	3.08	0	48972	0	0
Mary Street Option 2	Highway 312	Bitterroot Drive	0	0.97	0	0	8730	0
	Bitterroot Drive	Five Mile Road	0	1.18	0	0	12862	0
	Five Mile Road	Johnson Lane	0	2.75	0	0	42900	0
Five Mile Road Align.	Highway 312	Dover Road	0	0.93	0	0	0	4092
	Dover Road	Five Mile/Mary	100	0.45	225	0	0	2340
	Five Mile/Mary	Johnson Lane	0	2.82	0	0	0	36660
	ADT = Average Daily Traffic Along Entire Link		**Totals =**		**666798**	**670398**	**670281**	**674250**
			Differences between No-Build =			**3600**	**3483**	**7452**

Year 2035 Alternative Alignment Capacity & LOS

Capacity calculations along existing roads and streets that have the most probable impacts were completed for the alternative alignments based upon year 2035 traffic at critical intersections illustrated in Figures 11 through 16. Capacity analysis was not performed on the three sections of Interstate-90 and the associated interchange ramps, since all of the alternative alignments would result in traffic volumes that would be lower than the No-Build alternative. Because all capacity calculations on I-90 and interchange ramps for the year 2035 No-Build alternative indicated that the LOS would be at “C” or better, it can be assumed that the alternative alignments’ LOS would be measurably better than the No-

Build alternative. The capacity analysis calculations for each location can be found in the Appendix of this report.

Unlike the No-Build Alternative, there are only seven intersections on the existing system that would be impacted by the new alignments. The remaining intersections would be included as improvements integral to construction of the alternative alignments. Table 8 presents a LOS and delay (sec/vehicle) summary for each of the seven intersections associated with the Mary Street Option 1 Alignment alternatives. In comparing these intersections to the same intersections in Table 5 (No-Build alternative), it can be seen that the alternative alignment would provide significant improvements to the intersection of Main Street/1st Avenue N./US 87. That intersection would still operate at relatively acceptably LOS “C” – “D”, whereas the No-Build alternative would have both EB and WB approaches operating at LOS “F”. In a similar manner, the I-90 Lockwood Interchange EB and WB ramps would have substantial improvements over the No-Build Alternative LOS “F” operations.

Since there would be very minimal changes in total traffic volumes at the intersections along Dover Road, the No-Build capacity calculations would also apply to all of the new alternative alignments. It was assumed that the unacceptable LOS for the Dover Road approach to Old Highway 312, shown in Table 5, would require alternative traffic control features be built well in advance of the year 2035.

Table 8. Mary Street Option 1 Alignment - Existing Street System Capacity

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
Highway 312 & Dover*	F	194					B	13
Dover & Bitterroot*	B	12					A	8
Main & Wicks Lane	F	105	D	45	D	45	F	100
Main & Airport Road	F	81	C	34	F	93	F	177
Main/1st Ave N/US 87			C	26	C	29	D	48
Lockwood US87/WB I-90 Ramps			C	29	C	29	B	16
Lockwood US87/EB I-90 Ramps	D	54			D	43	E	64

* Minimal Difference from No-Build Alt.

= LOS D & E   = LOS F

Table 9 is the capacity summary for the Mary Street Option 2 Alignment. In comparing this table to Table 8, it can be seen that there is very little if any difference in LOS or delay measures. Only minor changes in delay would be evident at most of the intersections since the differences in traffic volume reductions on the Main Street corridor are very minor in comparison to total traffic demand.

Table 9. Mary Street Option 2 Alignment - Existing Street System Capacity

Intersection	NB LOS	NB Delay (s/v)	SB LOS	SB Delay (s/v)	EB LOS	EB Delay (s/v)	WB LOS	WB Delay (s/v)
Highway 312 & Dover*	F	194					B	13
Dover & Bitterroot*	B	12					A	8
Main & Wicks Lane	F	100	D	45	D	45	F	100
Main & Airport Road	F	84	C	35	F	93	F	178
Main/1st Ave N/US 87			C	27	C	29	D	49
Lockwood US87/WB I-90 Ramps			C	30	C	30	B	17
Lockwood US87/EB I-90 Ramps	D	50			D	46	E	68

* Minimal Difference from No-Build Alt.

(green) = LOS D & E (pink) = LOS F

Table 10 illustrates LOS and delay measures on the impacted system that is associated with the Five Mile Road Alignment alternative. It can be seen that there are some measurable differences between LOS and delay at a number of system intersections associated with this alternative and those indicated in Tables 8 and 9. The only substantial difference would be at the Main Street/1st Avenue N/US 87 intersection, where relatively acceptable levels of service would exist for the Mary Street alignments. The LOS would drop to "D" and "E" for traffic demand associated with the Five Mile Road Alignment alternative.

Table 10. Five Mile Road Alignment - Existing Street System Capacity

Intersection	NB LOS	NB Delay (s/v)	SB LOS	SB Delay (s/v)	EB LOS	EB Delay (s/v)	WB LOS	WB Delay (s/v)
Highway 312 & Dover*	F	194					B	13
Dover & Bitterroot*	B	12					A	8
Main & Wicks Lane	F	95	D	42	E	57	F	102
Main & Airport Road	F	111	C	33	F	93	F	178
Main/1st Ave N/US 87			D	35	D	37	E	57
Lockwood US87/WB I-90 Ramps			C	30	C	30	B	17
Lockwood US87/EB I-90 Ramps	F	80			D	44	E	64

* Minimal Difference from No-Build Alt.

(green) = LOS D & E (pink) = LOS F

Crash Projections

Table 11 represents a projection of future crash statistics that would be associated with each of the Build alternative alignments if current crash and severity rates were applicable in the design year 2035. Crash and severity rates on the new alignments were estimated based upon historic crash data on similar facilities that were constructed using current design standards, including Old HWY 312 from US 87 to Five Mile Road and Airport Road. In order to provide a sense of the associated impacts, the No-Build crash projections are included in Table 11. Crash projections for the alternative alignment systems indicated in Table 11 are also subject to the same limitations associated with the no-build alternative. Thus, relative differences in the number and type of crashes are more significant than the total numbers.

The No-Build alternative is projected to have an annual total of 551 crashes on the impacted system, while the Mary Option 1 Alignment alternative would experience approximately 503 crashed. A reduction of 48 crashes would be projected on the alternative system even though there would be an additional 4.5 miles of roadway. The number of injuries and injury crash would have a similar proportion while the number of fatalities would remain at about the same level. Mary Street Option 2 Alignment alternative would be at about the same level as the Option 1 alternative and the Five Mile Alignment alternative would have higher crash rates, yet still substantially lower than the No-Build alternative. All of the alternative alignments would have safety benefits over the No-Build alternative by reducing exposure (traffic) on the existing streets and diverting traffic to newer, safer facilities.

Table 11. Alternative Alignments Annual Crash Projections on Existing Road & Street System Year 2035

EXISTING STREET LINK SEGMENTS				No Build Projections					Mary Alignment Opt. 1					Mary Alignment Opt 2					Five Mile Road Alignment				
ROUTE NAME	from	to	Length (miles)	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals
Interstate 94	Pinehill Interchange	Huntley Interchange	6.21	10600	23.6	5.4	6.9	0.0	9200	20.5	4.7	6.0	0.0	8900	19.8	4.5	5.8	0.0	8900	19.8	4.5	5.8	0.0
Interstate 90	Johnson Lane	Lockwood	1.27	32700	22.2	6.0	9.6	0.0	27550	18.7	5.1	8.1	0.0	27950	19.0	5.1	8.2	0.0	27100	18.4	5.0	8.0	0.0
Interstate 90	Pinehill Interchange	Johnson Lane	2.45	21200	2.1	0.3	0.3	0.0	19800	2.0	0.3	0.3	0.0	19500	1.9	0.3	0.3	0.0	19600	1.9	0.3	0.3	0.0
Johnson Lane	I-90 Interchange	Coulson Road	0.29	6900	6.0	0.9	1.5	0.0	18000	15.7	2.3	3.9	0.0	17700	15.4	2.3	3.8	0.0	15100	13.1	2.0	3.3	0.0
Johnson Lane	Old Hardin Road	I-90 Interchange	0.17	18000	3.0	0.6	1.5	0.0	18800	3.1	0.6	1.6	0.0	18800	3.1	0.6	1.6	0.0	18800	3.1	0.6	1.6	0.0
(Old US 87)	Lockwood Interchang	Jct Old Hardin Road	0.58	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0
Highway 87	I-90 Lockwood Inter	1st Avenue N	1.25	42000	53.8	15.3	22.3	0.0	29350	37.6	10.7	15.6	0.0	29850	38.2	10.9	15.8	0.0	32350	41.4	11.8	17.2	0.0
Main Street	1st Avenue N	6th Avenue N	0.35	54000	40.1	12.4	17.9	0.0	41350	30.7	9.5	13.7	0.0	41850	31.1	9.6	13.8	0.0	44350	33.0	10.2	14.7	0.0
Main Street	6th Avenue N	Airport Road	0.37	62400	27.5	8.7	14.4	0.0	52150	23.0	7.3	12.0	0.0	52400	23.1	7.3	12.1	0.0	54900	24.2	7.7	12.7	0.0
Main Street	Airport Road	Hilltop Road	0.64	62400	83.0	28.5	46.1	0.0	49750	66.1	22.7	36.7	0.0	50000	66.5	22.8	36.9	0.0	52500	69.8	24.0	38.8	0.0
Main Street	Hilltop Road	Wicks Lane	1.02	49100	81.4	30.9	47.7	0.6	39500	65.5	24.8	38.4	0.5	39700	65.8	25.0	38.6	0.5	42250	70.0	26.6	41.0	0.5
Main Street	Wicks Lane	HWY 312/Bench	1.00	30700	46.4	9.9	0.0	0.0	28350	42.9	9.1	0.0	0.0	28650	43.3	9.2	0.0	0.0	27750	42.0	8.9	0.0	0.0
Highway 87	HWY 312/Bench	Independence Road	0.96	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0
Wicks Lane	Lake Elmo	Main Street	0.24	21000	5.3	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0
Wicks Lane	Main Street	Bench Boulevard	0.24	21900	13.1	4.7	5.5	0.0	21600	13.0	4.6	5.5	0.0	21550	12.9	4.6	5.5	0.0	21550	12.9	4.6	5.5	0.0
Wicks Lane	Bench Boulevard	Bitterroot Drive	1.00	6400	15.1	2.7	4.1	0.0	6050	14.3	2.6	3.9	0.0	6050	14.3	2.6	3.9	0.0	6050	14.3	2.6	3.9	0.0
Mary Street	Bench Boulevard	Five Mile Road	1.67	4500	5.4	0.0	0.0	0.0	2050	2.5	0.0	0.0	0.0	2050	2.5	0.0	0.0	0.0	9250	11.1	0.0	0.0	0.0
Highway 312	US 87 (N16)	Dover Road	1.32	16600	6.2	0.9	0.9	0.3	13550	5.1	0.8	0.8	0.3	13550	5.1	0.8	0.8	0.3	13500	5.0	0.8	0.8	0.3
Highway 312	Dover Road	Pioneer Road	2.20	13600	19.5	8.0	11.9	0.4	10950	15.7	6.5	9.6	0.3	10550	15.2	6.2	9.2	0.3	10900	15.7	6.4	9.5	0.3
Highway 312	Pioneer Road	S-522 Huntley	5.43	9000	28.8	11.4	18.9	0.3	10500	33.6	13.3	22.1	0.4	10800	34.6	13.7	22.7	0.4	10800	34.6	13.7	22.7	0.4
Bench Bld	Wicks Lane U-1012	US 87 (N16)	1.03	5800	24.0	8.4	10.8	0.0	5350	22.1	7.7	10.0	0.0	4900	20.3	7.1	9.1	0.0	5200	21.5	7.5	9.7	0.0
Dover Road	HWY 312 CO56788	Pioneer Road	1.56	2300	2.3	0.4	0.4	0.0	3100	3.1	0.5	0.5	0.0	3100	3.1	0.5	0.5	0.0	3100	3.1	0.5	0.5	0.0
Bitterroot Drive	Wicks (U-1012)	Mary Street	1.00	4000	10.5	1.8	3.1	0.0	4250	11.1	2.0	3.3	0.0	4100	10.7	1.9	3.2	0.0	4100	10.7	1.9	3.2	0.0
Bitterroot Drive	Mary Street	Dover Road	0.96	2500	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0
5 Mile Road	Mary Street	Dover Road	0.65	500	0.7	0.7	0.7	0.0	4850	3.2	3.2	3.2	0.0	5150	3.4	3.4	3.4	0.0	0	0.0	0.0	0.0	0.0
Pioneer Road	Dover Road	HWY 312 CO56788	1.50	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0
Huntley Main St	I-94 Huntley Inter	CO56788 (HWY 312	2.37	5500	8.6	4.2	4.8	0.0	4800	7.5	3.6	4.2	0.0	4200	6.6	3.2	3.6	0.0	4200	6.6	3.2	3.6	0.0
Mary St Opt 1	Highway 312	Bitterroot Drive	0.97						9400	2.6	0.4	0.5	0.1										
	Bitterroot Drive	Five Mile Road	0.65						11550	2.1	0.3	0.4	0.0										
	Five Mile Road	Johnson Lane	3.08						15900	13.9	2.1	2.8	0.3										
Mary St Opt 2	Highway 312	Bitterroot Drive	0.97											9000	2.5	0.4	0.5	0.0					
	Bitterroot Drive	Five Mile Road	1.18											10900	3.6	0.5	0.7	0.1					
	Five Mile Road	Johnson Lane	2.75											15600	12.1	1.8	2.4	0.2					
5 Mile Rd Align	Highway 312	Dover Road	0.93																4400	1.2	0.2	0.2	0.0
	Dover Road	Five Mile/Mary	0.45																5200	0.7	0.1	0.1	0.0
	Five Mile/Mary	Johnson Lane	2.82																13000	10.4	1.6	2.1	0.2
Totals =			51.53	19756	551.3	170.3	241.8	1.6	17013	503.3	152.9	215.4	1.7	17556	501.9	152.6	215.0	1.7	17961	512.3	152.7	217.5	1.6
				Avg					Avg					Avg					Avg				

ALTERNATIVE ALIGNMENT INTERSECTIONS

This section of the report deals with intersections located along each of the three alternative alignments. The intersection design concepts presented herein were evaluated by the project team and it was determined that the intersection geometry and operational characteristics would be appropriate for the anticipated traffic demand. While various design options may be considered in final design, the basic geometry and controls proposed herein will be carried through into the final EIS. All capacity calculations for the intersections presented in this section of the report can be found in Appendix G.

Johnson Lane/Coulson Road Intersections

All of the alternative alignments would intersect Coulson Road and Johnson Lane at the same location. Figure 17 Illustrates the proposed geometry associated with the intersection of Coulson Road and Johnson Lane with the alternatives' alignment. The Johnson Lane intersection with the new alignment would be a "T"-intersection on the outside of a curve. Sufficient intersection sight distance would be available for the Johnson Lane approach to the new alignment. Sufficient storage would be available for the Johnson Lane approach and an existing railroad crossing north of the new intersection.

Coulson Road would curve into the intersection with the new arterial road alignment at a location opposite an existing commercial access road on the south side of Coulson Road. The Coulson Road approach would have a left-turn lane and a right/thru lane at the intersection. The existing section of Coulson Road would be obliterated between that intersection and the current intersection with Johnson Lane.

Capacity calculations (Appendix G) indicate that all approaches at these intersections would operate at LOS "B" or better in the year 2035. Adequate intersection sight distance and left-turn bays for movements on the new arterial would provide the safety potential of these intersections to meet current design standards.

Figure 17. Johnson Lane /Coulson Road – Proposed Arterial Intersections

Mary Street Alignment Intersections

There are three intersections on the Mary Street Alignments that are detailed within this section of the report. Mary Street Options 1 & 2 Alignments intersect with Five Mile Road at two different locations, but both Mary Street Alignments intersect Hawthorne Lane at the same location, and thus, both alignments are covered by the same concept design.

Option 1 & Five Mile Road

Figure 18 illustrates the proposed design geometry and operational controls for the intersection of Mary Street Option 1 Alignment and the existing Mary Street/Five Mile Road corridor. A signalized intersection alternative was investigated at this location, however it was determined that a roundabout intersection would be more adaptable to the numerous driveway and roadway approaches that exist within the operational area of influence of this intersection.

The year 2035 typical section of the Mary Street Option 1 Alignment would have two through lanes in each direction and the roundabout would perpetuate the thru-lanes through the intersection. The Mary Street (Frontage Road) approach would serve a minor volume of traffic only requiring a single lane approach. The Five Mile Road approach would have a higher volume of traffic, but a single lane approach would be sufficient for operations at this intersection. The two-lane facility to the north would be associated with secondary improvements to Five Mile Road, for which the typical sections indicate that a median section would apply. A simple two-lane approach is illustrated in Figure 18 to indicate that the existing bridge over Five Mile Creek could be utilized in the future.

Capacity calculations (Appendix G) indicated that all approaches to this intersection would operate at a LOS “A” in the year 2035. The immediately adjacent approaches and intersections would be limited to right-in and right-out movements. However, the roundabout intersection would allow departures and arrivals from and to all approaches from all directions.

Option 2 & Five Mile Road

Figure 19 presents the intersection geometry and associated traffic control related to the Mary Street Option 2 Alignment intersection with Five Mile Road. This intersection would be located north of the existing Mary Street corridor and in the middle of a long sweeping curve along the Mary Street Option 2 Alignment. A traffic signal was evaluated at this location, and it was determined that even though sight distance would be adequate, the approach angles from the Mary Street northbound approach could create a situation where the drivers’ judgment may be compromised. Even though this would not be an overwhelming consideration, there are no structures within the intersection area that would make it difficult to construct a roundabout, and the roundabout would have the benefit of slowing approach speeds enough to counter issues related to the curved approach on the Mary Street Option 2 Alignment.

Figure 18. Mary Street Option 1 Alignment – Five Mile Road Intersection

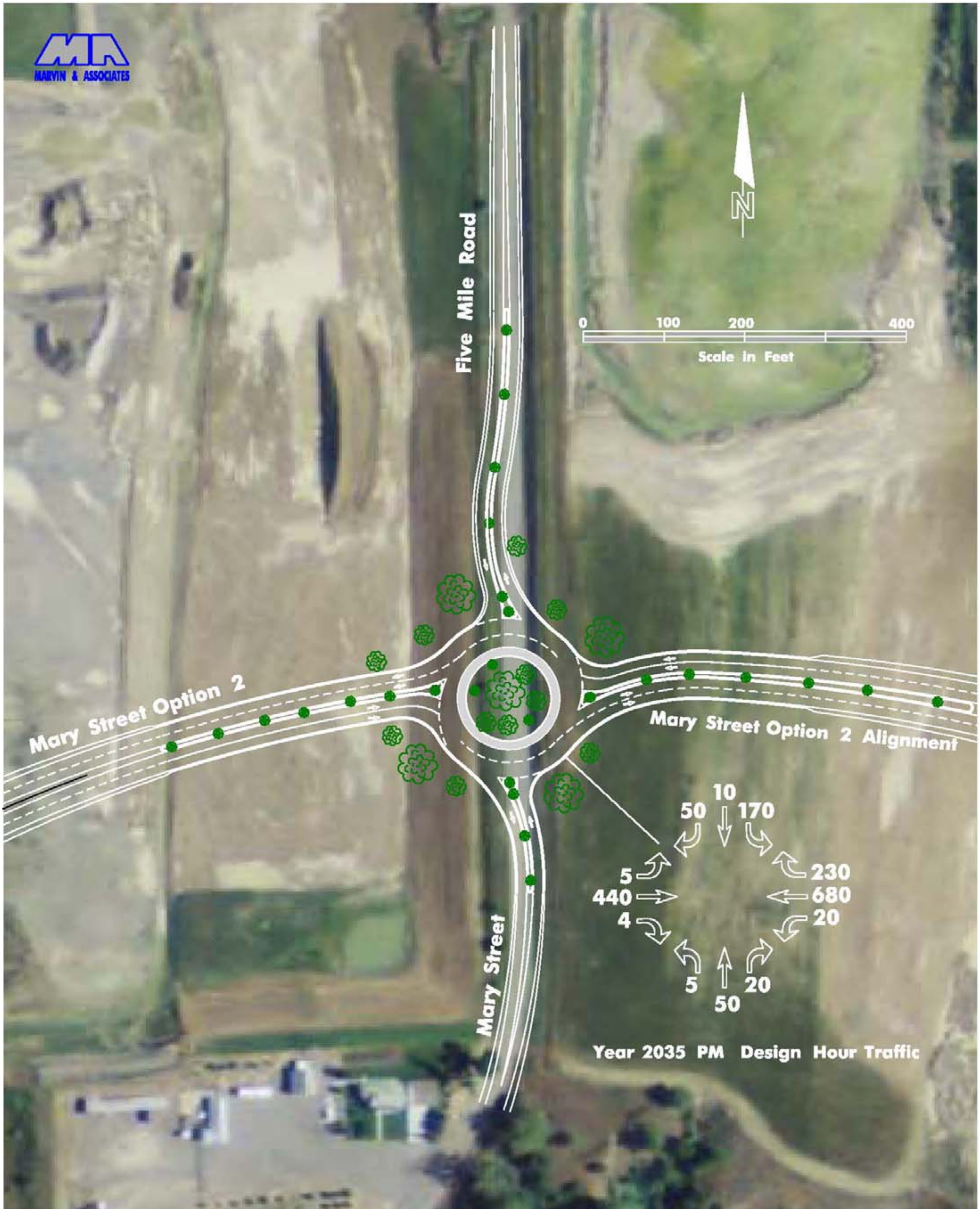


Figure 19. Mary Street Option 2 Alignment – Five Mile Road Intersection

Approach lane configurations would be similar to the assignments associated with Mary Street Option 1 Alignment design. Lane capacity calculations (Appendix G) indicate that all approaches would operate at LOS “A” in the design year 2035.

Options 1 & 2 & Hawthorne Lane

Both Mary Street Options 1 & 2 Alignments would be coincident at the Hawthorne Lane intersection. Thus, Figure 20 applies to both alternative alignments. Hawthorne Lane is currently a low volume, collector street approach at Mary Street. Hawthorne Lane is the only other north-south street, other than minor subdivision streets, that intersects the existing Mary Street corridor. A gated approach to an old gravel pit operation also intersects Mary Street from the north at this location. Figure 20 shows that a minor connection street between Mary Street and the Mary Street Alignment is proposed at this intersection. A raised median within the short connector street is proposed to ensure that vehicle approach angles are sharp enough to discourage higher speed short-cuts across opposing lanes.

Capacity Calculations (Appendix G) indicate that stop controls on the north-south approaches to both streets would be sufficient to ensure that all movements operate at LOS “B” or better in the year 2035.

Five Mile Road Alignment Intersections

There are four intersections related to the Five Mile Road Alignment. Only one of those intersections is related to the Five Mile Road Alignment geometry and the remaining three intersections involve secondary improvements on the existing Mary Street corridor necessary to accommodate the projected year 2035 traffic demands.

Five Mile Road and Mary Street

Figure 21 shows the proposed design geometry and operational controls for the intersection of Five Mile Road Alignment and existing Mary Street. A signalized intersection alternative was investigated, and it was determined that a roundabout intersection would be more appropriate at this location.

The year 2035 Five Mile Road Alignment typical section would have two thru-lanes in each direction and the thru-lanes would be perpetuated through the roundabout intersection. The Mary Street approach would only require a single lane approach. However, a short right-turn lane was added to that approach to provide sufficient capacity would be available well beyond the 2035 design year.

Capacity calculations (Appendix G) indicate that all approaches to this intersection would operate at a LOS “B” or better in the year 2035.

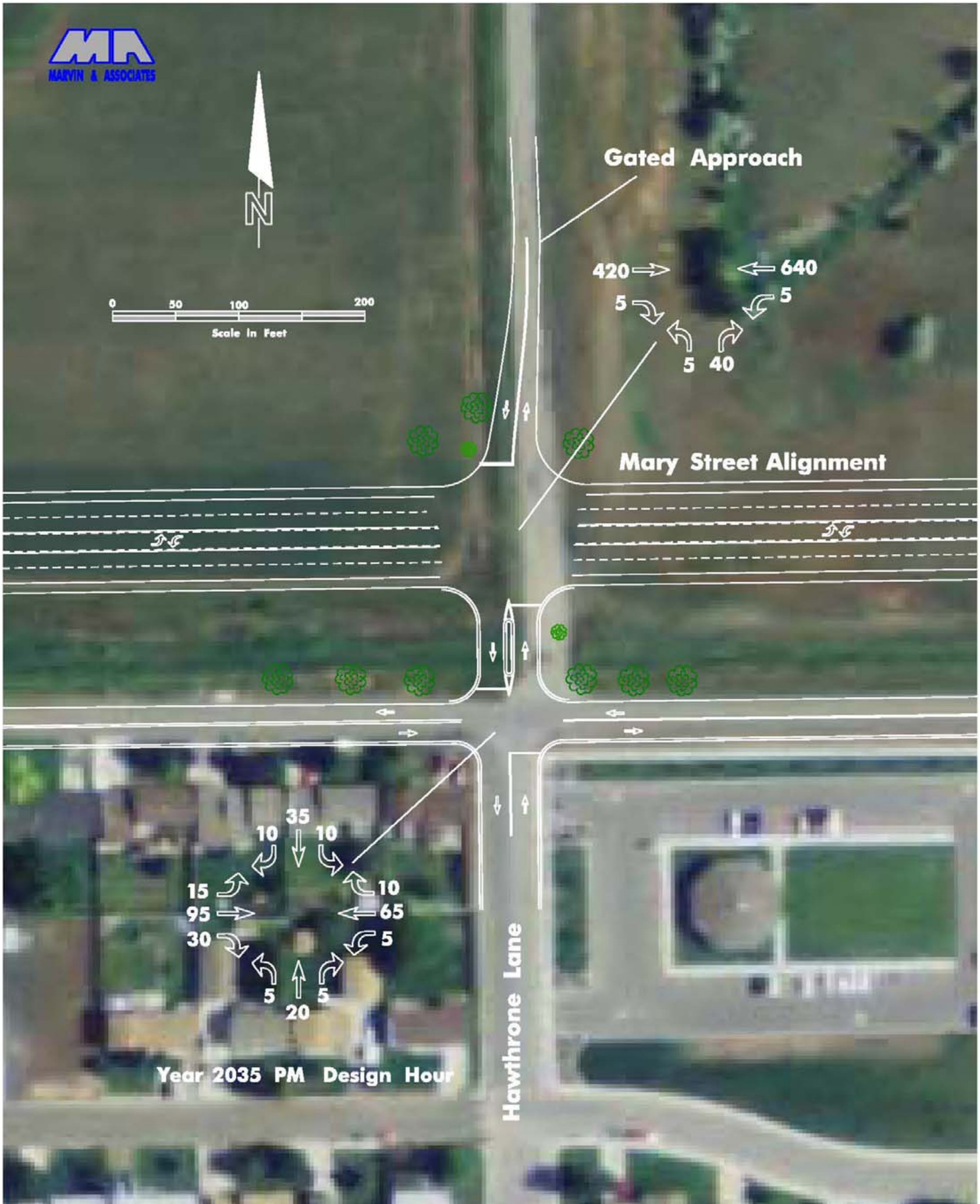


Figure 20. Mary Street Option 1 & 2 Alignments – Hawthorne Lane Intersection

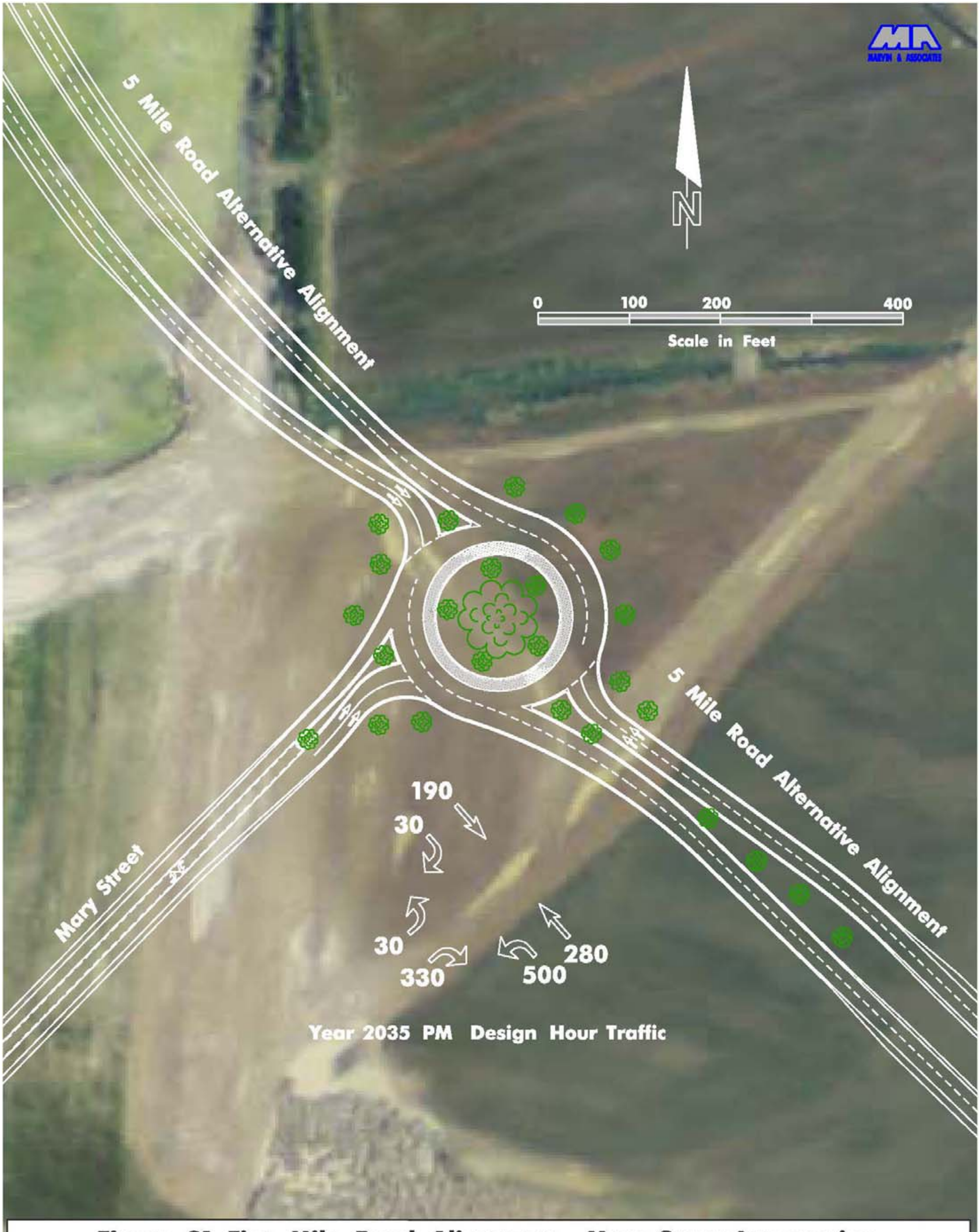


Figure 21. Five Mile Road Alignment – Mary Street Intersection

Mary Street & Bitterroot Drive Secondary Improvements

The typical section for Mary Street, as a secondary improvement associated with the Five Mile Road Alignment alternative, incorporates one vehicle and bike lane in each direction of travel plus a two-way left-turn lane (TWLTL) in the center. It was determined that a stop sign on Bitterroot Road would operate at LOS “F” and that a traffic signal would probably be justified. Figure 22 illustrates the traffic signal design concept that incorporates the secondary improvements’ typical section on Mary Street, and a single lane for each Bitterroot Drive approach.

Capacity calculations (Appendix G) indicate that all approaches would operate at LOS “B” or better in the design year 2035.

Mary Street & Hawthorne Lane Secondary Improvements

Secondary Five Mile Road Alignment alternative improvements for the Mary Street and Hawthorne Lane intersection would involve a northbound stop sign on Hawthorne Lane. Capacity calculations (Appendix G) indicate that the northbound approach to the improved Mary Street section would operate at LOS “B” in the design year 2035. Traffic pavement markings on Mary Street would include left-turn lanes at the intersection.

US87/HWY 312 Secondary Improvements

Figure 23 illustrates the design concept proposed for the intersection of Mary Street with US 87/Old Hwy 312/Bench Boulevard as a secondary improvement to the Five Mile Road Alignment alternative. The proposed concept includes a large diameter (220 feet), five legged roundabout. The Main Street – Hwy 312 corridor would be the major traffic movement, and two traffic lanes would be perpetuated in each direction through the roundabout. Two right-turn slip ramps for northbound Bench Boulevard and southbound US 87 would be used to enhance operations within the roundabout.

A short section of Mary Street, serving approximately five residences, would be accessed by a stop controlled intersection east of the roundabout. Bikes lanes along Mary Street would converge at that intersection and proceed west to connect with new bike lanes along Bench Boulevard.

A new traffic signal currently in design as a part of the Bench Boulevard reconstruction project was evaluated with the Five Mile Road Alignment and it was determined that the signal would not be able to accommodate the addition traffic demands. In addition, the acute angle of the intersection (37 degrees) and number of approaches at this intersection made it impractical to use traffic signals at this location. Capacity calculations (Appendix G) indicated that the roundabout would operate at a LOS “C” or better on all legs.

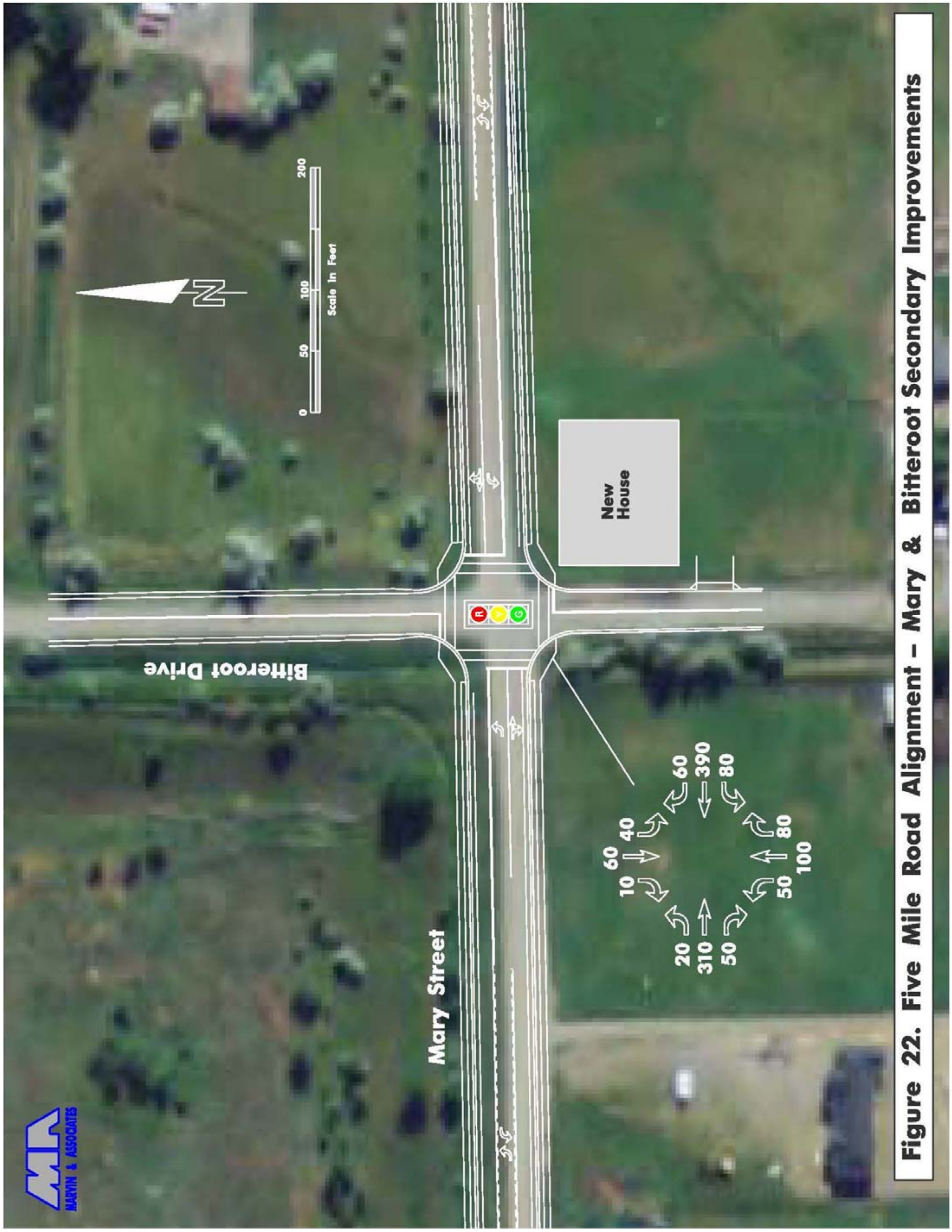


Figure 22. Five Mile Road Alignment – Mary & Bitteroot Secondary Improvements

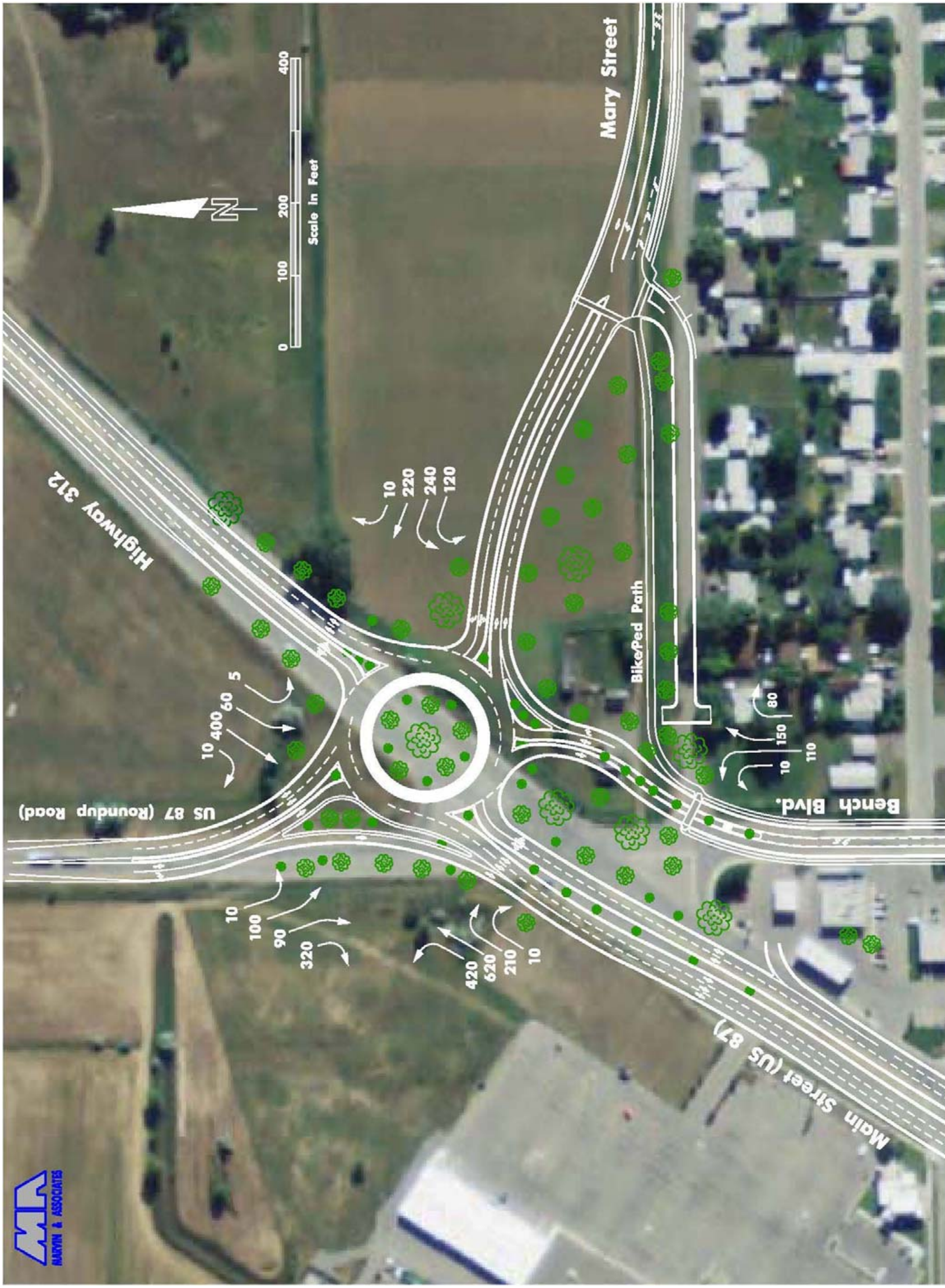


Figure 23. Five Mile Road Alignment US87–312–Main–Bench–Mary Secondary Intersection Improvements

Five Mile Road and Dover Road

Operations at the intersection of Five Mile Road and Dover Road for all alternative alignments were investigated and capacity calculations (Appendix G) indicated that stop control on the Dover Road approaches would result in LOS “C” in all cases. As traffic on Dover Road increases beyond design year 2035 projections, alternative traffic control may be necessary.

ALTERNATIVE INTERCHANGE/INTERSECTION DESIGN OPTIONS

Johnson Lane Interchange

The existing Johnson Lane Interchange is a conventional diamond type interchange that was constructed to serve residential areas in the community of Lockwood. Johnson Lane is a north-south arterial roadway that connects Old US 87 1.6 miles south of I-90 and Coulson Road, south of the railroad tracks. Interstate-90 crosses above Johnson lane at a skew angle of approximately 53 degrees. Johnson Lane intersects the North I-90 Frontage Road, north of I-90, and Old Hardin Road, south of I-90. The separation distance between these two intersections is approximately 1,450 feet. Located between I-90 and the adjacent roadway intersections are the eastbound (EB) and westbound (WB) I-90 interchange ramps. The ramp separation distance is approximately 750 feet and the WB Ramps are located only 250 feet away from the North Frontage intersection. The EB Ramps are located 450 feet north of Old Hardin Road.

Intensive development exists around both the Old Hardin Road/Johnson Lane intersection and the North Frontage Road/Johnson Lane intersection. Two large trucks plazas exist on the west side of Johnson Lane north and south of the interchange. The east side of Johnson Lane, at the North Frontage Road intersection, has relatively sparse development. However, there are numerous commercial developments that exist on the east side of Johnson Lane at the Old Hardin Road intersection. Since the degree of development on either side of the interchange makes it impractical to expand the existing interchange footprint to any substantial degree, interchange design options at this location must necessarily embrace relatively recent and non-conventional intersection design configurations. Because many of these options are not commonly used in Montana, it was decided that all five design options developed during the EIS screening process would be carried forward. It is anticipated that some of the alternatives will be screened-out prior to final design and the remaining design options will allow enough flexibility to allow for unforeseen situations that may be encountered during final design.

Design concept drawings for all of the Johnson Lane Interchange design options can be found in Appendix H of this report. Capacity calculations for individual intersections associated with each of the design options can also be found in Appendix H of this report. All capacity calculations were based upon the Mary Option 1 Alignment year 2035 volumes, as the worst case scenario. Note that all design options have the same turning movements at the North Frontage Road, Old Hardin Road, and Becraft intersections, where capacity calculations for either the roundabouts or the signals at those intersections apply to all of the design options.

It should also be noted that that there are a number of roundabout intersection concepts where one of more of the approach legs has a v/c ratio of 0.81 or greater. Normally this would indicate that operations on that approach leg are unstable and large queues could result when sort duration traffic peaks occurred. In this case, the most recent software was used for capacity calculations, and the newer software analysis makes this less of an issue. In addition, the higher v/c ratios analyzed within this study were on approach legs with minor traffic volumes. Reassessment of these approaches should be made during design to insure that short-term queue formations would not impede overall operations.

Design Option Descriptions

Option 1 – Modified Diamond with Roundabouts

This option would modify the existing standard diamond interchange by reconstructing the signalized intersections at North Frontage Road, north access ramps, south access ramps, and Old Hardin Road with roundabouts. I-90 would be realigned slightly to the south, enabling equal spacing of the roundabout intersections, and Johnson Lane would pass underneath the interstate via new I-90 structures. A schematic of this interchange design is shown in Appendix H, Figure H1.

This option would also require modifications to the Becraft Lane/Old Hardin Road intersection immediately east of the Johnson lane/Old Hardin Road intersection. The Becraft/Old Hardin Road intersection currently operates at unacceptable levels of service and a future traffic signal constructed so close to the Old Hardin Road/Johnson Lane roundabout would negatively impact operations along Johnson Lane. Thus, the Becraft Lane intersection would be reconstructed, at its current location, to include a second roundabout as a part of Option 1. Modifications to adjacent business approaches would be required to enable safe and efficient operations at the two new roundabouts on Old Hardin Road. Some accesses would have limited movements.

The alternative alignments' typical section incorporates two through lanes in each direction and that section would be carried through the interchange roundabouts on the Johnson Lane corridor. Slip ramps at the Old Hardin Road/Johnson Lane roundabout and at the WB ramps roundabout would be provided to remove high traffic volumes from circulating flows. Other lane configurations were determined by demand, capacity constraints, and weaving requirements at the intersections. All of the intersections associated with this design option would operate at LOS "B" or better. The worst movements would be the WB Off-ramp left-turn movement and the NB Johnson Lane through movement at Old Hardin Road. Both of these movements would operate at LOS "C".

Option 2 – Single-Point Urban Interchange

This option would implement a single-point urban interchange (SPUI) to replace the standard diamond interchange. The signalized intersections at North Frontage Road and Old Hardin Road would be reconstructed. This option could be modified to use either signalized intersections or roundabouts at these locations. The north and south access ramps would be controlled by one signalized intersection located below new I-90 structures. A schematic of this interchange design is shown in Appendix H, Figure H2.

The Old Hardin Road/Johnson Lane intersection would require four approach lanes on the SB and WB intersection approaches. Operational controls at the signal would create vehicle queues during the peak design hours that would limit access to existing driveway within its operational area of influence. Driveway closures and relocations would be necessary for the traffic signal to operate safely and efficiently. The intersection of Becraft and Old Hardin Road would need to be modified to allow only right-turn-in and right-turn-out movements, and a new connector road would need to be constructed east of Becraft Lane's current location, between two existing commercial properties. This would allow eastbound traffic on Becraft Lane to access Old Hardin Road/Johnson Lane. The new connector road would require modifications to existing driveways accessing the two adjacent commercial properties. The eastern most commercial property could benefit from the new connector street since it is a retail building that would gain a substantial volume of passerby traffic adjacent to its site.

Access to the truck plaza on the west side of the Old Hardin Road/Johnson Lane intersection would also need to be modified to avoid conflicts within the intersection's operational area-of-influence. Some on-site circulation modifications may be required to accommodate the access changes shown in Figure H-2.

All of the intersections associated with this design option would operate at LOS "B" or better except for the Old Hardin Road intersection, which would operate at LOS "C". A 80 second cycle length was used in the capacity calculations which assumed minimal pedestrian activity. Additional pedestrian clearance time may actually be required for future operations and the cycle length could increase to 90 seconds. Thus, the operation of some movements at this intersection could be less than those calculated herein. The worst movements would be the EB Off-ramp approach and the SB Johnson Lane approach at Old Hardin Road. Both of these movements would operate at LOS "C".

The eastbound off-ramp free-right-turn movement weaving section between its intersection with Johnson Lane and the Old Hardin Road intersection has an overall weave distance of 500 feet. The capacity calculation for the weave movements (appendix) indicate that a LOS "B" could be achieved. However, there is a potential for trapping eastbound right-turn vehicles in the wrong lane or for timid drivers to block the free-right movement by stopping in the traffic lane before weaving.

Option 3 – Single-Point Urban Interchange with Roundabouts

Similar to Option 2, Option 3 would implement a single-point urban interchange to replace the standard diamond interchange. However, the signalized intersections at the North Frontage Road and Old Hardin Road intersections would be roundabouts instead of traffic signals, and the eastbound and westbound I-90 ramps would be controlled by one large diameter (300 foot) roundabout located below new double-span I-90 structures. A schematic of this interchange design is shown in Appendix H, Figure H3.

The roundabouts at the North Frontage Road and Old Hardin Road intersections would be identical in appearance and operations to the Option 1 design concept. The large diameter roundabout located beneath the new I-90 structures would accommodate entering traffic at four locations and departing traffic at four locations, similar to typical four-legged roundabouts. However, a wide separation between entering and departing traffic would exist for the minor street legs (EB and WB Ramps). Slip ramps would be used in each quadrant of the SPUI roundabout to avoid high circulation flows, except for the WB Off-ramp right-turn movements. A slip ramp would not be workable at that location since the majority of approach traffic on the ramp would turn left at the North frontage Road intersection and there is insufficient separation between intersections to accommodate the weaving movement. Circulation speeds within the SPUI roundabout would be higher than with a conventional multi-lane roundabout. Thus, crash severity potential could be relatively higher. There are only a few modern roundabouts of this nature that currently exist and thus, it is not known with any certainty whether there are operational problems that could accompany this concept.

The North Frontage Road and Old Hardin Road intersections that are also associated with Option 1 would operate at LOS “B” or better. The SPUI roundabout would operate at LOS “C” and the worst movement would be the EB Ramp left-turn movement, which would also operate at LOS “C” with a maximum vehicular storage distance of 225 feet.

Option 4 – Double Crossover Diamond with Traffic Signals

This option would implement a diverging diamond interchange to replace the standard diamond interchange. The signalized intersections at North Frontage Road and Old Hardin Road would be reconstructed. The north and south access ramps would be controlled by cross-over signalized intersections. I-90 would be realigned slightly to the south in order to provide equal spacing of the four Johnson Lane corridor intersections. Johnson Lane would pass below the new I-90 structures. A schematic of this interchange design is shown in Appendix H, Figure H4.

The Double Crossover Diamond interchange is a relatively new concept in the United States, although it has been used extensively in Europe for a number of years. The basic operational concept of the interchange involves two signalized intersections that allow traffic on the crossroad to cross each other’s paths to allow traffic entering the freeway free right or left turns onto the freeway on-ramps. Traffic on the off-ramps would be controlled by two phased traffic signals. This would result in four approaches at each intersection and a total of six conflict movements, or approximately one fourth the number of conflicts associated with a normal four-legged approach. From the schematic layout, it would appear that vehicles on Johnson Lane would be driving on the wrong side of the road between the intersections, but they can actually be considered one-way streets with only a small separation between them. The median section between intersections would have barriers and would provide a refuge for pedestrian traffic. The ramp intersections would operate with simple two phase signals that can be demand responsive and coordinated. Phasing diagrams for these signals are illustrated in Figure H4. Since Design Option 4 would utilize four interconnected signals, the cycle lengths for the ramp signals would necessarily need to be on the same cycle as the adjacent intersections, which may reduce the level of efficiency that the ramp signals would be able to achieve independently.

The access conditions and other operational characteristics of the North Frontage Road and Old Hardin Road intersections would be the same as was detailed for Option 2. Capacity calculations for Option 4 indicate that the two ramp intersections would operate at LOS "B". The worst movement would be associated with the Old Hardin Road intersection signal, similar to Option 2.

Option 5 – Double Crossover Diamond with Roundabouts

This option would be similar to Option 4 except that the signalized intersections at North Frontage Road and Old Hardin Road would be reconstructed with roundabouts. A schematic of this interchange design is shown in Appendix H, Figure H5.

The roundabout intersection at Old Hardin Road and North Frontage would be identical to those detailed in Options 1 and 3, above. With the adjacent roundabouts on either side of the ramp signals, the two ramp intersections could be fully coordinated and cycle lengths adjusted to coincide with traffic demand during different times of the day. Capacity calculations indicate that the maximum vehicle queues at the signals and roundabouts would not impede operations at any of the intersections. All of the intersections associated with this design option would operate at LOS "B" or better. The worst movement would be the NB Johnson Lane through movement at Old Hardin Road, which would operate at LOS "C".

Capacity Comparisons

Table 12 presents the LOS, volume to capacity (v/c) ratios, and hours of delay for each of the five design options. For more detailed information on individual movements, Appendix H provides individual intersection capacity analysis summaries.

Table 12. Johnson Lane Interchange Design Options Capacity Summary

Option 1 Modified Diamond with Roundabouts	PM Hour LOS	PM Hour V/C	PM Hour Hrs Delay	Max Queue	Comments
North Frontage Road	A	0.81	4.92	181' WB	Worst Move SB Left LOS B
WB Ramps	A	0.76	3.64	143' EB	Worst Move WB Left LOS C
SPUI Intersection					
EB Ramps	B	0.78	8.36	307' NB	Worst Move NB Thru LOS B
Old Hardin Road	B	0.72	9.70	224 SB	Worst Move NB LOS C
Average All Intersections	**A**	**0.77**	**6.66**		
	Total Delay =		**26.62**		

Option 2 - Single-Point Urban Interchange	PM Hour LOS	PM Hour V/C	PM Hour Hrs Delay	Max Queue	Comments
North Frontage Road	B	0.56	10.07	175' NB Thru	Worst Move EB Thru LOS C
WB Ramps					
SPUI Intersection	B	0.89	12.10	270' WB Off	Worst Move EB Ramp LOS C
EB Ramps					
Old Hardin Road	C	0.77	21.90	250' SB LT	Worst Move SB LT LOS C
Average All Intersections	**A**	**0.74**	**14.69**		
	Total Delay =		**44.07**		

Option 3- Single-Point Urban with Roundabouts	PM Hour LOS	PM Hour V/C	PM Hour Hrs Delay	Max Queue	Comments
North Frontage Road	A	0.81	4.92	181' WB	Worst Move SB Left LOS B
WB Ramps					
SPUI Intersection	C	0.73	18.49	200' NB Thru	Worst Move EB LT LOS C
EB Ramps					
Old Hardin Road	B	0.72	9.70	224 SB	Worst Move NB LOS C
Average All Intersections	**C**	**0.75**	**11.04**		
	Total Delay =		**33.11**		

Option 4 - Double Crossover Diamond with Signals	PM Hour LOS	PM Hour V/C	PM Hour Hrs Delay	Max Queue	Comments
North Frontage Road	B	0.56	10.07	175' NB Thru	Worst Move EB Thru LOS C
WB Ramps	B	0.58	8.72	175' NB Thru	Worst Move NB Thru LOS B
SPUI Intersection					
EB Ramps	B	0.43	8.39	125' WB RT	Worst Move NB Thru LOS B
Old Hardin Road	C	0.77	21.90	250' SB LT	Worst Move SB LT LOS C
Average All Intersections	**B**	**0.59**	**12.27**		
	Total Delay =		**49.08**		

Option 5 - Double Crossover Diamond with Roundabouts	PM Hour LOS	PM Hour V/C	PM Hour Hrs Delay	Max Queue	Comments
North Frontage Road	A	0.81	4.92	181' WB	Worst Move SB Left LOS B
WB Ramps	B	0.64	6.83	150' NB Thru	Worst Move NB Thru LOS B
SPUI Intersection					
EB Ramps	B	0.46	6.34	175' NB Thru	Worst Move NB Thru LOS B
Old Hardin Road	B	0.72	9.70	224' SB	Worst Move NB LOS C
Average All Intersections	**B**	**0.66**	**6.95**		
	Total Delay =		**27.79**		

Corridor Travel Speeds

Travel times are the average travel times along a 1,650 foot segment of Johnson Lane. They were calculated based upon average speeds between intersections, stopped delay, and circulation speeds within roundabouts. The speeds were calculated in an effort to compare relative travel efficiencies along the Johnson Lane corridor. However, travel speeds on the Johnson Lane corridor would actually be a minor consideration with regard to interchange efficiency, since the majority of traffic on Johnson Lane involves turning movements at ramps and local intersecting roads, yet it does provide one additional measure of efficiency that may be considered in the final design screening process.

Table 13 summarizes the calculations for each design option and provides the relative travel time and travel speed associated with each option. The highest travel speeds are associated with Option 1 and Option 3 roundabouts and the slowest travel speeds are associated with Option 2 and Option 4 traffic signals. It should be noted that differences between the maximum and minimum times are less than one minute and the differences in travel speeds are less than six mph.

Table 13. Johnson Lane Corridor Travel Speeds Through Interchange

Option 1 Modified Diamond Round Intersection	From	To	SB PM Int. Delay	Distance Between	Speed Between	Distance In Circle	Speed In Circle	Southbound Time (sec)
Old Hardin Rd			10.2			248	20	18.6
	Old Hardin	EB Ramps		320	35			6.2
EB Ramps			3.1			200	20	9.9
	EB Ramps	WB Ramps		380	35			7.4
WB Ramps			3.5			155	20	8.7
	WB Ramps	N Frontage		300	35			5.8
N Frontage			3.9			185	20	10.2
						Travel Time (sec) =		66.8
						Travel Speed (mph) =		16.7

Option 2 - Single-Point Urban Signals Intersection	From	To	SB PM Int. Delay	Distance Between	Speed Between	Distance In Circle	Speed In Circle	Southbound Time (sec)
Old Hardin Rd			22.4					22.4
	Old Hardin	SPUI		1110	35			21.6
SPUI			30					30.0
	SPUI	N Frontage		540	35			10.5
N Frontage			17.4					17.4
						Travel Time (sec) =		102.0
						Travel Speed (mph) =		10.9

Option 3- Single-Point Urabn Round Intersection	From	To	SB PM Int. Delay	Distance Between	Speed Between	Distance In Circle	Speed In Circle	Southbound Time (sec)
Old Hardin Rd			10.2			250	20	18.6
	Old Hardin	SPUI		690	35			13.5
SPUI			7.3			380	25	17.6
	SPUI	N Frontage		350	35			6.8
N Frontage			3.9			185	20	10.2
						Travel Time (sec) =		66.6
						Travel Speed (mph) =		16.7

Option 4 - Double Crossover Signals Intersection	From	To	SB PM Int. Delay	Distance Between	Speed Between	Distance In Circle	Speed In Circle	Southbound Time (sec)
Old Hardin Rd			22.4					22.4
	Old Hardin	EB Ramps		530	35			10.3
EB Ramps			13.4					13.4
	EB Ramps	WB Ramps		560	35			10.9
WB Ramps			16.7					16.7
	WB Ramps	N Frontage		550	35			10.7
N Frontage			17.4					17.4
						Travel Time (sec) =		101.9
						Travel Speed (mph) =		10.9

Option 5 - Double Crossover Round Intersection	From	To	SB PM Int. Delay	Distance Between	Speed Between	Distance In Circle	Speed In Circle	Southbound Time (sec)
Old Hardin Rd			10.2			248	20	18.6
	Old Hardin	EB Ramps		315	35			6.1
EB Ramps			11.1					11.1
	EB Ramps	WB Ramps		560	35			10.9
WB Ramps			13.5					13.5
	WB Ramps	N Frontage		380	35			7.4
N Frontage			3.9			185	20	10.2
						Travel Time (sec) =		77.8
						Travel Speed (mph) =		14.3

Mary Street Alignments - US 87/ Old Hwy 312 Intersection

The existing intersection of US 87/Old Hwy 312 incorporates approaches to only Main Street and Bench Boulevard. Mary Street intersects Bench Boulevard immediately south of the Main Street Intersection with access from northeast bound Main Street to Bench and Mary, but does not allow access from Mary Street directly onto Main Street. Westbound traffic on Mary Street can access Main Street by either executing a left-turn at the stop controlled US 87/Old Hwy 312 intersection or can turn left onto Bench and turn right onto Pemberton Lane, which intersects Main Street at an existing signalized intersection. The latter movement is more common since the Main Street/Old Hwy 312 roadway alignment is sharply skewed (37 degree angle) to the north-south alignment of Bench Boulevard/US 87 and it is difficult to judge gaps on the higher speed facility. In addition, that movement involves out of direction travel and more potential for delay than the Pemberton Lane/Main Street intersection.

The Bench Boulevard reconstruction project, currently in final design stages, would modify access to Mary Street by further limiting access to Mary Street from Main Street, US 87, and Old Hwy 312. A raised median on Bench Boulevard at Mary Street is planned to better accommodate major traffic movements at the planned signalized intersection. Implementation of a new alignment associated with this project would substantially change traffic patterns at this intersection and the following design options were conceived for potential implementation in the final design of either the Mary Street Option 1 or Option 2 Alignment alternatives. Improvements to this intersection would also be required for the Five Mile Road Alignment alternative and the proposed design concept was presented in the previous section of this report.

Design concept drawings for the three US 87/Old Hwy 312 design options can be found in Appendix I of this report. Capacity calculations for individual intersections associated with each of the design options can also be found in Appendix I. All capacity calculations were based upon the Mary Option 1 Alignment year 2035 volumes, which has the highest traffic volumes and was used as the worst case scenario.

Design Option Descriptions

Option 1 - Main Street Roundabout with Access to Mary Street/Bench T-intersection

Option 1 involves a 200 foot diameter roundabout on the Main Street/Highway 312 corridor. The roundabout would include Main Street, Old Hwy 312, US 87, and the Mary Street Options 1 or 2 Alignments. Bench Boulevard and Existing Mary Street would intersect at a channelized T-intersection southeast of the roundabout, and Bench Boulevard would access the Mary Street Alignment as shown on Figure I-1 (Appendix I). Option 1 would utilize a roundabout to serve the major street facilities while separating the lower volume, localized traffic at a stop controlled intersection. Main Street/Old Hwy 312 is the primary corridor at this intersection, and two thru-lanes of traffic would be carried through the roundabout. The roundabout would have a right-turn slip ramp to remove southbound traffic on US 87 from the circulating roundabout traffic.

Option 1 does not provide for direct access from Main Street, US 87, or Old Hwy 312 to the existing Mary Street corridor. Traffic from those routes, that need to access Mary Street, would do so by using the Hawthorne Street connection to the Mary Street Option 1 & 2 Alignments. Hawthorne Street is located approximately 0.46 miles east of the Option 1 roundabout. There are approximately 25 residential properties that this access restriction would affect, and it is estimated that total volume of traffic that would experience out of direction travel would be less than 50 ADT.

Capacity calculations (see Appendix I) indicate that the Option 1 Roundabout would operate at an overall LOS “B” in the year 2035. The worst LOS would be LOS “C” for the Mary Street Alignment approach. The Bench Boulevard approach to the Mary Street Alignment would operate at LOS “E”. However, a 30 foot wide raised median in the Mary Street Alignment design would allow for two-stage left-turns from Bench Boulevard, and the resultant capacity would then be LOS “D”. The Existing Mary Street approach to Bench Boulevard would operate at LOS “B”. However, there is a possibility that vehicle queues on Bench Boulevard could impede westbound traffic on Existing Mary Street.

Option 2 – Primary & Secondary Roundabouts

Option 2 involves two roundabouts. One is a 280 foot diameter roundabout at the Main Street/US87/312 intersection and the other is a single lane roundabout that would be located south of the larger roundabout at an intersection with Bench and Mary Street. The single lane roundabout would connect to the major roundabout as a fifth approach leg. Access from US 87 to Bench would be a more direct path than that associated with Option 1. A southbound US 87 slip ramp would also be provided with this alternative.

The major feature of this design option is its ability to isolate localized traffic on Bench and Mary Street, which would have little if any truck traffic. The US 87/Old Hwy 312/Mary Street Alignment traffic would have approximately 4% heavy trucks, and longer trips lengths. Unlike Option 1, Option 2 would serve all traffic movements to and from the six roadways intersecting at this junction. While not unique, the five legged roundabout configuration is not common in the United States, and signing for proper lane usage and directional exits would be critical during final design.

Capacity calculations (see Appendix I) indicate that the primary roundabout would operate at an overall LOS “B”, and the worst movement would be the Mary Street Alignment through and left-turn lane which would operate at LOS “C”. The secondary roundabout would operate at an overall LOS “A”, and the worst movement would be the Existing Mary Street approach which would operate at LOS “B”.

Option 3 - Dual Roundabouts

Option 3 would use two roundabouts on the US 87/Mary Street Alignment corridor. The first roundabout would include Main Street, Old Hwy 312, US 87 and the Mary Street Alignment, and would be a multilane roundabout with an approximate diameter of 200 feet. The second roundabout would be a smaller single lane roundabout serving the Mary Street Option 1 or 2 Alignment, Existing Mary Street, Bench Boulevard, and the connector link to the larger northern roundabout. There would be a US 87 southbound slip ramp that is common to all of the options and a westbound Mary Street Alignment slip ramp. This option would partially segregate localized traffic between Existing Mary Street and Bench, but US 87/Mary Street Alignment traffic, which has heavy trucks and longer trip lengths, would interact with local traffic within the smaller roundabout. Circulation traffic within the roundabout would only include half of the US 87/Mary Street Alignment traffic volumes, since the other half would use the Mary Street Alignment slip ramp.

Option 3 would involve realignment of the Main Street/Old Hwy 312 corridor to the north in order to achieve acceptable roundabout entry angles, and to provide sufficient separation between the two roundabouts. Each roundabout would have four approach legs and would serve all traffic movements to and from the six intersecting roadway approaches. Some out-of-direction travel between Main Street and the Mary Street Alignment would be perceived, but the actual travel time would be similar to Option 2 and only slightly longer than Option 1.

Capacity calculations (see Appendix I) indicate that the roundabout at US 87/Old Hwy 312/Main Street would operate at an overall LOS “B”, and the worst movement would be the Mary Street Alignment (connector road) left-turn and through lane at LOS “C”. The smaller roundabout at Existing Mary Street and Bench Boulevard would operate at an overall LOS “A”, and the worst movement would be the Bench Boulevard approach at LOS “B”. The Bench Boulevard approach would also have the longest maximum vehicle queue of approximately seven vehicles. That length of queue would not impede vehicle movements at any adjacent intersections or approaches.

Capacity Comparisons

Table 14 presents the LOS, delay (seconds/vehicle), volume to capacity (v/c) ratios, and maximum queue lengths (feet) for each of the three design options. For more detailed information on individual movements, Appendix I provides individual intersection capacity analysis summaries.

Table 14. Mary Street Alignments US 87/Old Hwy 312 Capacity

Intersection	Approach	Measures of Efficiency LOS	Delay(sec)	V/C	Qmax(ft)
Design Option 1 - Main Street Roundabout with Access to Mary Street/Bench T-intersection					
US87/312/Main/ Bench Intersection	Main Street NEB	B	13.5	0.66	190
	HWY 3 SWB	C	23.1	0.73	155
	Mary Align NWB	C	21.8	0.85	210
	US 87 SEB	B	13.0	0.46	65
	Intersection	**B**	**17.9**	**0.85**	**210**
Bench & Mary Intersection	Bench NB	D	27.5	0.76	150
	Mary St WB	B	12.3	0.21	25
	Intersection	**D**	**27.5**	**0.76**	**150**
Design Option 2 - Primary & Secondary Roundabouts					
US87/312/Main/ Bench Intersection	Main Street NEB	B	11.0	0.60	150
	HWY 3 SWB	B	16.8	0.58	120
	Mary Align NWB	B	18.4	0.66	125
	US 87 SEB	A	9.4	0.39	55
	Bench NB	B	11.3	0.58	100
	Intersection	**B**	**13.5**	**0.66**	**150**
Bench & Mary Intersection	Mary Align WB	B	10.6	0.19	25
	Bench EB	A	6.2	0.54	125
	Bench SB	A	3.2	0.34	60
	Intersection	**A**	**6.0**	**0.54**	**125**
Design Option 3 - Dual Roundabouts					
US87/312/Main/ Bench Intersection	Main Street NEB	B	11.1	0.62	155
	HWY 3 SWB	B	17.0	0.59	115
	Mary Align NWB	B	17.4	0.82	195
	US 87 SEB	B	10.7	0.41	55
	Intersection	**B**	**14.2**	**0.82**	**195**
Bench & Mary Intersection	Mary Align WB	A	5.7	0.34	25
	Bench EB	B	10.8	0.64	165
	Bench SB	A	6.2	0.30	50
	Mary St NB	B	12.0	0.23	40
	Intersection	**A**	**7.7**	**0.65**	**165**

Five Mile Road/Old Hwy 312

There are two proposed locations for a connection of Five Mile Road to Old Hwy 312 that have been carried forward in this project. The western most location, Option A, involves a sweeping curve to the northwest from the north-south alignment of Five Mile Road. The eastern most location, Option B, would be located approximately 900 feet farther northeast on Old Hwy 312, involves a shorter curve to intersect Old Hwy 312. Because there may be yet unidentified impacts at either location, both a signal and a roundabout have been identified as potential design configurations for both locations, resulting in four optional designs. The figures contained in Appendix J of this report represent the Five Mile Road Alignment alternative connections, yet the final design of this intersection would also apply to secondary Five Mile Road improvements associated with the Mary Street Option 1 or 2 Alignment alternatives. The only difference would be the number of lanes on the Five Mile Road approach. The typical section for the Five Mile Road secondary improvements alignment would involve a two-lane facility. Thus, at its approach to Old Hwy 312, Five Mile Road as a secondary improvement facility would either have a single approach lane for the roundabout option or one through/left-lane and one right-turn lane for the signal alternative. Capacity calculations for the secondary improvement signal option is included in Appendix J.

For all alternative design options, it was assumed that the newly constructed section of Old Highway 312 between US 87 and a point 900 feet west of the Option A intersection would be extended east beyond the Option B intersection location. A five lane section on Old Hwy 312 is shown for all of the Five Mile Road connection figures.

Design Option Descriptions

Option A

Figures J1 and J2, in Appendix J, illustrate the traffic signal and roundabout design options, respectively, at this location. The Option A traffic signal configuration would incorporate three approach lanes on Five Mile Road. Modifications to an existing private roadway approach on the north side of the intersection would align that approach with the Five Mile Road approach. The middle lane on Five Mile Road would accommodate a through movement to the private approach road on the north side of the intersection. This configuration allows the potential for a future continuation of Five Mile that would connect to US 87, at some future time. For Five Mile Road secondary improvements associated with the Mary Street Option 1 or 2 Alignments, there would be one approach lane accommodating left and through traffic movements, and an auxiliary right-turn lane, which would accommodate the majority of traffic on the Five Mile Road approach. In addition, there would only be one departure lane on Five Mile Road for the secondary improvements alternative.

The Option A roundabout design is shown in Figure J2. It shows the two approach and departure lanes associated with the Five Mile Road Alignment typical section. The two approach and departure lanes would allow for a future extension north to US 87. Five Mile Road as a secondary improvement would have single approach and departure lanes.

Capacity calculations (see Appendix J) indicate that the Option A traffic signal intersection would operate at LOS “A” in the design year 2035. The v/c ratio would be 0.37, and the intersection delay would be 8.7 seconds per vehicle. The worst movement would be the Five Mile Road approach at LOS “B”. The maximum queue in any lane would be three vehicles in the Five Mile Road right-turn lane. For the Option A roundabout intersection, the overall LOS would be “A” and the worst movement would be the Five Mile Road left-turn lane which would operate at LOS “B”. The intersection’s v/c ratio would be 0.28 and none of the approaches would have more than two vehicles in the maximum queue.

If the Five Mile Road connection is made as a secondary improvement associated with the Mary Street Option 1 or 2 Alignment, the capacity calculations indicated that for a signal with a single through/left lane and an auxiliary right-turn lane on the Five Mile Road approach the intersection LOS would be "A". All other measures of efficiency would be almost identical to the Five Mile Road alignment Intersection.

Option B

Figures J3 and J4 in Appendix J illustrate the traffic signal and roundabout design options, respectively, at this location. These two design options are almost identical to the Option A geometric layout for the signal and roundabout, including the private approach road relocation on the north side of Old Hwy 312. In addition, the close proximity of Option B to Option A would result in identical traffic demands. Therefore, the analysis results for Option A would be identical to those detailed in the preceding section.

Final design of the Five Mile Road connection to Old Hwy 312 would ultimately be determined by factors other than traffic operations.

Mary Street/Bitterroot Drive

The original concept design for the intersection of Bitterroot Drive and Mary Street Option 1 and 2 Alignments occurred early in the development of screening alternatives for the EIS. Since that time, a new residential dwelling was constructed in the southeast corner of the intersection of Mary Street and Bitterroot Lane. Because the original concept involved a realignment of Mary Street that would be in direct conflict with the new house, it was determined that additional design concepts would be required in an attempt to minimize impacts at this intersection location.

The design options presented within this section of the report include the original concept and six additional options. Three of the new options are based upon adjustments that move the Mary Street Option 1 and 2 Alignment to the north while maintaining the existing Mary Street alignment as it currently exists. The remaining three options are based on maintaining the Mary Street Alignment location and modify the existing Mary Street intersection with Bitterroot Drive.

Design Option Descriptions

Option A – Signal

Option A was the original concept that was prepared prior to knowledge of the new house. This concept involves realigning the existing Mary Street to the south of the signalized intersection to maintain adequate spacing between intersections. In this concept, the realignment of Mary Street would require removal of the new house. Left-turn lanes would be constructed on Bitterroot Drive, both north and south of the Mary Street Alignment intersection. The intersection of Bitterroot and existing Mary Street would operate with stop control on Mary Street which would allow through traffic movements on the higher volume street (Bitterroot Drive).

Capacity calculations (see Appendix K) indicate that the intersection of Mary Street Option 1 Alignment and Bitterroot Drive would operate at LOS “B” with the worst movement being LOS “B” on the northbound Bitterroot Drive approach. At the stopped controlled intersection of Bitterroot Drive and Mary Street, Bitterroot Drive would operate at LOS “A” and Mary Street would operate at LOS”B”.

Option B – Roundabout

Options B and C involve shifting the proposed Mary Street Alternative alignment to the north at Bitterroot Drive to achieve the necessary spacing from the intersection of Mary Street and Bitterroot Drive. Option B uses a roundabout and Option C uses a traffic signal. These alternatives would avoid removing a house on the southeast corner but would in-turn impact landowners on the north side of the Mary Street Option 1 and 2 Alignment.

The roundabout shown in Figure K2 (Appendix K) would perpetuate the Mary Street Alignments’ typical section of two lanes in each direction through the roundabout. Bitterroot Drive would have single entrance and exit lanes on both sides of the intersection. The intersection of Mary Street and Bitterroot would be stop controlled on Mary Street, similar to Option A, except both Bitterroot Drive approaches would have a single lane of travel in each direction without a left-turn lane. Traffic volumes for Option B are the same as all of the intersections’ design options.

Appendix K capacity calculations indicate that the Mary Street Option 1 Alignment roundabout would operate at LOS “A” and all of the approaches and movement would operate at the same LOS.

Option C – Signal

Option C is the same as Option B except the roundabout on the Mary Street Option 1 Alignment would be replaced with a traffic signal. This Option would require more gradual entry curves on the Mary Street Alignment approaches which would impact a garage structure in the private parcel northeast of the intersection. All of the traffic volumes would be the same as the other design options, and the same geometry and control features at the existing Mary Street/ Bitterroot Drive intersection would be the same as that used for Option B.

Capacity calculations for the Mary Street Alignment signalized intersection would be the same as the Option A design, the existing Mary Street/Bitterroot Drive intersection LOS would be the same as design Option B.

Option D – Raised Median Bitterroot Drive

Option D would involve a signalized intersection at the Mary Street Alignment and Bitterroot Drive, as shown in Figure K4. The southern approach to the intersection would have a raised median between the northbound left-turn lane and the southbound lane. The adjacent intersection of Mary Street and Bitterroot Drive would only allow right-turn entry and exit movements. This would eliminate

6 of the 12 movements that are currently served by this intersection. East-west through and left-turn movements on Mary Street would then be served by the Mary Street Alignment roadway. Northbound and southbound left-turn movements on Bitterroot Drive at Mary Street would be detoured onto the new Mary Street alignment and would access Mary Street at either Hawthorne Lane or at Five Mile Road. The total volume of traffic that would be redistributed due to prohibited movements would be approximately 130 vehicles during the peak pm design hour period in the year 2035. This amounts to about 24% of the total projected traffic that would be entering the Mary Street-Bitterroot Drive intersection.

Most of the additional right-of-way necessary for construction of this option would be on the west side of Bitterroot Drive. This option requires the least amount of total new R/W area of any of the options. This option also has the least potential impact on adjacent property in terms of structure relocation and access.

This option allows full operational signal control of the Mary Street Alignment intersection with Bitterroot Drive with little if any conflicts created by the adjacent intersection. The only issue would involve westbound right-turn movements from Mary Street that could have a minor volume of traffic associated with a weave across the northbound through traffic lane. Conflicts points at the Mary Street and Bitterroot Drive intersection would be reduced from 32 to 2, thus increasing the safety potentially dramatically. Capacity calculations for both of the intersections involved with this option are attached.

Design Option E – Grade Separation

Option E represents a grade separation option that would have the least impact to adjacent properties while providing full access to the Mary Street Alignment from Bitterroot Drive. The grade separation Option E, shown in Figure K5, would have Bitterroot Drive overpass a slightly horizontally shifted Mary Street allowing a fully operation signal for the Bitterroot Drive intersection with the Mary Street Alignment. The vertical profile of the Mary Street Alignment would be raised, along with the north and south approaches on Bitterroot Drive. The option would eliminate all but the east-west through movements on Mary Street, at its intersection with Bitterroot Drive, and would only serve 55 east-west vehicles in the peak pm design hour. Other grade separation options would involve a Bitterroot Drive overpass of the Mary Street Alignment, which without connecting ramps would either create a circuitous route for traffic accessing the Mary Street Alignment or actually reduce traffic demand on the Mary Street Alternative by approximately 3,000 ADT.

The R/W required for this option would be measurably greater than Option D, but somewhat less than some of the other options. The large fill sections and retaining walls that would be required could possibly impact access to adjacent properties and would create a circuitous route for adjacent residents living along Mary Street. Nearby residents, especially those in the new house located in the southeast corner of the intersection would have their views substantially altered by the raised profile of Bitterroot drive and the Mary Street Alignment.

Design Option F – Signal Northwest

Option F is similar to design Option C except that the intersection of Bitterroot Drive and Mary Street Alignment would be shifted west of the current Bitterroot Drive Alignment, thus minimizing the impacts to developed property in the northeast corner of the intersection that would be associated with Option C. All movements would be served at both intersections. Figure K6 illustrates the reverse curves and approach angles that would be needed to achieve the shifted intersection alignment associated with Design Option F. Some degree of crash potential would be associated with this option due to operational conditions typically inherent within curvilinear alignments. Thus, it is noted in Figure K6 that a roundabout could also be considered as a control option at the Mary Street Alignment intersection with Bitterroot Drive.

This design option would entail the most R/W acquisition of all alternatives, but would minimize impacts to structures and access to adjacent developed properties. There would also be a larger tract of land between Mary Street and the Mary Street Alignment that could not be developed, but would still need to be maintained.

Design Option G – Mary Street Termination

Option G would involve termination of Mary Street at Bitterroot Drive. Figure K7 illustrates the realignment of the Mary Street west approach to the south, which would create a “T” intersection at the intersection Mary Street and Bitterroot Drive. Since existing and future traffic demand on Mary Street, east of Bitterroot Drive, would be substantially less than on Mary Street west of Bitterroot Drive, Mary Street would be terminated at a cul de sac and a minor connection road between Mary Street and the Mary Street Alignment roadway would be constructed. Capacity calculations indicate that all three intersections would operate at acceptable levels of service (LOS) and the separation distances between intersections would be conducive to safe operations.

The large tract of land between Mary Street and the Mary Street Alignment could be accessed from Mary Street. This would allow for potential development of that property.

Capacity

A summary of the additional design options capacity calculations is shown in Table 15. It can be seen that all of the alternatives would provide a desirable LOS. There are no substantial differences in the LOS and other measures of effectiveness between all of the alternatives. Thus, deciding factors would be: safety, impacts to adjacent properties, and responsiveness to overall travel demands. Final design of the intersection geometry and control will involve coordination with the City of Billings and a complete evaluation of traffic operations and land use impacts.

Table 15. Mary Street Alignment - Bitteroot Drive Design Options - Capacity Summary

Intersection	Approach	LOS	Delay(sec)	V/C	Qmax(ft)
DESIGN ALTERNATIVE A					
Mary Alignment & Bitteroot	Mary Align EB	A	7.7	0.22	75
	Mary Align WB	A	8.5	0.34	100
	Bitteroot NB	B	16.6	0.38	75
	Bitteroot SB	B	15.4	0.16	50
	Intersection	**B**	**10.0**	**0.35**	**100**
Bitteroot & Mary Street	Mary Street EB	C	15.9	0.32	35
	Mary Street WB	C	15.2	0.12	15
	Bitteroot NB	A	7.8	0.03	5
	Bitteroot SB	A	7.8	0.01	5
	Intersection	**na**	**na**	**na**	**na**
DESIGN ALTERNATIVE B					
Mary Alignment & Bitteroot	Mary Align EB	A	5.7	0.17	25
	Mary Align WB	A	6.6	0.29	50
	Bitteroot NB	A	4.7	0.31	35
	Bitteroot SB	A	6.9	0.20	20
	Intersection	**A**	**6.0**	**0.31**	**50**
Bitteroot & Mary Street	Mary Street EB	C	15.9	0.32	35
	Mary Street WB	C	15.2	0.12	15
	Bitteroot NB	A	7.8	0.03	5
	Bitteroot SB	A	7.8	0.01	5
	Intersection	**na**	**na**	**na**	**na**
DESIGN ALTERNATIVE C					
Mary Alignment & Bitteroot	Mary Align EB	A	7.7	0.22	75
	Mary Align WB	A	8.5	0.34	100
	Bitteroot NB	B	17.0	0.42	75
	Bitteroot SB	B	16.1	0.28	50
	Intersection	**B**	**10.0**	**0.35**	**100**
Bitteroot & Mary Street	Mary Street EB	C	15.9	0.32	35
	Mary Street WB	C	15.2	0.12	15
	Bitteroot NB	A	7.8	0.03	5
	Bitteroot SB	A	7.8	0.01	5
	Intersection	**na**	**na**	**na**	**na**

Intersection	Approach	LOS	Delay(sec)	V/C	Qmax(ft)
DESIGN ALTERNATIVE D					
Mary Alignment & Bitteroot	Mary Align EB	A	7.9	0.25	100
	Mary Align WB	A	8.6	0.35	150
	Bitteroot NB	B	16.2	0.31	75
	Bitteroot SB	B	15.4	0.16	50
	Intersection	**A**	**9.9**	**0.34**	**150**
Bitteroot & Mary Street	Mary Street EB	A	9.3	0.05	25
	Mary Street WB	A	9.4	0.05	25
	Bitteroot NB	A	0.0	na	na
	Bitteroot SB	A	0.0	na	na
	Intersection	**na**	**na**	**na**	**na**
DESIGN ALTERNATIVE E					
Mary Alignment & Bitteroot	Mary Align EB	A	7.9	0.26	75
	Mary Align WB	A	8.6	0.37	100
	Bitteroot NB	B	16.1	0.32	75
	Bitteroot SB	B	15.4	0.14	50
	Intersection	**A**	**9.9**	**0.35**	**100**
Bitteroot & Mary Street	Mary Street EB	A	0.0	na	0
	Mary Street WB	A	0.0	na	0
	Bitteroot NB	A	0.0	na	0
	Bitteroot SB	A	0.0	na	0
	Intersection	**na**	**na**	**na**	**na**
DESIGN ALTERNATIVE F					
Mary Alignment & Bitteroot	Mary Align EB	A	7.7	0.22	75
	Mary Align WB	A	8.7	0.38	125
	Bitteroot NB	B	16.4	0.36	100
	Bitteroot SB	B	15.4	0.14	50
	Intersection	**A**	**10.0**	**0.37**	**125**
Bitteroot & Mary Street	Mary Street EB	C	15.9	0.32	35
	Mary Street WB	C	15.2	0.12	15
	Bitteroot NB	A	7.8	0.03	5
	Bitteroot SB	A	7.8	0.01	5
	Intersection	**na**	**na**	**na**	**na**

Intersection	Approach	LOS	Delay(sec)	V/C	Qmax(ft)
DESIGN ALTERNATIVE G					
Mary Alignment & Bitteroot	Mary Align EB	A	7.7	0.22	75
	Mary Align WB	A	8.7	0.35	100
	Bitteroot NB	B	16.9	0.43	100
	Bitteroot SB	B	15.4	0.15	50
	Intersection	**B**	**10.2**	**0.38**	**100**
Bitteroot & Mary Street	Mary Street EB	B	11.0	0.15	25
	Mary Street WB	na	na	na	na
	Bitteroot NB	A	7.7	0.02	25
	Bitteroot SB	na	na	na	na
	Intersection	**na**	**na**	**na**	**na**

City of Billings Coordination

Consultant team members met with the City Engineer and members of the Traffic Engineering Department to obtain feedback regarding design options being considered for the Mary Street alignments and Bitterroot Drive intersection. They reviewed the genesis of the intersection design and subsequent analysis of all seven design options. Through the process of elimination, the City felt that they could provide strong support for Option G which involves a cul de sac on Mary Street east of Bitterroot and a realignment of Mary Street on the west side of the intersection. The reasons behind their selection of Option G were:

1 - When the Mary Street Alignment is constructed, it will replace Mary Street as the east-west Principal Arterial and Mary Street's functional classification will revert to a local street or a collector street, at best. Thus, the continuity of Mary Street must be broken to ensure that it does not function as a parallel arterial.

2 - The cul de sac located in the southeast corner of the intersection would serve as a buffer between the signalized intersection and the residence located in that corner.

3 - The three lane street section on Bitterroot between Mary Street Alignment and the Mary Street intersection would fit with improvements that would eventually be made on Bitterroot Drive at some future date.

4- They also indicated that if an alternative to Option G were to be considered they could support Option D, the raised median separator on Bitterroot that would limit movements to right-in and right-out on Mary Street at Bitterroot.

SUMMARY & CONCLUSIONS

The proposed alternative alignments between Old Highway 312 and I-90 being carried forward into the EIS would provide an alternate Yellowstone River crossing to the existing US 87 river crossing between the I-90 Lockwood Interchange and the intersection of Main Street and 1st Avenue North. With respect to impacts on the existing street system, the alternative alignments would substantially reduce future traffic demand on the existing river crossing and on Main Street. No-Build traffic projections in the year 2035 indicate that both corridors would suffer from poor levels-of-service and congestion. At some corridor intersections, the reduction in traffic demand associated with the new alignment alternative is substantial enough to delay major improvements that may be required before the year 2035. This study has also determined that the design year (2035) street system, with the new alignments, would have safety benefits by reducing exposure (traffic) on the existing streets and diverting traffic to a newer, safer facility.

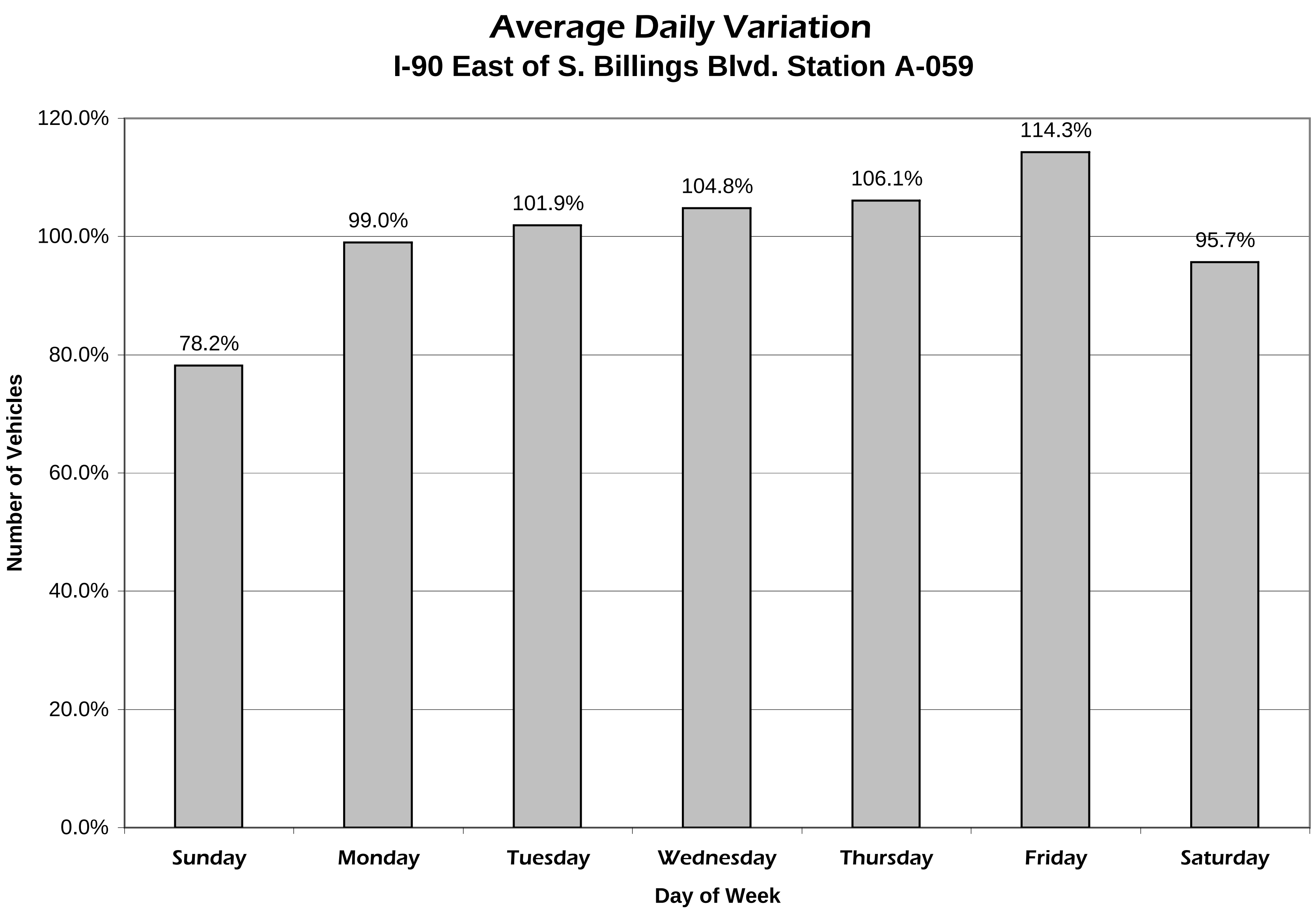
All of the new alignment alternatives would require substantial improvements at the alignment connections to Old Hwy 312 and Johnson Lane. At Old Hwy 312, two connections are required: one at an extension of Five Mile Road, and the other at the intersection of US 87/Old Hwy 312/Main Street/Bench. Various conditions exist at both of these connection points that create complex traffic control issues. A number of design options have been proposed at these intersections. Since all of the design options are viable, MDT and the project team have decided to carry the design options further into the EIS and potentially, final design.

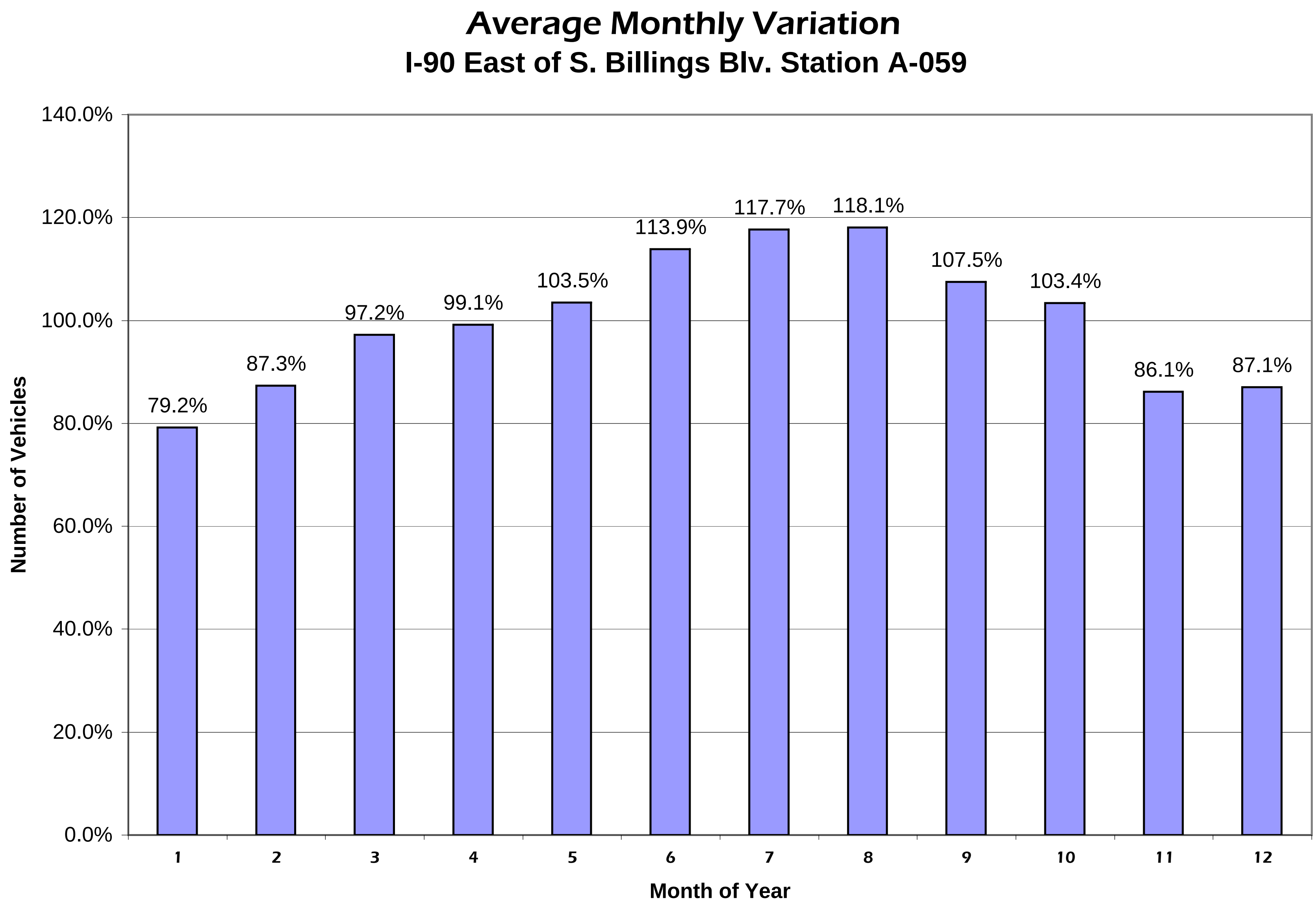
The Johnson Lane Interchange is currently in the early stages of congestion and projected growth in the area will create capacity problems which will eventually require major reconstruction. The directional flow of traffic would change dramatically with the alignment alternatives. Current geometric and surrounding land use conditions at the interchange will require a higher level of traffic control using contemporary design solutions. Five design options at the Johnson Lane Interchange have been proposed and evaluated. All of the options will provide acceptable operations with varying degrees of impacts. Because of the complexities involve, a decision was made to advance all five options, similar to the Old Hwy 312 connection.

Other intersections along the project alignment have been proposed and evaluated within this study. All of the intersections would provide good LOS well beyond the design year. The intersection of Bitterroot Drive and the project alignments would be a critical intersection, and as with Johnson Lane and Old Hwy 312 connections, design options are being carried forward.

APPENDIX A

Traffic Volume Variations


Average Daily Variation
I-90 East of S. Billings Blvd. Station A-059
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Number of Vehicles
78.2%
99.0%
101.9%
104.8%
106.1%
114.3%
95.7%
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Day of Week


Average Monthly Variation
I-90 East of S. Billings Blv. Station A-059
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Number of Vehicles
79.2%
87.3%
97.2%
99.1%
103.5%
113.9%
117.7%
118.1%
107.5%
103.4%
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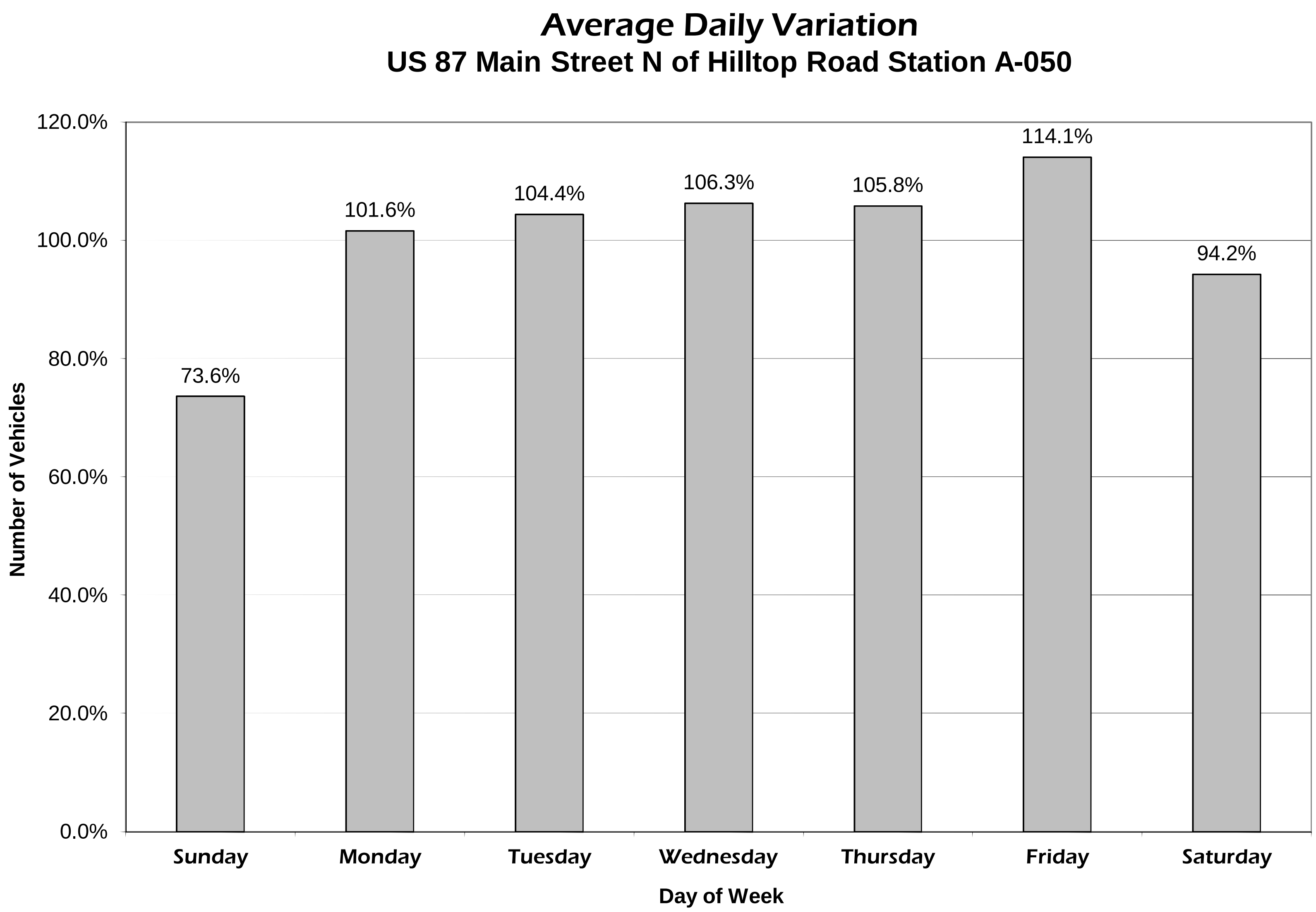
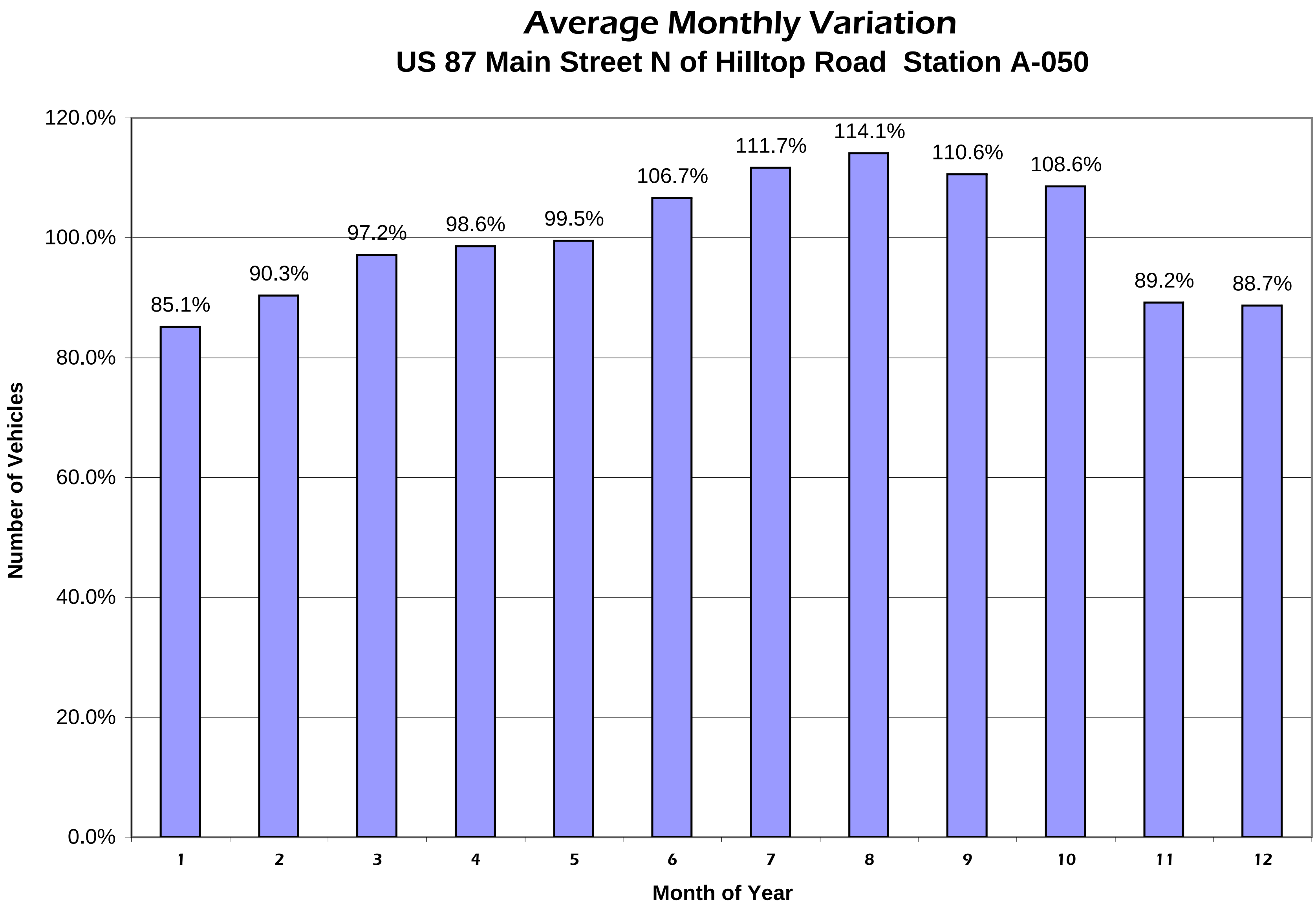
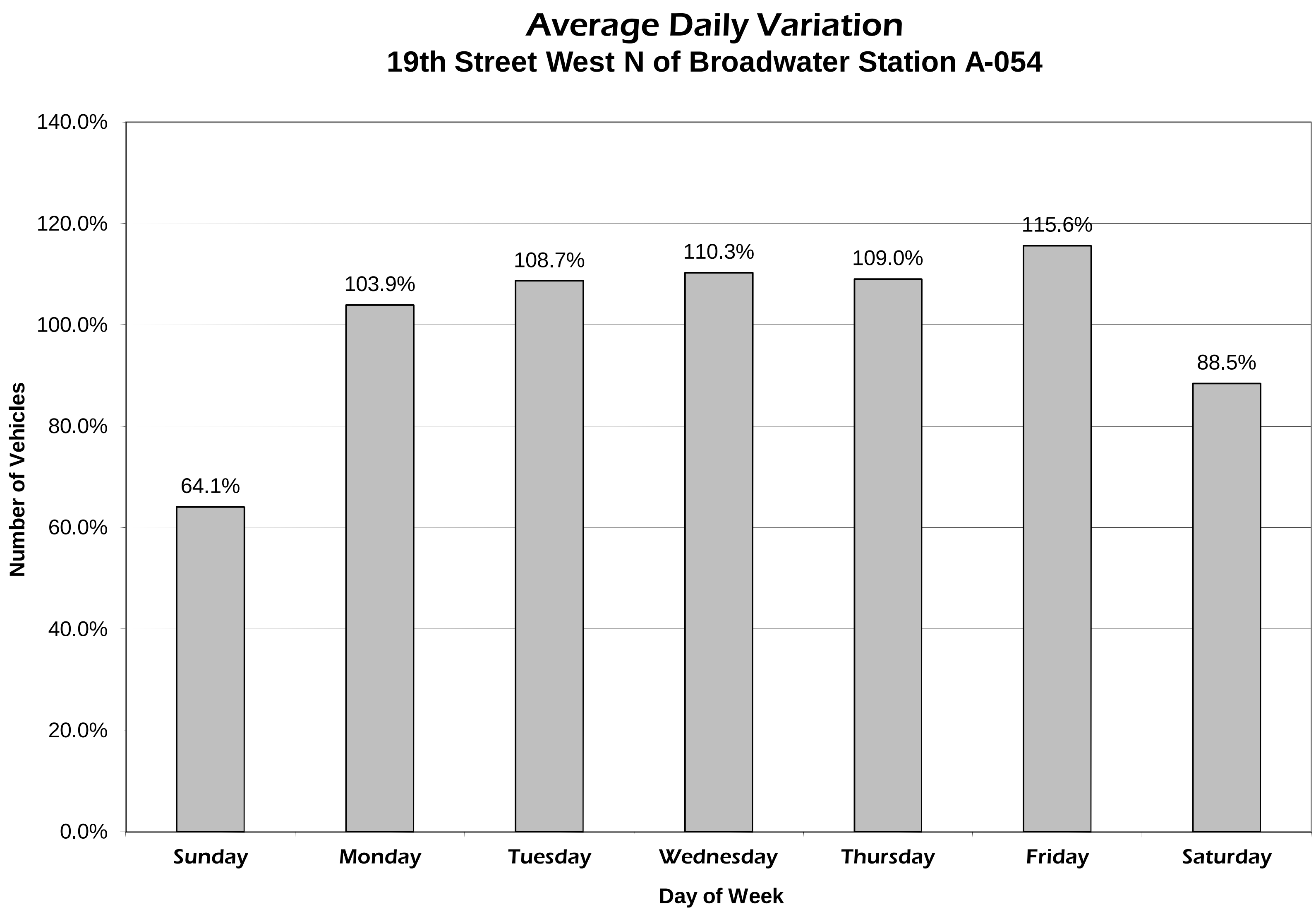
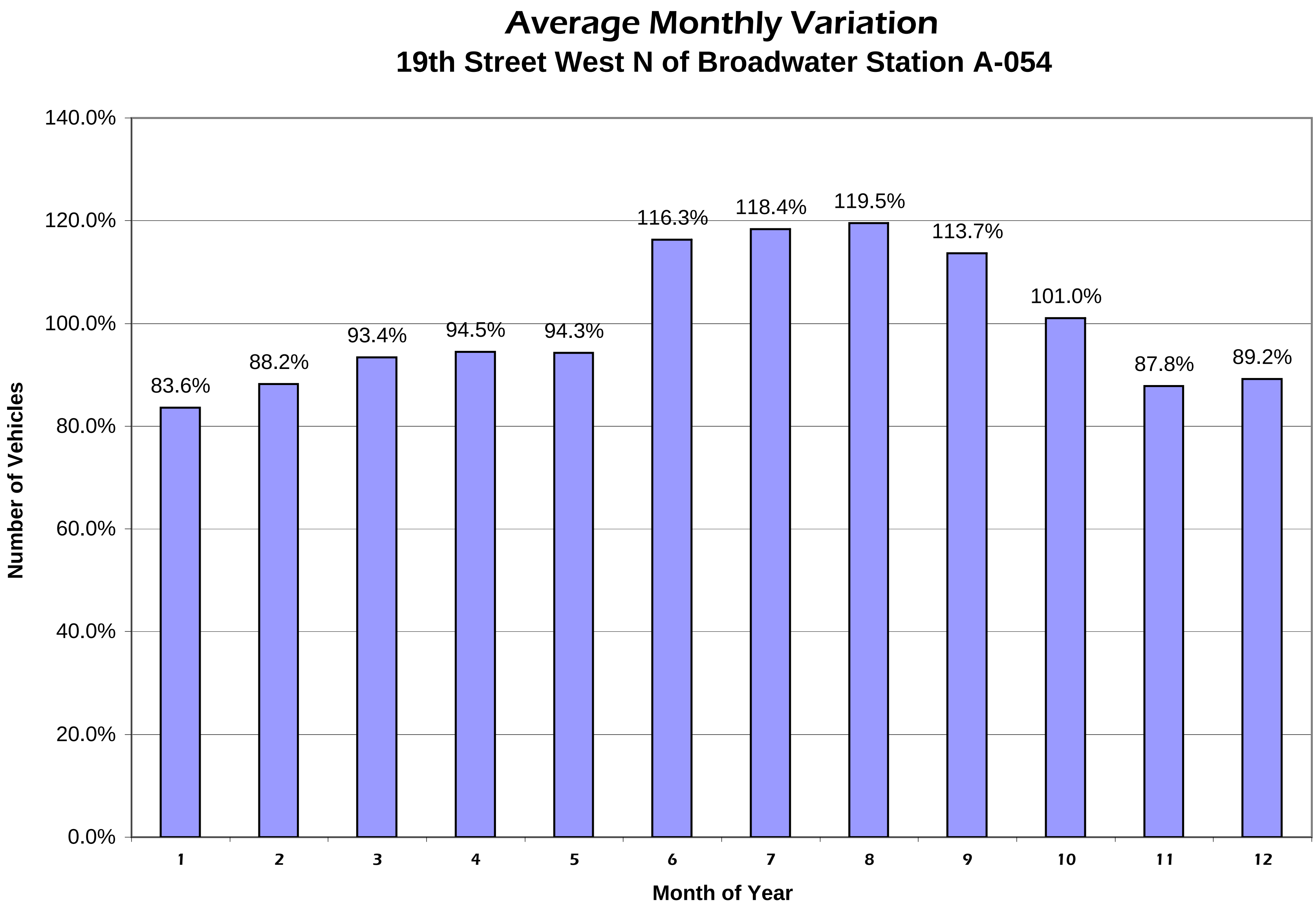
7
8
9
10
11
12
Month of Year


Average Daily Variation
US 87 Main Street N of Hilltop Road Station A-050
Number of Vehicles
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
73.6%
101.6%
104.4%
106.3%
105.8%
114.1%
94.2%
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Day of Week


Average Monthly Variation
US 87 Main Street N of Hilltop Road Station A-050
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Number of Vehicles
85.1%
90.3%
97.2%
98.6%
99.5%
106.7%
111.7%
114.1%
110.6%
108.6%
89.2%
88.7%
1
2
3
4
5
6
7
8
9
10
11
12
Month of Year


Average Daily Variation
19th Street West N of Broadwater Station A-054
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Number of Vehicles
64.1%
103.9%
108.7%
110.3%
109.0%
115.6%
88.5%
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Day of Week


Average Monthly Variation
19th Street West N of Broadwater Station A-054
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Number of Vehicles
83.6%
88.2%
93.4%
94.5%
94.3%
116.3%
118.4%
119.5%
113.7%
101.0%
87.8%
89.2%
1
2
3
4
5
6
7
8
9
10
11
12
Month of Year

APPENDIX B

Existing Roads & Streets

Capacity Calculations

TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Dover & Five Mile*
Agency/Co.	*Marvin & Associates*	Jurisdiction	*MDT*
Date Performed	*10/27/2011*	Analysis Year	*2010 Existing*
Analysis Time Period	*Peak PM*		

Project Description *Billings Bypass*

East/West Street: *Dover Road*	North/South Street: *Five Mile Road*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*40*	*1*	*4*	*37*	
Peak-Hour Factor, PHF	*1.00*	*0.50*	*0.50*	*0.50*	*0.50*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*80*	*2*	*8*	*74*	*0*
Percent Heavy Vehicles	*0*	--	--	*5*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*1*		*4*			
Peak-Hour Factor, PHF	*0.50*	*1.00*	*0.50*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*2*	*0*	*8*	*0*	*0*	*0*
Percent Heavy Vehicles	*5*	*0*	*5*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*8*		*10*				
C (m) (veh/h)		*1497*		*933*				
v/c		*0.01*		*0.01*				
95% queue length		*0.02*		*0.03*				
Control Delay (s/veh)		*7.4*		*8.9*				
LOS		*A*		*A*				
Approach Delay (s/veh)	--	--	*8.9*					
Approach LOS	--	--	*A*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*12/8/2011*
Analysis Time Period	*PM Design Hour*

Site Information

Intersection	*Dover & Bitteroot*
Jurisdiction	*MDT*
Analysis Year	*Existing 2010*

Project Description *Billings Bypass*

East/West Street: *Dover Road* | North/South Street: *Bitteroot*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*51*	*38*	*10*	*29*	
Peak-Hour Factor, PHF	*1.00*	*0.80*	*0.80*	*0.70*	*0.70*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*63*	*47*	*14*	*41*	*0*
Percent Heavy Vehicles	*0*	--	--	*1*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*22*		*6*			
Peak-Hour Factor, PHF	*0.60*	*1.00*	*0.60*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*36*	*0*	*9*	*0*	*0*	*0*
Percent Heavy Vehicles	*1*	*0*	*1*	*0*	*0*	*0*
Percent Grade (%)	*3*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*14*		*45*				
C (m) (veh/h)		*1486*		*837*				
v/c		*0.01*		*0.05*				
95% queue length		*0.03*		*0.17*				
Control Delay (s/veh)		*7.4*		*9.5*				
LOS		*A*		*A*				
Approach Delay (s/veh)	--	--	*9.5*					
Approach LOS	--	--	*A*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Peak PM Hour*

Site Information

Intersection	*Mary & Bitteroot*
Jurisdiction	*MDT*
Analysis Year	*Existing 2010*

Project Description *Billings Bypass*	
East/West Street: *Mary Street*	North/South Street: *Bitteroot*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*8*	*16*	*13*	*9*	*17*	*4*
Peak-Hour Factor, PHF	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*16*	*32*	*26*	*18*	*34*	*8*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration	*LTR*			*LTR*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*14*	*27*	*5*	*1*	*26*	*20*
Peak-Hour Factor, PHF	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*28*	*54*	*10*	*2*	*52*	*40*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*LTR*	*LTR*		*LTR*			*LTR*	
v (veh/h)	*16*	*18*		*92*			*94*	
C (m) (veh/h)	*1580*	*1559*		*735*			*826*	
v/c	*0.01*	*0.01*		*0.13*			*0.11*	
95% queue length	*0.03*	*0.04*		*0.43*			*0.38*	
Control Delay (s/veh)	*7.3*	*7.3*		*10.6*			*9.9*	
LOS	*A*	*A*		*B*			*A*	
Approach Delay (s/veh)	--	--	*10.6*			*9.9*		
Approach LOS	--	--	*B*			*A*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Associates*
Date Performed	*10/27/2011*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*Mary & Hawthorne*
Jurisdiction	*MDT*
Analysis Year	*2010 Existing*

Project Description *Billings Bypass*

East/West Street: *Mary Street*
North/South Street: *Hawthorne*

Intersection Orientation: *East-West*
Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*38*	*35*	*1*	*29*	
Peak-Hour Factor, PHF	*1.00*	*0.50*	*0.50*	*0.50*	*0.50*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*76*	*70*	*2*	*58*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*19*		*1*			
Peak-Hour Factor, PHF	*0.50*	*1.00*	*0.50*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*38*	*0*	*2*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*5*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*2*		*40*				
C (m) (veh/h)		*1448*		*826*				
v/c		*0.00*		*0.05*				
95% queue length		*0.00*		*0.15*				
Control Delay (s/veh)		*7.5*		*9.6*				
LOS		*A*		*A*				
Approach Delay (s/veh)	--	--	*9.6*					
Approach LOS	--	--	*A*					

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Mary & Bench*
Agency/Co.	*Marvin & Associates*	Jurisdiction	*MDT*
Date Performed	*10/27/2011*	Analysis Year	*Existing 2010*
Analysis Time Period	*Peak PM Hour*		

Project Description *Billings Bypass*

East/West Street: *Mary Street* — North/South Street: *Bench Blvd*

Intersection Orientation: *North-South* — Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*106*	*32*	*6*	*57*	
Peak-Hour Factor, PHF	*1.00*	*0.75*	*0.75*	*0.70*	*0.70*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*141*	*42*	*8*	*81*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)		*66*	*6*	*59*		*6*
Peak-Hour Factor, PHF	*1.00*	*0.75*	*0.75*	*0.70*	*1.00*	*0.70*
Hourly Flow Rate, HFR (veh/h)	*0*	*88*	*8*	*84*	*0*	*8*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)		*0*			*0*	
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*0*	*0*
Configuration			*TR*		*LR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				*TR*
v (veh/h)		*8*		*92*				*96*
C (m) (veh/h)		*1404*		*590*				*648*
v/c		*0.01*		*0.16*				*0.15*
95% queue length		*0.02*		*0.55*				*0.52*
Control Delay (s/veh)		*7.6*		*12.2*				*11.5*
LOS		*A*		*B*				*B*
Approach Delay (s/veh)	--	--	*12.2*			*11.5*		
Approach LOS	--	--	*B*			*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*12/8/2011*
Analysis Time Period	*PM Design Hour*

Site Information

Intersection	*Dover & Highway 312*
Jurisdiction	*MDT*
Analysis Year	*Existing 2010*

Project Description *Billings Bypass*

East/West Street: *Highway 312* | North/South Street: *Dover Road*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*574*	*69*	*20*	*272*	
Peak-Hour Factor, PHF	*1.00*	*0.92*	*0.92*	*0.90*	*0.90*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*623*	*74*	*22*	*302*	*0*
Percent Heavy Vehicles	*0*	--	--	*4*	--	--
Median Type	*Two Way Left Turn Lane*					
RT Channelized			*0*			*0*
Lanes	*0*	*2*	*0*	*1*	*2*	*0*
Configuration		*T*	*TR*	*L*	*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*36*		*16*			
Peak-Hour Factor, PHF	*0.60*	*1.00*	*0.60*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*59*	*0*	*26*	*0*	*0*	*0*
Percent Heavy Vehicles	*4*	*0*	*4*	*0*	*0*	*0*
Percent Grade (%)	*2*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*0*	*1*	*0*	*0*	*0*
Configuration	*L*		*R*			

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*L*	*L*		*R*			
v (veh/h)		*22*	*59*		*26*			
C (m) (veh/h)		*882*	*358*		*674*			
v/c		*0.02*	*0.16*		*0.04*			
95% queue length		*0.08*	*0.58*		*0.12*			
Control Delay (s/veh)		*9.2*	*17.0*		*10.6*			
LOS		*A*	*C*		*B*			
Approach Delay (s/veh)	--	--	*15.0*					
Approach LOS	--	--	*C*					

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Main & Bench US87*
Agency/Co.	*Marvin & Associates*	Jurisdiction	*MDT*
Date Performed	*10/27/2011*	Analysis Year	*2010 Exsiting*
Analysis Time Period	*Peak PM*		

Project Description *Billings Bypass*

East/West Street: *Main HWY 312* | North/South Street: *Bench US87*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	302	541		49	330	3
Peak-Hour Factor, PHF	0.90	0.90	1.00	0.88	0.88	0.88
Hourly Flow Rate, HFR (veh/h)	335	601	0	55	375	3
Percent Heavy Vehicles	5	--	--	0	--	--
Median Type	Raised curb					
RT Channelized			0			0
Lanes	1	2	0	1	2	0
Configuration	L	T		L	T	TR
Upstream Signal		1			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	2	25	85	8	13	194
Peak-Hour Factor, PHF	0.75	0.75	0.75	0.80	0.80	0.80
Hourly Flow Rate, HFR (veh/h)	2	33	113	9	16	242
Percent Heavy Vehicles	0	0	0	1	0	5
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	1	0	1	1
Configuration	LT		R	LT		R

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L	L	LT		R	LT		R
v (veh/h)	335	55	35		113	25		242
C (m) (veh/h)	1156	1071	59		902	51		842
v/c	0.29	0.05	0.59		0.13	0.49		0.29
95% queue length	1.21	0.16	2.42		0.43	1.84		1.19
Control Delay (s/veh)	9.4	8.5	131.5		9.6	130.4		11.0
LOS	A	A	F		A	F		B
Approach Delay (s/veh)	--	--	38.4			22.2		
Approach LOS	--	--	E			C		

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HCM Analysis Summary

Existing 2010	Wicks Lane/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
Peak PM Hour	Case: WICKSM~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	158	306	235	386	274	26	468	1098	228	38	553	93
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			5			80			30		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	--- | ---			--- | ---			--- | ---			--- | ---		

Signal Settings: Actuated   Operational Analysis   Cycle Length: 120.0 Sec   Lost Time Per Cycle: 18.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB				LTR					
WB			LTP						
NB	L	TP							
SB	L	TP							
Green	21.0	36.0	25.0	20.0					0
Yellow / All Red	3.0 / 0.0	3.5 / 1.5	3.5 / 1.5	3.5 / 1.5					

App	Capacity Analysis Results								Approach:	
	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	301	0.098	0.167	L	0.585	48.1	D	58.3	E
	* TR	571	0.149	0.167	TR	0.897	61.8	E		
WB										
	* L	376	0.166	0.208	L	0.798	55.7	E	48.9	D
	LTR	736	0.129	0.208	LTR	0.620	44.4	D		
NB										
	* L	613	0.148	0.175	L	0.848	54.8	D	44.1	D
	* TR	1498	0.277	0.300	TR	0.924	40.1	D		
SB										
	L	316	0.023	0.175	L	0.133	42.7	D	35.0	D
	TR	1502	0.137	0.300	TR	0.455	34.6	C		

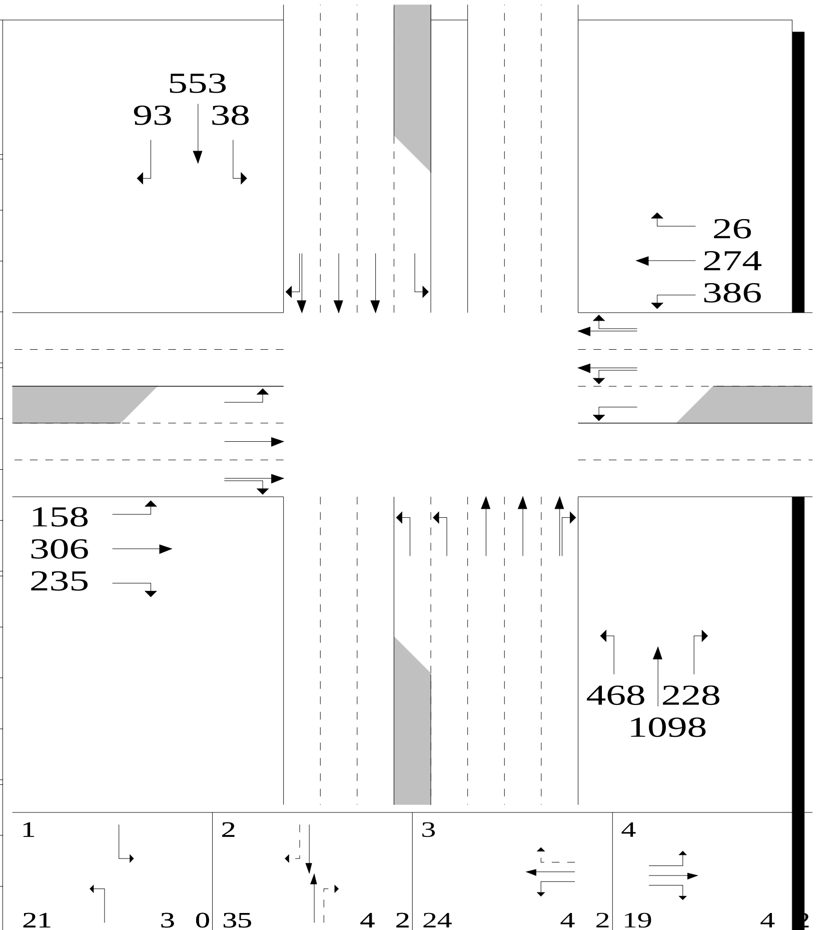
Intersection: Delay = 45.8 sec/veh   Int. LOS=D X_c= 0.87   * Critical Lane Group Σ(v/s)Crit= 0.74

NETSIM Summary Results

Existing 2010
R Marvin
Peak PM Hour

Wicks Lane/Main Street
10/12/2011
Case: WICKSM~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	3 / 7	7.6	0.0
	TR	3 / 6	13.5	0.0
	All		11.8	0.0
WB	L	7 / 9	4.1	0.0
	LTR	7 / 8	8.6	0.0
	All		7.2	0.0
NB	L	9 / 9	4.0	0.0
	TR	7 / 10	8.9	0.0
	All		6.8	0.0
SB	L	3 / 5	3.2	0.0
	TR	2 / 5	14.9	0.0
	All		11.8	0.0
Intersect.			8.1	



HCM Analysis Summary

Existing 2010	Airport Road/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
Peak PM Hour	Case: AIRPOR~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	576	12	26	24	39	89	142	2757	9	69	1743	265
PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 150.0 Sec   Lost Time Per Cycle: 20.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP				R												
WB				LTP														
NB						LTP		TP										
SB								TP		LTR								
Green		32.0		7.0		15.0		66.0		7.0								0
Yellow	All Red	3.5	1.5	3.5	1.5	3.0	0.0	3.5	1.5	3.5	1.5							

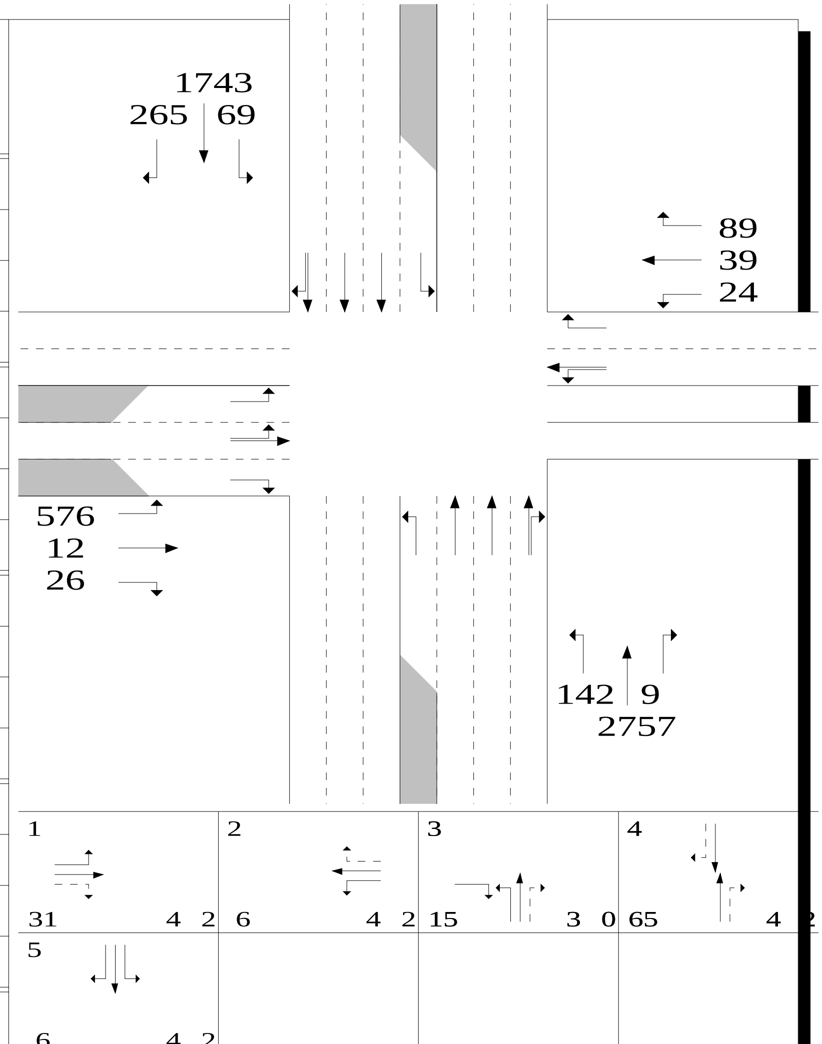
	Capacity Analysis Results								Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	378	0.175	0.213	L	0.817	68.5	E	70.4	E
	* LT	379	0.182	0.213	LT	0.852	72.8	E		
	R	515	0.004	0.333	R	0.012	33.5	C		
WB										
	LT	86	0.037	0.047	LT	0.791	106.1	F	114.1	F
	* R	75	0.039	0.047	R	0.840	122.7	F		
NB										
	L	177	0.086	0.100	L	0.864	101.0	F	38.4	D
	* TR	2846	0.585	0.560	TR	1.045	35.2	D		
SB										
	* L	84	0.041	0.047	L	0.881	138.0	F	15.0	B
	TR	2609	0.409	0.520	TR	0.786	10.6	B		

Intersection: Delay = 35.2 sec/veh   Int. LOS=D X_c= 0.98   * Critical Lane Group Σ(v/s)Crit= 0.85

NETSIM Summary Results

Existing 2010 | Airport Road/Main Street
R Marvin | 10/12/2011
Peak PM Hour | Case: AIRPOR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	11 / 12	5.0	0.0
	LT	11 / 11	6.5	0.0
	R	1 / 1	17.4	0.0
	All		5.9	0.0
WB	LT	3 / 4	5.3	0.0
	R	3 / 4	9.8	0.0
	All		7.8	0.0
NB	L	5 / 8	4.6	0.0
	TR	17 / 21	9.4	1.4
	All		9.1	1.4
SB	L	4 / 7	3.4	0.0
	TR	6 / 10	15.2	0.0
	All		13.7	0.0
Intersect.			9.7	



HCM Analysis Summary

Existing 2010	1st Ave N/	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
Peak PM Hour	Case: US87MA~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1207	318	0	0	345	899	0	0	0	889	0	429
PHF	0.93	0.93	0.90	0.90	0.93	0.93	0.90	0.90	0.90	0.93	0.90	0.93
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			200			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 140.0 Sec Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		45.0		25.0		55.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

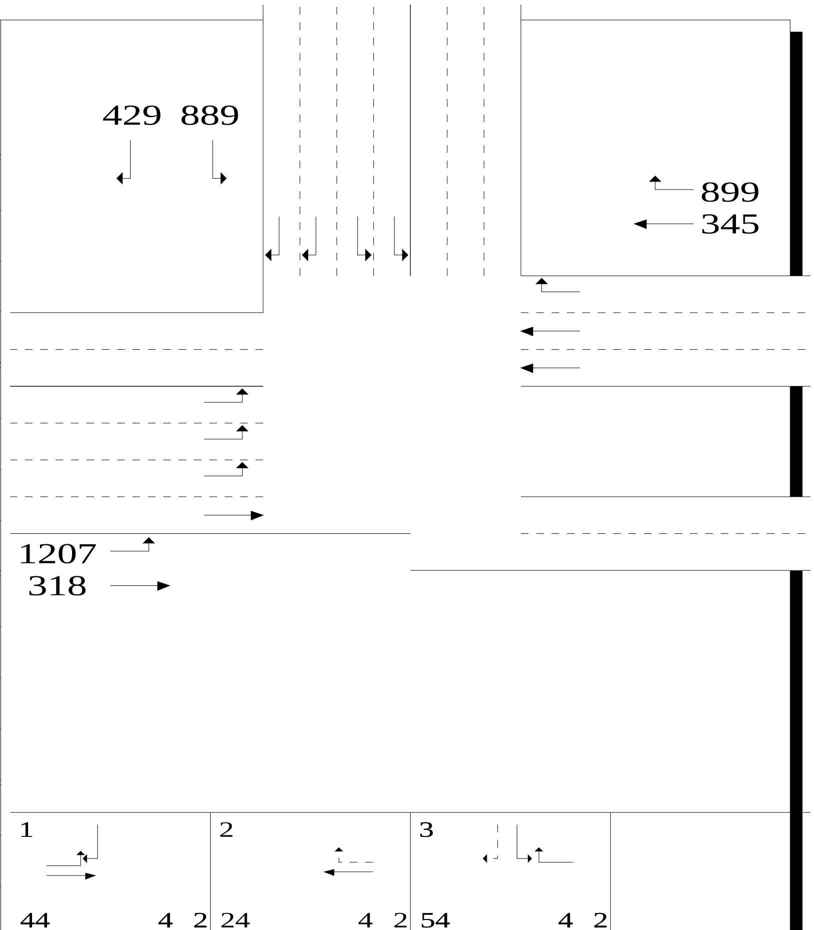
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	1655	0.252	0.321	L	0.784	33.3	C	32.8	C
	T	599	0.184	0.321	T	0.571	30.9	C		
WB										
	T	632	0.105	0.179	T	0.587	53.7	D	34.8	C
	* R	943	0.484	0.607	R	0.797	25.4	C		
SB										
	L	1323	0.284	0.393	L	0.723	23.9	C	16.2	B
	R	2090	0.165	0.750	R	0.221	0.2	A		

Intersection: Delay = 27.7 sec/veh Int. LOS=C X_c= 0.79 * Critical Lane Group Σ(v/s)Crit= 0.74

NETSIM Summary Results

Existing 2010	1st Ave N/
R Marvin	10/12/2011
Peak PM Hour	Case: US87MA~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	10 / 19	5.3	0.0
	T	3 / 3	13.6	0.0
	All		6.0	0.0
WB	T	6 / 9	6.1	0.0
	R	7 / 8	15.7	0.0
	All		11.0	0.0
	All		6.1	0.0
SB	L	18 / 24	4.5	0.0
	R	1 / 2	22.5	0.0
Intersect.			7.0	



HCM Analysis Summary

Existing 2010	Old US 87/I90 WB On Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: WBRAMP~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	776	323	145	696	0	0	0	0	9	2	289
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)		120			0			0			80	
Peds/Hour		0			5			0			0	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 90.0 Sec   Lost Time Per Cycle: 14.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB			TR														
WB	LT		LT														
NB																	
SB					LTR												
Green	10.0		44.0		22.0												0
Yellow / All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1628	0.327	0.489	TR	0.668	23.6	C	23.6	C
WB	Lper	134	0.000	0.544					12.1	B
	* Lpro	199	0.090	0.111	L	0.483	15.8	B		
	T	2216	0.225	0.644	T	0.349	11.4	B		
SB										
	* LTR	385	0.155	0.244	LTR	0.634	33.0	C	33.0	C

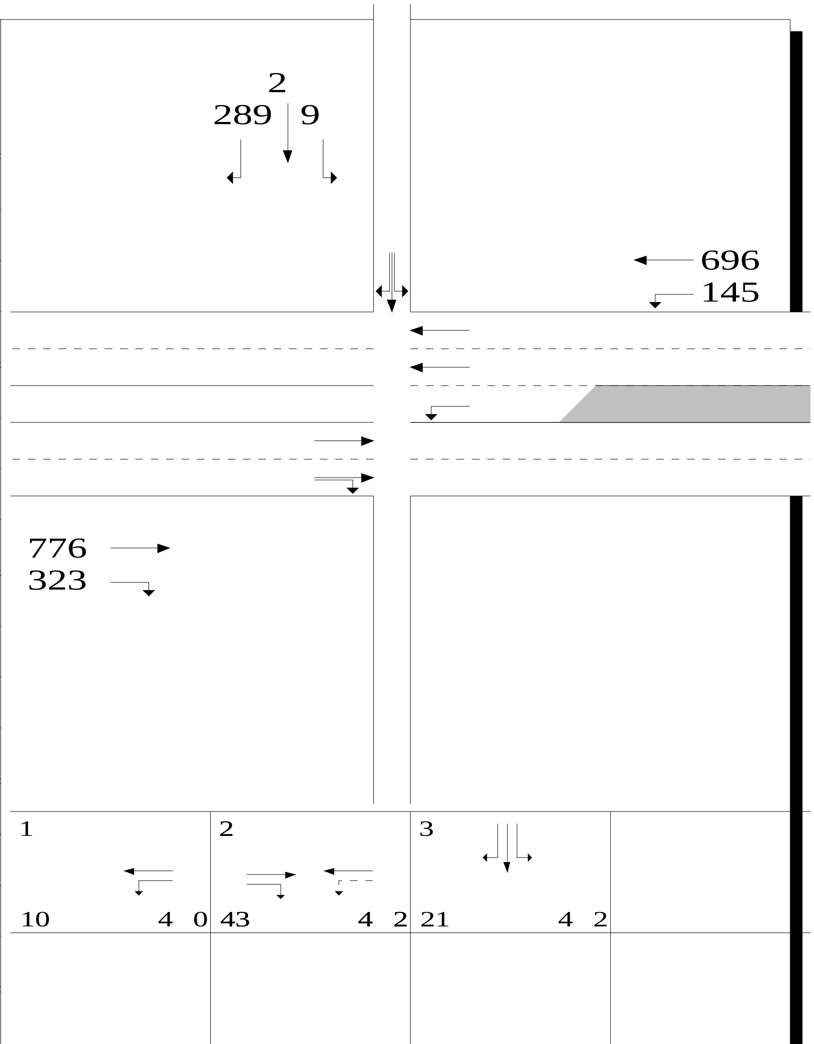
Intersection: Delay = 19.9 sec/veh   Int. LOS=B X_c= 0.68   * Critical Lane Group Σ(v/s)Crit= 0.57

NETSIM Summary Results

Existing 2010
R Marvin
PM Design Hour

Old US 87/I90 WB On Ramp
10/13/2011
Case: WBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 14	12.0	0.0
	All		12.0	0.0
WB	L	1 / 3	7.7	0.0
	T	0 / 1	25.5	0.0
	All		21.2	0.0
	All		16.6	0.0
SB	LTR	3 / 5	16.6	0.0
Intersect.			14.9	



HCM Analysis Summary

Existing 2010	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
Peak PM Hour	Case: EBRAMP~2	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	360	426	0	0	375	10	466	1	222	0	0	0
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 100.0 Sec Lost Time Per Cycle: 9.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT		LT														
WB				TR														
NB						LTP												
SB																		
Green		18.0		30.0		38.0												0
Yellow	All Red	4.0	0.0	3.5	1.5	3.5	1.5											

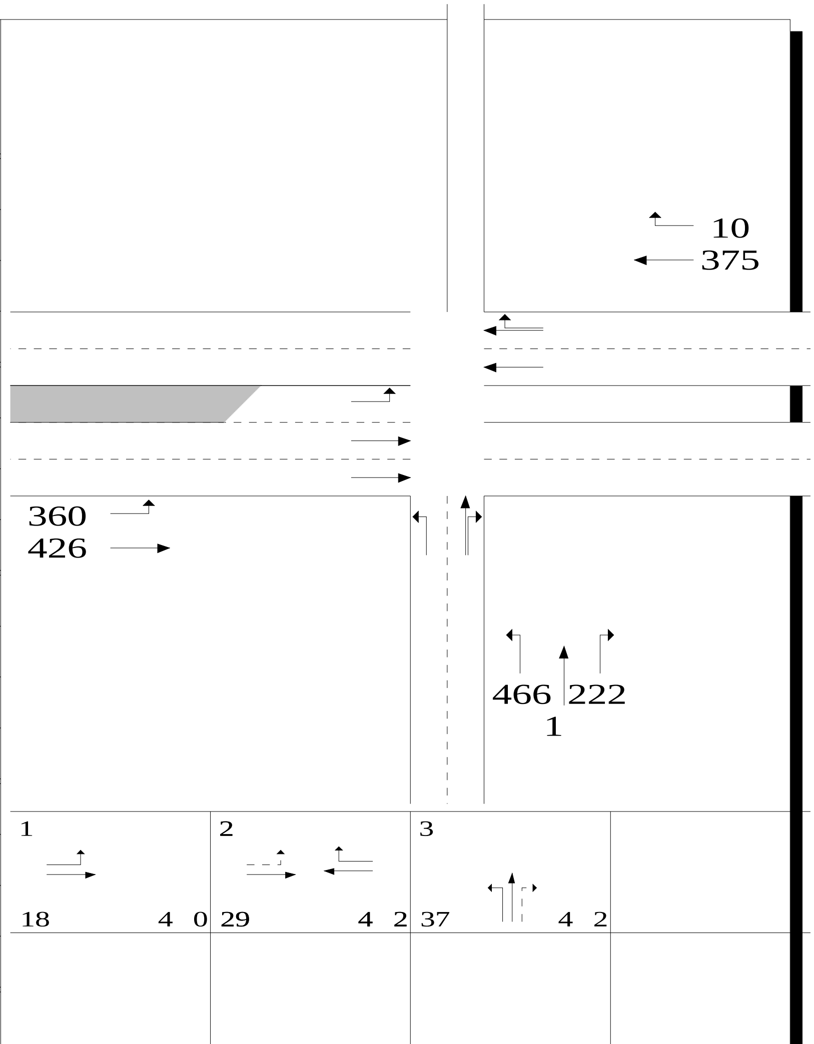
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	232	0.133	0.350					18.3	B
	* Lpro	312	0.180	0.180	L	0.735	23.8	C		
	T	1858	0.132	0.520	T	0.255	13.6	B		
WB										
	TR	1060	0.120	0.300	TR	0.399	29.0	C	29.0	C
NB										
	* L	651	0.303	0.380	L	0.796	33.8	C	31.2	C
	TR	602	0.086	0.380	TR	0.228	21.1	C		

Intersection: Delay = 24.9 sec/veh Int. LOS=C X_c= 0.68 * Critical Lane Group Σ(v/s)Crit= 0.62

NETSIM Summary Results

Existing 2010	Old US 87/I90 EB Off Ramp
R Marvin	10/13/2011
Peak PM Hour	Case: EBRAMP~2

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	9 / 14	6.8	0.0
	T	4 / 5	18.8	0.0
	All		12.9	0.0
WB	TR	4 / 6	10.2	0.0
	All		10.2	0.0
NB	L	10 / 12	9.4	0.0
	TR	2 / 2	20.6	0.0
	All		11.2	0.0
Intersect.			11.6	



HCM Analysis Summary

Existing 2010	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
Peak PM Hour	Case: EBRAMP~2	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	360	426	0	0	375	10	466	1	222	0	0	0
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 100.0 Sec Lost Time Per Cycle: 9.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LT	LT							
WB		TR							
NB			LTP						
SB									
Green	18.0	30.0	38.0						0
Yellow / All Red	4.0 / 0.0	3.5 / 1.5	3.5 / 1.5						

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB	* Lper	232	0.133	0.350					18.3	B
	* Lpro	312	0.180	0.180	L	0.735	23.8	C		
	T	1858	0.132	0.520	T	0.255	13.6	B		
WB										
	TR	1060	0.120	0.300	TR	0.399	29.0	C	29.0	C
NB										
	* L	651	0.303	0.380	L	0.796	33.8	C	31.2	C
	TR	602	0.086	0.380	TR	0.228	21.1	C		

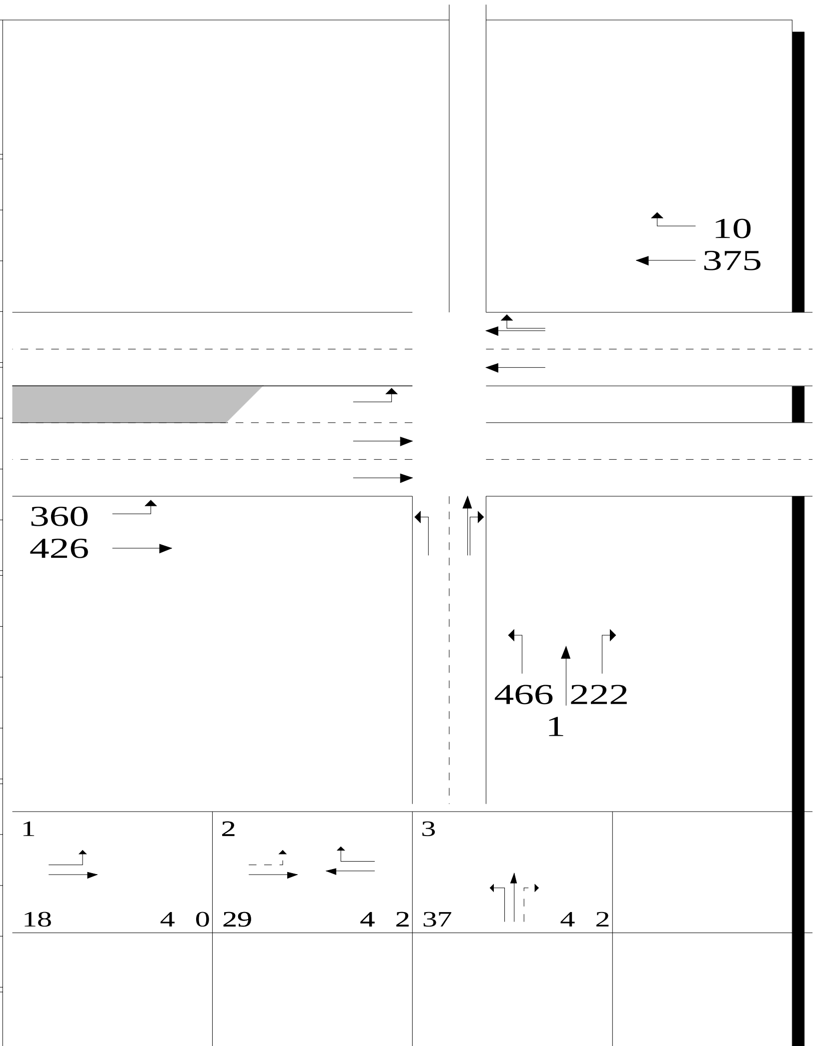
Intersection: Delay = 24.9 sec/veh Int. LOS=C X_c= 0.68 * Critical Lane Group Σ(v/s)Crit= 0.62

NETSIM Summary Results

Existing 2010
R Marvin
Peak PM Hour

Old US 87/I90 EB Off Ramp
10/13/2011
Case: EBRAMP~2

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	9 / 14	6.8	0.0
	T	4 / 5	18.8	0.0
	All		12.9	0.0
WB	TR	4 / 6	10.2	0.0
	All		10.2	0.0
NB	L	10 / 12	9.4	0.0
	TR	2 / 2	20.6	0.0
	All		11.2	0.0
Intersect.			11.6	



TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Johnson WB Ramps*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*10/10/2011*	Analysis Year	*Existing PM*
Analysis Time Period	*Peak PM Hour*		

Project Description *Billings Bypass*	
East/West Street: *WB Ramps*	North/South Street: *Johnson Lane*
Intersection Orientation: *North-South*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*253*	*157*			*186*	*63*
Peak-Hour Factor, PHF	*0.80*	*0.80*	*1.00*	*1.00*	*0.80*	*0.80*
Hourly Flow Rate, HFR (veh/h)	*316*	*196*	*0*	*0*	*232*	*78*
Percent Heavy Vehicles	*8*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*0*	*1*	*1*
Configuration	*L*	*T*			*T*	*R*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*82*		*38*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.75*	*1.00*	*0.75*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*109*	*0*	*50*
Percent Heavy Vehicles	*0*	*0*	*0*	*8*	*0*	*10*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*			*LR*				
v (veh/h)	*316*			*159*				
C (m) (veh/h)	*1217*			*227*				
v/c	*0.26*			*0.70*				
95% queue length	*1.04*			*4.56*				
Control Delay (s/veh)	*9.0*			*51.1*				
LOS	*A*			*F*				
Approach Delay (s/veh)	--	--	*51.1*					
Approach LOS	--	--	*F*					

 *HCS+*TM Version 5.6 Generated: 12/7/2011 8:50 PM

HCM Analysis Summary

Existing 2010
R Marvin
Peak PM Hour

Old Hardin Road/Johnson lane
10/13/2011
Case: OLDHAR~1

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	LT	12.0	R	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	3	1	L	12.0	T	12.0	R	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	116	314	18	28	82	288	18	64	28	480	70	128
PHF	0.88	0.88	0.88	0.80	0.80	0.80	0.75	0.75	0.75	0.90	0.90	0.90
% Heavy Vehicles	10	0	0	0	0	0	1	1	0	0	1	10
Lane Groups	L	TR			LT	R	L	TR		L	T	R
Arrival Type	3	3			3	3	3	3		3	3	3
RTOR Vol (vph)	5			60			5			15		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 100.0 Sec   Lost Time Per Cycle: 14.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP	LTP							
WB		LTR	R						
NB				LTP					
SB			LTP	LTP					
Green	12.0	20.0	30.0	20.0					0
Yellow / All Red	4.0 / 0.0	3.5 / 1.5	4.0 / 0.0	3.5 / 1.5					

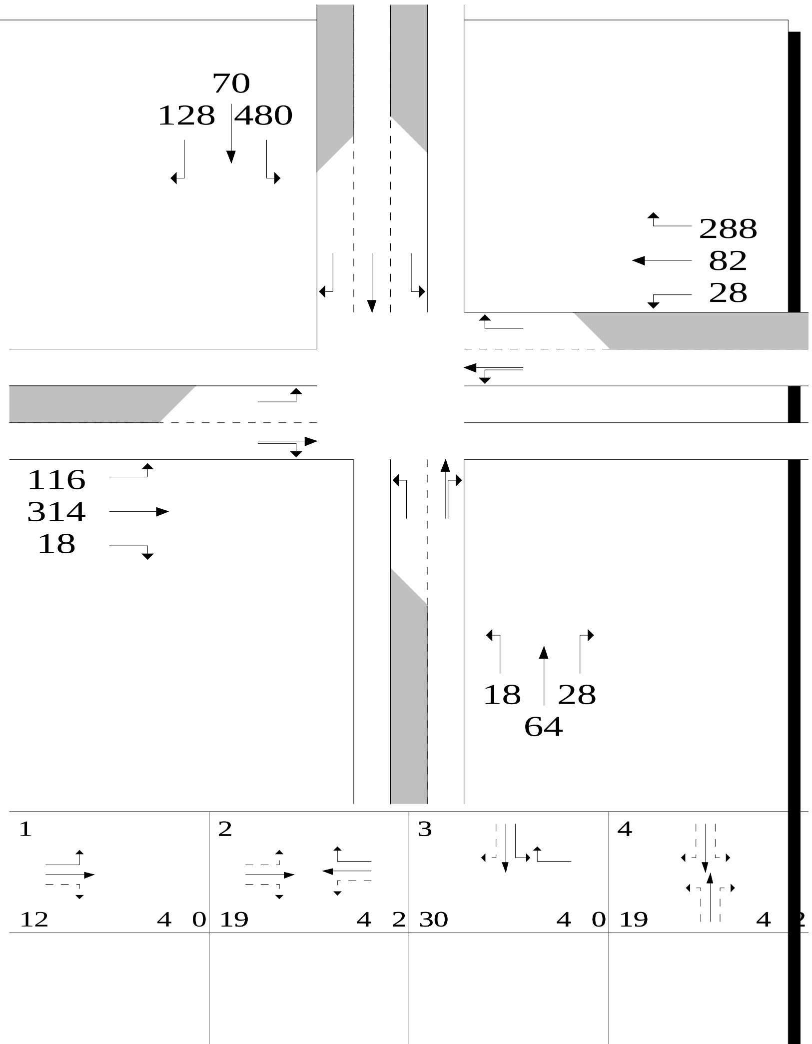
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	Lper	213	0.000	0.250					25.0	C
	Lpro	197	0.080	0.120	L	0.322	22.0	C		
	* TR	680	0.197	0.360	TR	0.547	26.0	C		
WB										
	LT	314	0.087	0.200	LT	0.436	35.4	D	19.9	B
	R	888	0.176	0.550	R	0.321	12.4	B		
NB										
	L	265	0.018	0.200	L	0.091	32.6	C	34.1	C
	* TR	360	0.064	0.200	TR	0.322	34.4	C		
SB	Lper	252	0.000	0.250					15.0	B
	* Lpro	542	0.295	0.300	L	0.671	16.4	B		
	T	1016	0.041	0.540	T	0.077	11.0	B		
	R	789	0.086	0.540	R	0.160	11.6	B		

Intersection: Delay = 20.4 sec/veh   Int. LOS=C X_c= 0.65   * Critical Lane Group Σ(v/s)Crit= 0.56

NETSIM Summary Results

Existing 2010	Old Hardin Road/Johnson lane
R Marvin	10/13/2011
Peak PM Hour	Case: OLDHAR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	3 / 4	7.7	0.0
	TR	7 / 9	11.9	0.0
	All		10.9	0.0
WB	LT	3 / 4	17.7	0.0
	R	2 / 4	18.7	0.0
	All		18.0	0.0
NB	L	1 / 2	4.7	0.0
	TR	2 / 3	11.6	0.0
	All		10.5	0.0
SB	L	7 / 10	12.8	0.0
	T	1 / 4	19.2	0.0
	R	1 / 2	21.5	0.0
	All		14.7	0.0
Intersect.			13.7	



TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/28/2011*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*Becraft & Old Hardin Road*
Jurisdiction	*MDT*
Analysis Year	*Existing PM*

Project Description *Billings Bypass*

East/West Street: *Old Hardin Road* | North/South Street: *Becraft Lane*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*400*	*410*	*30*	*300*	
Peak-Hour Factor, PHF	*1.00*	*0.92*	*0.92*	*0.88*	*0.88*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*434*	*445*	*34*	*340*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*1*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*95*		*25*			
Peak-Hour Factor, PHF	*0.80*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*118*	*0*	*31*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)		*0*			*0*	
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*34*		*149*				
C (m) (veh/h)		*670*		*243*				
v/c		*0.05*		*0.61*				
95% queue length		*0.16*		*3.63*				
Control Delay (s/veh)		*10.7*		*40.8*				
LOS		*B*		*E*				
Approach Delay (s/veh)	--	--		*40.8*				
Approach LOS	--	--		*E*				

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Peak MPM Hour*

Site Information

Intersection	*N Frntg & Johnson*
Jurisdiction	*MDT*
Analysis Year	*Existing 2010*

Project Description *Billings Bypass*

East/West Street: *N Frontage Road* | North/South Street: *Johnson Lane*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*155*	*30*	*10*	*1*	*32*	*20*
Peak-Hour Factor, PHF	*0.75*	*0.75*	*0.75*	*0.50*	*0.50*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*206*	*40*	*13*	*2*	*64*	*40*
Percent Heavy Vehicles	*10*	--	--	*4*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*23*	*4*	*192*	*25*	*7*	*1*
Peak-Hour Factor, PHF	*0.75*	*0.75*	*0.75*	*0.50*	*0.50*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*30*	*5*	*256*	*50*	*14*	*2*
Percent Heavy Vehicles	*4*	*4*	*10*	*4*	*4*	*4*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*	*L*		*TR*	*L*		*TR*
v (veh/h)	*206*	*2*	*50*		*16*	*30*		*261*
C (m) (veh/h)	*1439*	*1540*	*235*		*401*	*379*		*927*
v/c	*0.14*	*0.00*	*0.21*		*0.04*	*0.08*		*0.28*
95% queue length	*0.50*	*0.00*	*0.78*		*0.12*	*0.26*		*1.16*
Control Delay (s/veh)	*7.9*	*7.3*	*24.4*		*14.4*	*15.3*		*10.4*
LOS	*A*	*A*	*C*		*B*	*C*		*B*
Approach Delay (s/veh)	--	--	*22.0*			*10.9*		
Approach LOS	--	--	*C*			*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Peak PM Hour*

Site Information

Intersection	*Coulson & Johnson*
Jurisdiction	*MDT*
Analysis Year	*Existing 2010*

Project Description *Billings Bypass*

East/West Street: *Coulson Road* North/South Street: *Johnson Lane*

Intersection Orientation: *North-South* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*2*	*28*	*1*	*15*	
Peak-Hour Factor, PHF	*1.00*	*0.50*	*0.50*	*0.50*	*0.50*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*4*	*56*	*2*	*30*	*0*
Percent Heavy Vehicles	*0*	--	--	*5*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*38*		*2*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.50*	*1.00*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*76*	*0*	*4*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*2*		*80*				
C (m) (veh/h)		*1525*		*936*				
v/c		*0.00*		*0.09*				
95% queue length		*0.00*		*0.28*				
Control Delay (s/veh)		*7.4*		*9.2*				
LOS		*A*		*A*				
Approach Delay (s/veh)	--	--	*9.2*					
Approach LOS	--	--	*A*					

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BASIC FREEWAY SEGMENTS WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway/Direction of Travel	*EB*
Agency or Company	*Marvin Associates*	From/To	*N 27th to Lockwood*
Date Performed	*12/5/2011*	Jurisdiction	*MDT*
Analysis Time Period	*PM Design Hour*	Analysis Year	*2010 Existing*

Project Description *Billings Bypass*

☑ Oper.(LOS) ☐ Des.(N) ☐ Planning Data

Flow Inputs

Volume, V	*1500*	veh/h	Peak-Hour Factor, PHF	*0.92*
AADT		veh/day	%Trucks and Buses, P_T	*15*
Peak-Hr Prop. of AADT, K			%RVs, P_R	*2*
Peak-Hr Direction Prop, D			General Terrain:	*Level*
DDHV = AADT x K x D		veh/h	Grade % Length Up/Down %	*mi*

Calculate Flow Adjustments

f_p	*0.95*	E_R	*1.2*
E_T	*1.5*	$f_{HV} = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]$	*0.927*

Speed Inputs			Calc Speed Adj and FFS		
Lane Width		ft	f_{LW}		mph
Rt-Side Lat. Clearance		ft	f_{LC}		mph
Number of Lanes, N	*2*		TRD Adjustment		mph
Total Ramp Density, TRD		ramps/mi	FFS	*65.0*	mph
FFS (measured)	*65.0*	mph			
Base free-flow Speed, BFFS		mph			

LOS and Performance Measures			Design (N)	
Operational (LOS)			Design (N)	
			Design LOS	
v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	*926*	pc/h/ln	v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	pc/h/ln
S	*65.0*	mph	S	mph
D = v_p / S	*14.2*	pc/mi/ln	D = v_p / S	pc/mi/ln
LOS	*B*		Required Number of Lanes, N	

Glossary

N - Number of lanes
S - Speed
V - Hourly volume
D - Density
v_p - Flow rate
FFS - Free-flow speed
LOS - Level of service
BFFS - Base free-flow speed
DDHV - Directional design hour volume

Factor Location

E_R - Exhibits 11-10, 11-12
f_{LW} - Exhibit 11-8
E_T - Exhibits 11-10, 11-11, 11-13
f_{LC} - Exhibit 11-9
f_p - Page 11-18
TRD - Page 11-11
LOS, S, FFS, v_p - Exhibits 11-2, 11-3

 HCS 2010™ Version 6.1 Generated: 12/16/2011 5:08 PM

BASIC FREEWAY SEGMENTS WORKSHEET

General Information		**Site Information**	
Analyst	*R Marvin*	Highway/Direction of Travel	*EB*
Agency or Company	*Marvin Associates*	From/To	*Lockwood to Johnson*
Date Performed	*12/5/2011*	Jurisdiction	*MDT*
Analysis Time Period	*PM Design Hour*	Analysis Year	*2010 Existing*

Project Description *Billings Bypass*

☑ Oper.(LOS) ☐ Des.(N) ☐ Planning Data

Flow Inputs

Volume, V	*1300*	veh/h	Peak-Hour Factor, PHF	*0.90*
AADT		veh/day	%Trucks and Buses, P_T	*15*
Peak-Hr Prop. of AADT, K			%RVs, P_R	*2*
Peak-Hr Direction Prop, D			General Terrain:	*Level*
DDHV = AADT x K x D		veh/h	Grade % Length Up/Down %	*mi*

Calculate Flow Adjustments

f_p	*0.95*	E_R	*1.2*
E_T	*1.5*	$f_{HV} = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]$	*0.927*

Speed Inputs			**Calc Speed Adj and FFS**		
Lane Width		ft			
Rt-Side Lat. Clearance		ft	f_{LW}		mph
Number of Lanes, N	*2*		f_{LC}		mph
Total Ramp Density, TRD		ramps/mi	TRD Adjustment		mph
FFS (measured)	*65.0*	mph	FFS	*65.0*	mph
Base free-flow Speed, BFFS		mph			

LOS and Performance Measures			**Design (N)**	
Operational (LOS)			Design (N)	
			Design LOS	
v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	*820*	pc/h/ln	v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	pc/h/ln
S	*65.0*	mph	S	mph
D = v_p / S	*12.6*	pc/mi/ln	D = v_p / S	pc/mi/ln
LOS	*B*		Required Number of Lanes, N	

Glossary		**Factor Location**	
N - Number of lanes	S - Speed	E_R - Exhibits 11-10, 11-12	f_{LW} - Exhibit 11-8
V - Hourly volume	D - Density	E_T - Exhibits 11-10, 11-11, 11-13	f_{LC} - Exhibit 11-9
v_p - Flow rate	FFS - Free-flow speed	f_p - Page 11-18	TRD - Page 11-11
LOS - Level of service	BFFS - Base free-flow speed	LOS, S, FFS, v_p - Exhibits 11-2, 11-3	
DDHV - Directional design hour volume			

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BASIC FREEWAY SEGMENTS WORKSHEET

General Information		***Site Information***	
Analyst	*R Marvin*	Highway/Direction of Travel	*EB*
Agency or Company	*Marvin Associates*	From/To	*Johnson to Pinehills*
Date Performed	*12/5/2011*	Jurisdiction	*MDT*
Analysis Time Period	*PM Design Hour*	Analysis Year	*2010 Existing*

Project Description *Billings Bypass*

☑ Oper.(LOS) ☐ Des.(N) ☐ Planning Data

Flow Inputs

Volume, V	*850*	veh/h	Peak-Hour Factor, PHF	*0.90*
AADT		veh/day	%Trucks and Buses, P_T	*22*
Peak-Hr Prop. of AADT, K			%RVs, P_R	*2*
Peak-Hr Direction Prop, D			General Terrain:	*Level*
DDHV = AADT x K x D		veh/h	Grade % Length Up/Down %	*mi*

Calculate Flow Adjustments

f_p	*0.95*	E_R	*1.2*
E_T	*1.5*	$f_{HV} = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]$	*0.898*

Speed Inputs

Lane Width		ft
Rt-Side Lat. Clearance		ft
Number of Lanes, N	*2*	
Total Ramp Density, TRD		ramps/mi
FFS (measured)	*65.0*	mph
Base free-flow Speed, BFFS		mph

Calc Speed Adj and FFS

f_{LW}		mph
f_{LC}		mph
TRD Adjustment		mph
FFS	*65.0*	mph

LOS and Performance Measures

Operational (LOS)

v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	*554*	pc/h/ln
S	*65.0*	mph
D = v_p / S	*8.5*	pc/mi/ln
LOS	*A*	

Design (N)

Design (N)

Design LOS		
v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)		pc/h/ln
S		mph
D = v_p / S		pc/mi/ln
Required Number of Lanes, N		

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design hour volume
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed

Factor Location

E_R - Exhibits 11-10, 11-12
E_T - Exhibits 11-10, 11-11, 11-13
f_p - Page 11-18
LOS, S, FFS, v_p - Exhibits 11-2, 11-3
f_{LW} - Exhibit 11-8
f_{LC} - Exhibit 11-9
TRD - Page 11-11

 HCS 2010™ Version 6.1 Generated: 12/16/2011 5:11 PM

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Lockwood
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: Yes ☐ On ☐ No ☑ Off ☐; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	500
Freeway Volume, V_F	1300
Ramp Volume, V_R	690
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: Yes ☐ On ☐ No ☑ Off ☐; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	1300	0.92	Level	15	0	0.930	0.95	1599
Ramp	690	0.92	Level	10	0	0.952	0.95	829
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = using Equation (Exhibit 13-6)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734 v_R + 0.0078 V_{12} - 0.00627 L_A$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)

S_R= mph (Exhibit 13-11)

S_0= mph (Exhibit 13-11)

S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 1.000 using Equation (Exhibit 13-7)

V_{12} = 1599 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	1599	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	770	Exhibit 13-8	4700	No
V_R	829	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1599	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086 V_{12} - 0.009 L_D$

D_R = 13.5 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

D_s = 0.503 (Exhibit 13-12)

S_R= 53.4 mph (Exhibit 13-12)

S_0= N/A mph (Exhibit 13-12)

S = 53.4 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB On-Ramp
Agency or Company	Marvin Associates	Junction	Lockwood
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp

- [ ] Yes [ ] On
- [x] No [ ] Off

L_{up} = ft

V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	930
Ramp Volume, V_R	370
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp

- [ ] Yes [ ] On
- [x] No [ ] Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	930	0.92	Level	15	4	0.923	0.95	1152
Ramp	370	0.92	Level	4	4	0.973	0.95	435
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$$V_{12} = V_F (P_{FM})$$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 1152 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? [ ] Yes [x] No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 [ ] Yes [x] No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1587	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1587	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$$

D_R = 11.4 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

M_S = 0.270 (Exhibit 13-11)

S_R= 58.8 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.8 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$$V_{12} = V_R + (V_F - V_R)P_{FD}$$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? [ ] Yes [ ] No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 [ ] Yes [ ] No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Lockwood
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	1000
Freeway Volume, V_F	950
Ramp Volume, V_R	300
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	950	0.90	Level	15	0	0.930	0.95	1194
Ramp	300	0.90	Level	10	0	0.952	0.95	368
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$$V_{12} = V_F (P_{FM})$$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = using Equation (Exhibit 13-6)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)

S_R= mph (Exhibit 13-11)

S_0= mph (Exhibit 13-11)

S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$$V_{12} = V_R + (V_F - V_R)P_{FD}$$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 1.000 using Equation (Exhibit 13-7)

V_{12} = 1194 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	1194	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	826	Exhibit 13-8	4700	No
V_R	368	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1194	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$$

D_R = 5.5 (pc/mi/ln)

LOS = A (Exhibit 13-2)

Speed Determination

D_s = 0.461 (Exhibit 13-12)

S_R= 54.4 mph (Exhibit 13-12)

S_0= N/A mph (Exhibit 13-12)

S = 54.4 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB On-Ramp
Agency or Company	Marvin Associates	Junction	Lockwood
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp			Downstream Adj Ramp
☐ Yes ☐ On	Number of Lanes, N	2	☐ Yes ☐ On
☑ No ☐ Off	Acceleration Lane Length, L_A	1000	☑ No ☐ Off
	Deceleration Lane Length L_D		
	Freeway Volume, V_F	655	
L_{up} = ft	Ramp Volume, V_R	470	L_{down} = ft
	Freeway Free-Flow Speed, S_{FF}	65.0	
V_u = veh/h	Ramp Free-Flow Speed, S_{FR}	35.0	V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	655	0.92	Level	15	4	0.923	0.95	812
Ramp	470	0.92	Level	4	4	0.973	0.95	553
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 812 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1365	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1365	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$

D_R = 9.6 (pc/mi/ln)

LOS = A (Exhibit 13-2)

Speed Determination

M_S = 0.266 (Exibit 13-11)

S_R= 58.9 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.9 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Johnson Lane
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	500
Freeway Volume, V_F	1300
Ramp Volume, V_R	550
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	1300	0.92	Level	15	0	0.930	0.95	1599
Ramp	550	0.92	Level	15	0	0.930	0.95	676
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = using Equation (Exhibit 13-6)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)

S_R= mph (Exhibit 13-11)

S_0= mph (Exhibit 13-11)

S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 1.000 using Equation (Exhibit 13-7)

V_{12} = 1599 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	1599	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	923	Exhibit 13-8	4700	No
V_R	676	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1599	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$

D_R = 13.5 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

D_s = 0.489 (Exhibit 13-12)

S_R= 53.8 mph (Exhibit 13-12)

S_0= N/A mph (Exhibit 13-12)

S = 53.8 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB On-Ramp
Agency or Company	Marvin Associates	Junction	Johnson Lane
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	640
Ramp Volume, V_R	210
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	640	0.92	Level	15	4	0.923	0.95	793
Ramp	210	0.92	Level	12	4	0.936	0.95	257
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 793 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1050	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1050	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 7.3 (pc/mi/ln)

LOS = A (Exhibit 13-2)

Speed Determination

M_S = 0.262 (Exhibit 13-11)

S_R= 59.0 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 59.0 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Johnson Lane
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp				Downstream Adj Ramp
☐ Yes ☐ On	Number of Lanes, N	2		☐ Yes ☐ On
☑ No ☐ Off	Acceleration Lane Length, L_A			☑ No ☐ Off
L_{up} = ft	Deceleration Lane Length L_D	1000		L_{down} = ft
V_u = veh/h	Freeway Volume, V_F	650		V_D = veh/h
	Ramp Volume, V_R	120		
	Freeway Free-Flow Speed, S_{FF}	65.0		
	Ramp Free-Flow Speed, S_{FR}	35.0		

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	650	0.90	Level	15	0	0.930	0.95	817
Ramp	120	0.90	Level	25	0	0.889	0.95	158
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$$V_{12} = V_F (P_{FM})$$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = using Equation (Exhibit 13-6)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)

S_R= mph (Exhibit 13-11)

S_0= mph (Exhibit 13-11)

S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$$V_{12} = V_R + (V_F - V_R)P_{FD}$$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 1.000 using Equation (Exhibit 13-7)

V_{12} = 817 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	817	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	659	Exhibit 13-8	4700	No
V_R	158	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	817	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$$

D_R = 2.3 (pc/mi/ln)

LOS = A (Exhibit 13-2)

Speed Determination

D_s = 0.442 (Exhibit 13-12)

S_R= 54.8 mph (Exhibit 13-12)

S_0= N/A mph (Exhibit 13-12)

S = 54.8 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB On-Ramp
Agency or Company	Marvin Associates	Junction	Johnson Lane
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2010 Existing

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: Yes ☐ On ☐ / No ☑ Off ☐

L_{up} = ft

V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	660
Ramp Volume, V_R	320
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: Yes ☐ On ☐ / No ☑ Off ☐

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	660	0.92	Level	15	4	0.923	0.95	818
Ramp	320	0.92	Level	12	4	0.936	0.95	391
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F\ (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 818 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1209	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1209	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$

D_R = 8.5 (pc/mi/ln)

LOS = A (Exhibit 13-2)

Speed Determination

M_S = 0.264 (Exhibit 13-11)

S_R= 58.9 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.9 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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APPENDIX C

No-Build Alternative Year 2035

Existing Roads & Streets

Capacity Calculations

TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/3/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Dover Rd & Five Mile No-build*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Dover Road* | North/South Street: *Five Mile Rd*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*105*	*5*	*5*	*75*	
Peak-Hour Factor, PHF	*1.00*	*0.80*	*0.80*	*0.80*	*0.80*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*131*	*6*	*6*	*93*	*0*
Percent Heavy Vehicles	*0*	*--*	*--*	*3*	*--*	*--*
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*5*		*25*			
Peak-Hour Factor, PHF	*0.60*	*1.00*	*0.60*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*8*	*0*	*41*	*0*	*0*	*0*
Percent Heavy Vehicles	*3*	*0*	*3*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*6*		*49*				
C (m) (veh/h)		*1441*		*880*				
v/c		*0.00*		*0.06*				
95% queue length		*0.01*		*0.18*				
Control Delay (s/veh)		*7.5*		*9.3*				
LOS		*A*		*A*				
Approach Delay (s/veh)	*--*	*--*	*9.3*					
Approach LOS	*--*	*--*	*A*					

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TWO-WAY STOP CONTROL SUMMARY

General Information / Site Information

Analyst	*R Marvin*	Intersection	*Dover & Bitteroot*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*12/8/2011*	Analysis Year	*No Build 2035*
Analysis Time Period	*PM Design Hour*		

Project Description *Billings Bypass*

East/West Street: *Dover Road*	North/South Street: *Bitteroot*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*115*	*90*	*25*	*65*	
Peak-Hour Factor, PHF	*1.00*	*0.80*	*0.80*	*0.75*	*0.75*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*143*	*112*	*33*	*86*	*0*
Percent Heavy Vehicles	*0*	*--*	*--*	*1*	*--*	*--*
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*50*		*15*			
Peak-Hour Factor, PHF	*0.75*	*1.00*	*0.75*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*66*	*0*	*20*	*0*	*0*	*0*
Percent Heavy Vehicles	*1*	*0*	*1*	*0*	*0*	*0*
Percent Grade (%)	*3*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*33*		*86*				
C (m) (veh/h)		*1316*		*639*				
v/c		*0.03*		*0.13*				
95% queue length		*0.08*		*0.46*				
Control Delay (s/veh)		*7.8*		*11.5*				
LOS		*A*		*B*				
Approach Delay (s/veh)	--	--	*11.5*					
Approach LOS	--	--	*B*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*12/8/2011*
Analysis Time Period	*PM Design Hour*

Site Information

Intersection	*Dover & Highway 312*
Jurisdiction	*MDT*
Analysis Year	*No Build 2035*

Project Description *Billings Bypass*

East/West Street: *Highway 312* | North/South Street: *Dover Road*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*990*	*160*	*80*	*35*	
Peak-Hour Factor, PHF	*1.00*	*0.95*	*0.95*	*0.90*	*0.90*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*1042*	*168*	*88*	*38*	*0*
Percent Heavy Vehicles	*0*	--	--	*4*	--	--
Median Type	*Two Way Left Turn Lane*					
RT Channelized			*0*			*0*
Lanes	*0*	*2*	*0*	*1*	*2*	*0*
Configuration		*T*	*TR*	*L*	*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*45*		*600*			
Peak-Hour Factor, PHF	*0.92*	*1.00*	*0.92*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*48*	*0*	*652*	*0*	*0*	*0*
Percent Heavy Vehicles	*4*	*0*	*4*	*0*	*0*	*0*
Percent Grade (%)	*2*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*0*	*1*	*0*	*0*	*0*
Configuration	*L*		*R*			

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*L*	*L*		*R*			
v (veh/h)		*88*	*48*		*652*			
C (m) (veh/h)		*561*	*193*		*474*			
v/c		*0.16*	*0.25*		*1.38*			
95% queue length		*0.55*	*0.94*		*30.32*			
Control Delay (s/veh)		*12.6*	*29.7*		*205.9*			
LOS		*B*	*D*		*F*			
Approach Delay (s/veh)	--	--	*193.8*					
Approach LOS	--	--	*F*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary & Bitteroot No Build*
Jurisdiction	*MDT*
Analysis Year	*Year 2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* North/South Street: *Bitteroot*

Intersection Orientation: *East-West* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*60*	*60*	*50*	*10*	*25*	*5*
Peak-Hour Factor, PHF	*0.70*	*0.70*	*0.70*	*0.60*	*0.60*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*85*	*85*	*71*	*16*	*41*	*8*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration	*LTR*			*LTR*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*50*	*110*	*10*	*5*	*60*	*50*
Peak-Hour Factor, PHF	*0.70*	*0.70*	*0.70*	*0.70*	*0.70*	*0.70*
Hourly Flow Rate, HFR (veh/h)	*71*	*157*	*14*	*7*	*85*	*71*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*LTR*	*LTR*		*LTR*			*LTR*	
v (veh/h)	*85*	*16*		*242*			*163*	
C (m) (veh/h)	*1571*	*1436*		*492*			*634*	
v/c	*0.05*	*0.01*		*0.49*			*0.26*	
95% queue length	*0.17*	*0.03*		*2.68*			*1.02*	
Control Delay (s/veh)	*7.4*	*7.5*		*19.2*			*12.6*	
LOS	*A*	*A*		*C*			*B*	
Approach Delay (s/veh)	--	--	*19.2*			*12.6*		
Approach LOS	--	--	*C*			*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary & Hawthrone NoBuild*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* North/South Street: *Hawthrone*

Intersection Orientation: *East-West* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*290*	*60*	*5*	*170*	
Peak-Hour Factor, PHF	*1.00*	*0.80*	*0.80*	*0.80*	*0.80*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*362*	*74*	*6*	*212*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*40*		*5*			
Peak-Hour Factor, PHF	*0.60*	*1.00*	*0.60*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*66*	*0*	*8*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*6*		*74*				
C (m) (veh/h)		*1134*		*467*				
v/c		*0.01*		*0.16*				
95% queue length		*0.02*		*0.56*				
Control Delay (s/veh)		*8.2*		*14.2*				
LOS		*A*		*B*				
Approach Delay (s/veh)	--	--	*14.2*					
Approach LOS	--	--	*B*					

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HCM Analysis Summary

No Build Alt 2035	HWY 312/Bench	Area Type: Non CBD
R Marvin	08/16/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: BENCHU~2	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	3	1	L	12.0	T	12.0	R	12.0						
SB	3	1	L	12.0	T	12.0	R	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	490	900	0	140	520	0	100	80	250	40	40	340
PHF	0.92	0.92	0.90	0.92	0.92	0.90	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	3	2	2	1	2	2	1	1	1	2	1	3
Lane Groups	L	T		L	T		L	T	R	L	T	R
Arrival Type	3	3		3	3		3	3	3	3	3	3
RTOR Vol (vph)	0			0			100			140		
Peds/Hour	0			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated　　Operational Analysis　　Cycle Length: 125.0 Sec　　Lost Time Per Cycle: 20.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		L		LT														
WB		L		LT														
NB		R				LTR		LTR										
SB		R				P		LTR										
Green		35.0		29.0		22.0		19.0										0
Yellow	All Red	4.0	0.0	4.0	2.0	3.5	1.5	3.5	1.5									

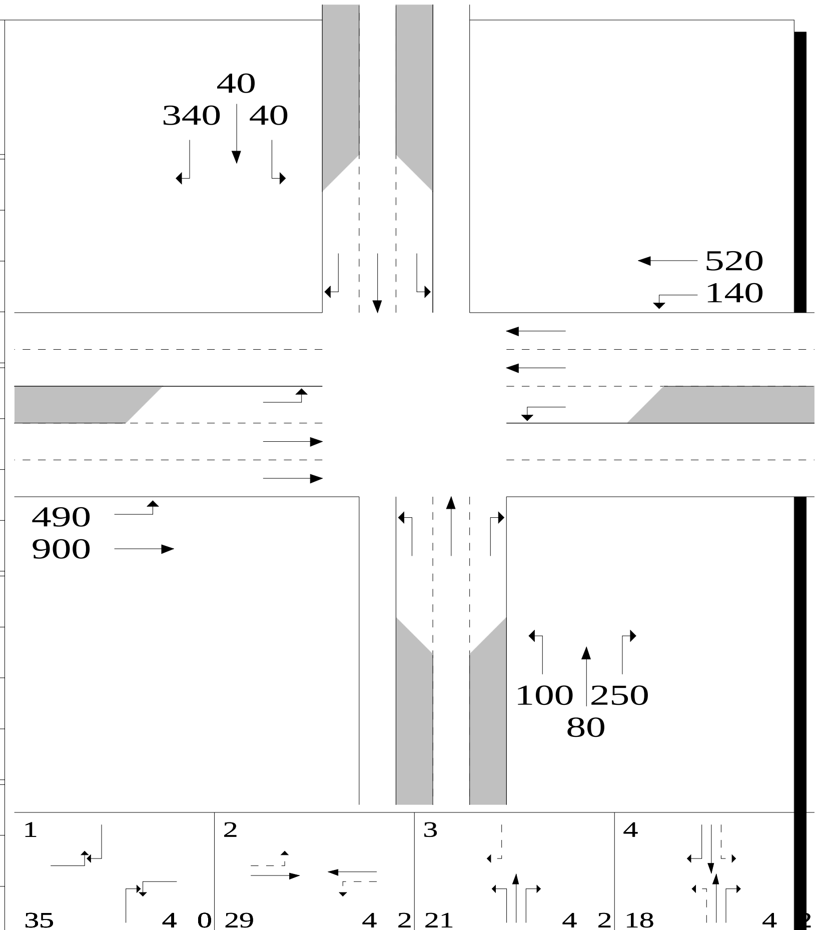
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	Lper	104	0.113	0.280					109.8	F
	* Lpro	491	0.280	0.280	L	0.896	43.4	D		
	* T	821	0.276	0.232	T	1.191	146.0	F		
WB	Lper	60	0.000	0.280					39.9	D
	Lpro	500	0.085	0.280	L	0.271	17.5	B		
	T	821	0.160	0.232	T	0.688	45.9	D		
NB	Lper	234	0.000	0.192					17.5	B
	* Lpro	315	0.061	0.176	L	0.199	26.7	C		
	T	692	0.046	0.368	T	0.126	26.2	C		
	R	1100	0.102	0.688	R	0.148	6.8	A		
SB										
	* L	198	0.033	0.152	L	0.217	46.7	D	18.2	B
	T	286	0.023	0.152	T	0.150	46.1	D		
	R	1077	0.139	0.688	R	0.201	7.1	A		

Intersection: Delay = 71.4 sec/veh　　Int. LOS=E　　X_c= 0.77　　* Critical Lane Group　　Σ(v/s)Crit= 0.65

NETSIM Summary Results

No Build Alt 2035	HWY 312/Bench
R Marvin	08/16/2011
PM Design Hour	Case: BENCHU~2

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	20 / 25	4.5	2.2
	T	15 / 19	5.8	0.1
	All		5.3	2.2
WB	L	4 / 5	7.2	0.0
	T	9 / 10	7.9	0.0
	All		7.8	0.0
NB	L	2 / 4	6.7	0.0
	T	2 / 2	18.9	0.0
	R	2 / 4	14.4	0.0
	All		14.3	0.0
SB	L	1 / 4	3.0	0.0
	T	2 / 4	16.0	0.0
	R	3 / 4	16.0	0.0
	All		13.2	0.0
Intersect.			7.1	



HCM Analysis Summary

No Build Alt 2035	Wicks Lane/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM	Case: WICKSM~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	200	450	250	540	390	70	560	1650	400	150	960	200
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			30			100			80		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 140.0 Sec   Lost Time Per Cycle: 18.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB							LTR										
WB					LTP												
NB	L		TP														
SB	L		TP														
Green	24.0		50.0		26.0		22.0										0
Yellow | All Red	3.0	0.0	3.5	1.5	3.5	1.5	3.5	1.5									

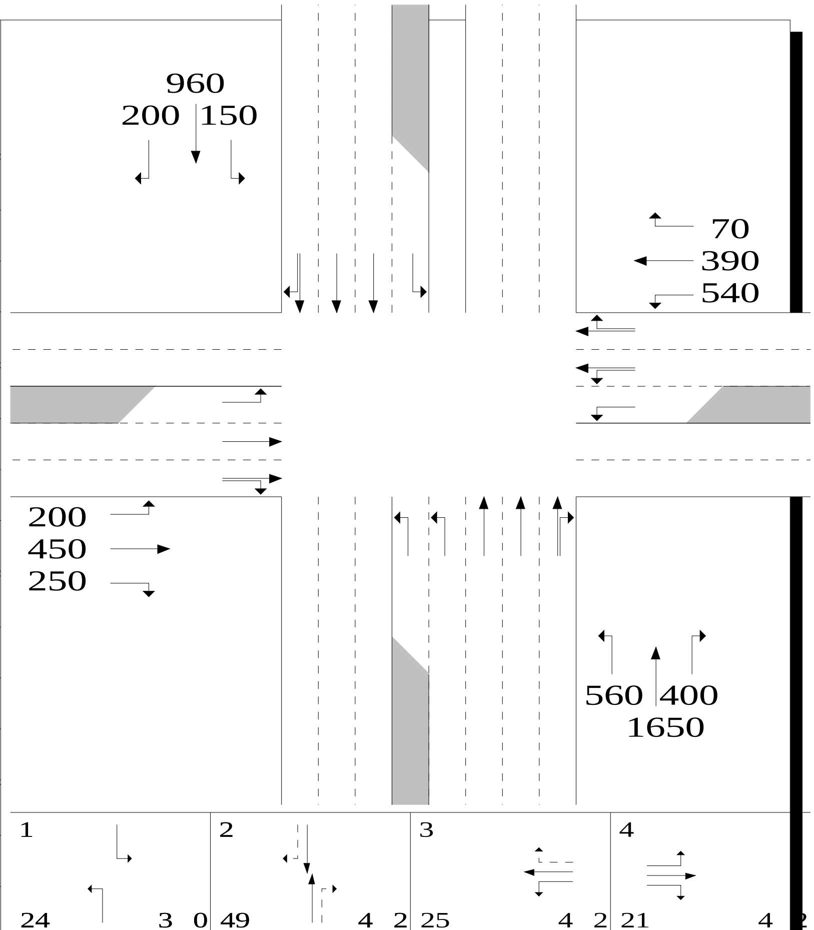
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	284	0.120	0.157	L	0.764	67.1	E	148.2	F
	* TR	544	0.195	0.157	TR	1.239	174.2	F		
WB										
	L	335	0.195	0.186	L	1.051	120.1	F	116.1	F
	* LTR	653	0.200	0.186	LTR	1.075	114.1	F		
NB										
	* L	600	0.174	0.171	L	1.015	90.5	F	115.0	F
	* TR	1773	0.427	0.357	TR	1.195	122.0	F		
SB										
	L	309	0.090	0.171	L	0.528	59.2	E	40.0	D
	TR	1785	0.235	0.357	TR	0.657	37.3	D		

Intersection: Delay = 103.4 sec/veh   Int. LOS=F X_c = 1.14   * Critical Lane Group Σ(v/s)Crit= 1.00

NETSIM Summary Results

No Build Alt 2035 | Wicks Lane/Main Street
R Marvin | 10/12/2011
PM | Case: WICKSM~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	6 / 8	5.1	0.0
	TR	10 / 16	5.4	0.0
	All		5.4	0.0
WB	L	14 / 17	3.0	0.0
	LTR	14 / 16	4.7	0.0
	All		4.1	0.0
NB	L	14 / 15	3.1	0.0
	TR	23 / 30	3.7	11.6
	All		3.5	11.6
SB	L	9 / 11	3.1	0.0
	TR	9 / 11	6.9	0.0
	All		6.1	0.0
Intersect.			4.3	



HCM Analysis Summary

No Build Alt 2035	Airport Road/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: AIRPOR~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	3500	10	70	2120	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 160.0 Sec   Lost Time Per Cycle: 20.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP				R												
WB				LTP														
NB						LTP		TP										
SB								TP		LTR								
Green		40.0		7.0		16.0		67.0		7.0								0
Yellow	All Red	3.5	1.5	3.5	1.5	3.0	0.0	3.5	1.5	3.5	1.5							

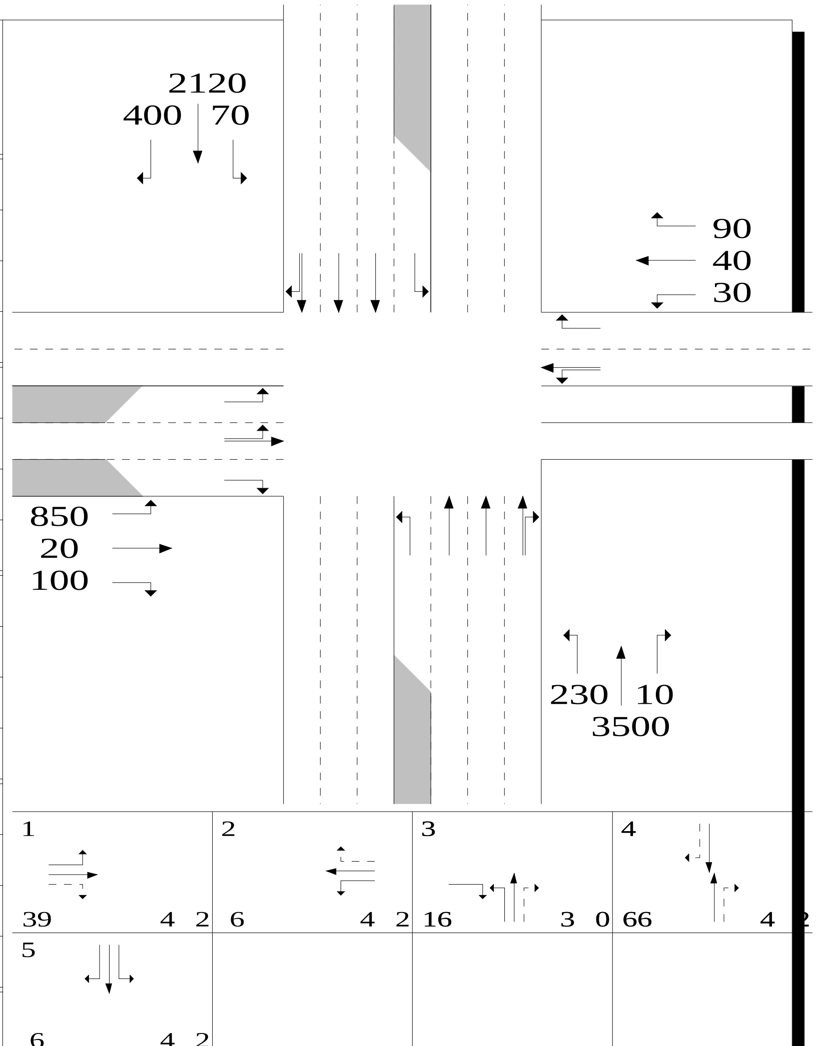
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	443	0.280	0.250	L	1.117	138.8	F	108.6	F
	LT	445	0.237	0.250	LT	0.946	88.0	F		
	R	570	0.054	0.369	R	0.147	33.8	C		
WB										
	* LT	81	0.040	0.044	LT	0.914	146.5	F	147.5	F
	R	70	0.039	0.044	R	0.900	148.5	F		
NB										
	L	177	0.137	0.100	L	1.367	263.7	F	175.2	F
	* TR	2732	0.727	0.538	TR	1.352	169.4	F		
SB										
	* L	79	0.041	0.044	L	0.937	158.7	F	45.2	D
	TR	2463	0.511	0.494	TR	1.035	41.9	D		

Intersection: Delay = 121.8 sec/veh   Int. LOS=F X_c = 1.24   * Critical Lane Group Σ(v/s)Crit= 1.09

NETSIM Summary Results

No Build Alt 2035	Airport Road/Main Street
R Marvin	10/12/2011
PM Design Hour	Case: AIRPOR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	21 / 22	3.2	0.0
	LT	20 / 21	4.8	0.0
	R	1 / 3	18.8	0.0
	All		4.3	0.0
WB	LT	3 / 4	4.3	0.0
	R	3 / 3	10.6	0.0
	All		7.1	0.0
NB	L	17 / 20	1.4	0.0
	TR	29 / 30	5.3	42.1
	All		4.7	42.1
SB	L	6 / 10	2.5	0.0
	TR	19 / 22	7.8	0.7
	All		7.3	0.7
Intersect.			5.4	



HCM Analysis Summary

No Build Alt 2035 | 1st Ave N/ | Area Type: Non CBD
R Marvin | 10/12/2011 | Analysis Duration: 15 mins.
PM design Hour | Case: US87MA~1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	1490	0	0	0	1450	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)		0			250			0			0	
Peds/Hour		5			0			0			0	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated | Operational Analysis | Cycle Length: 140.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		45.0		20.0		60.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	1655	0.368	0.321	L	1.145	105.4	F	100.2	F
	T	599	0.339	0.321	T	1.055	84.6	F		
WB										
	T	506	0.181	0.143	T	1.269	195.9	F	203.3	F
	* R	943	0.840	0.607	R	1.384	206.9	F		
SB										
	L	1443	0.453	0.429	L	1.058	60.5	E	41.5	D
	R	2190	0.253	0.786	R	0.322	0.4	A		

Intersection: Delay = 110.6 sec/veh | Int. LOS=F | X_c= 1.30 | * Critical Lane Group | Σ(v/s)Crit= 1.21

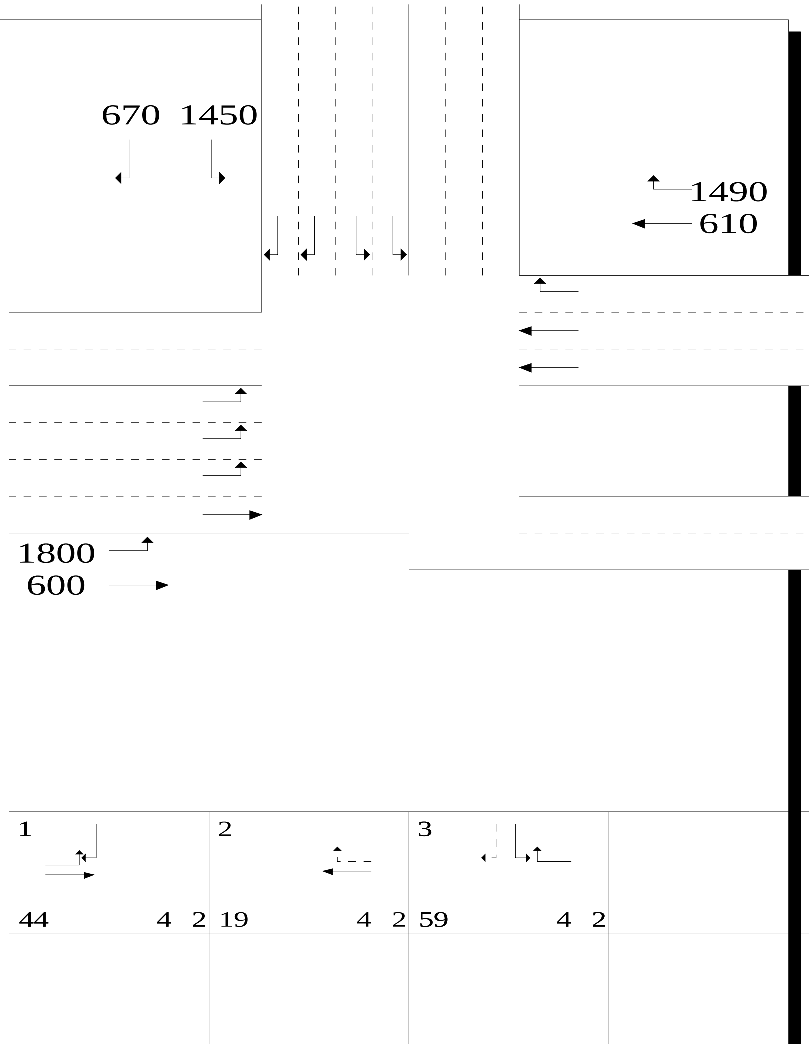
SIG/Cinema v3.08

NETSIM Summary Results

No Build Alt 2035
R Marvin
PM design Hour

1st Ave N/
10/12/2011
Case: US87MA~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	24 / 30	3.0	54.8
	T	16 / 25	4.8	2.3
	All		3.3	54.8
WB	T	8 / 11	5.6	0.0
	R	28 / 30	4.6	24.9
	All		4.9	24.9
	All		6.2	25.4
SB	L	27 / 30	4.6	25.4
	R	3 / 5	18.9	0.0
Intersect.			4.4	



HCM Analysis Summary

No Build Alt 2035	Old US 87/I90 WB On Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: WBRAMP~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	1430	480	220	1310	0	0	0	0	20	1	580
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)	150			0			0			100		
Peds/Hour	0			5			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	--- | ---			--- | ---			--- | ---			--- | ---		

Signal Settings: Actuated | Operational Analysis | Cycle Length: 90.0 Sec | Lost Time Per Cycle: 14.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB		TR							
WB	LT	LT							
NB									
SB			LTR						
Green	8.0	45.0	23.0						0
Yellow | All Red	4.0 | 0.0	3.5 | 1.5	3.5 | 1.5						

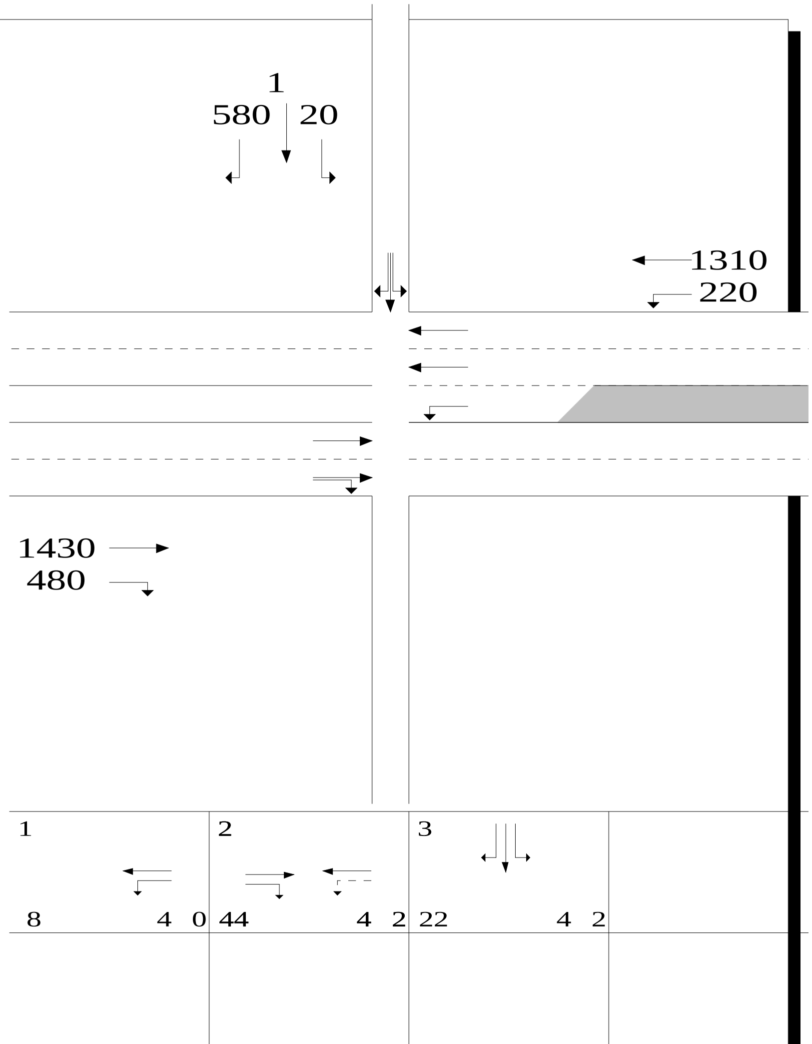
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1671	0.573	0.500	TR	1.145	100.7	F	100.7	F
WB	Lper	83	0.533	0.556					26.1	C
	* Lpro	159	0.089	0.089	L	0.988	82.5	F		
	T	2177	0.414	0.633	T	0.654	16.7	B		
SB										
	* LTR	402	0.347	0.256	LTR	1.356	209.1	F	209.1	F

Intersection: Delay = 84.9 sec/veh   Int. LOS=F X_c= 1.19   * Critical Lane Group Σ(v/s)Crit= 1.01

NETSIM Summary Results

No Build Alt 2035	Old US 87/I90 WB On Ramp
R Marvin	10/13/2011
PM Design Hour	Case: WBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	28 / 30	4.9	38.9
	All		4.9	38.9
WB	L	8 / 14	2.4	0.0
	T	6 / 10	18.0	0.0
	All		11.9	0.0
	All		4.1	1.3
SB	LTR	19 / 26	4.1	1.3
Intersect.			6.2	



HCM Analysis Summary

No Build 2035	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: EBRAMP~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	750	700	0	0	780	20	750	1	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 110.0 Sec Lost Time Per Cycle: 9.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT		LT														
WB				TR														
NB						LTP												
SB																		
Green		24.0		33.0		39.0												0
Yellow	All Red	4.0	0.0	3.5	1.5	3.5	1.5											

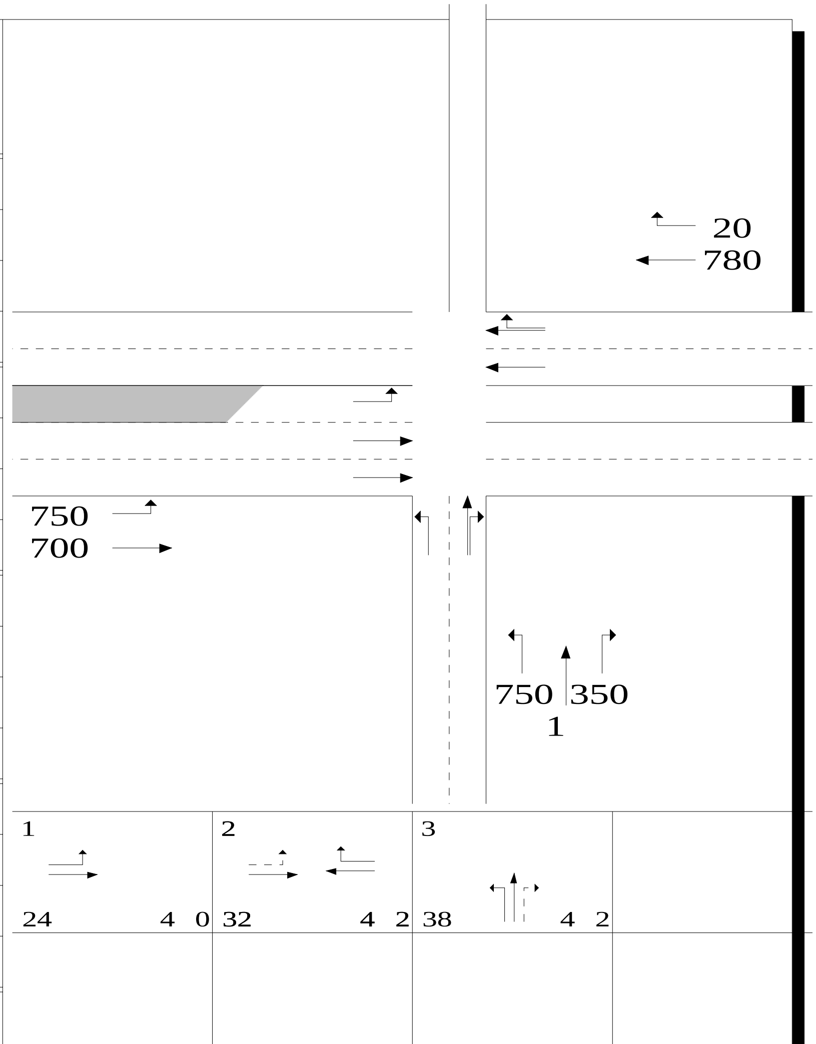
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	66	2.271	0.345					222.1	F
	* Lpro	379	0.218	0.218	L	1.831	416.0	F		
	T	1982	0.213	0.555	T	0.384	14.4	B		
WB										
	TR	1059	0.245	0.300	TR	0.816	42.6	D	42.6	D
NB										
	* L	607	0.476	0.355	L	1.343	200.6	F	157.2	F
	TR	562	0.172	0.355	TR	0.486	27.9	C		

Intersection: Delay = 158.2 sec/veh Int. LOS=F X_c= 3.23 * Critical Lane Group Σ(v/s)Crit= 2.97

NETSIM Summary Results

No Build 2035	Old US 87/I90 EB Off Ramp
R Marvin	10/13/2011
PM Design Hour	Case: EBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	29 / 29	2.1	63.3
	T	5 / 9	4.5	57.8
	All		3.5	63.3
WB	TR	10 / 11	8.0	0.0
	All		8.0	0.0
NB	L	28 / 29	3.1	56.4
	TR	3 / 5	18.2	0.0
	All		4.3	56.4
Intersect.			4.6	



HCM Analysis Summary

No Build Alt 2035	I90 EB Off Ramp/Johnson Lane	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
Design Hour PM	Case: EBRAMP~2	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	LT	12.0	R	12.0								
WB	0	0												
NB	1	1	TR	12.0										
SB	2	1	L	12.0	T	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	110	1	950	0	0	0	0	700	250	150	245	0
PHF	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92	0.92	0.90
% Heavy Vehicles	4	2	4	2	2	2	2	4	4	4	4	2
Lane Groups		LT	R					TR		L	T	
Arrival Type		3	3					3		3	3	
RTOR Vol (vph)	150			0			25			0		
Peds/Hour	0			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated		Operational Analysis			Cycle Length: 125.0 Sec				Lost Time Per Cycle: 10.0 Sec									
Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP		R														
WB																		
NB				TP		TR												
SB						LT												
Green		50.0		20.0		40.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

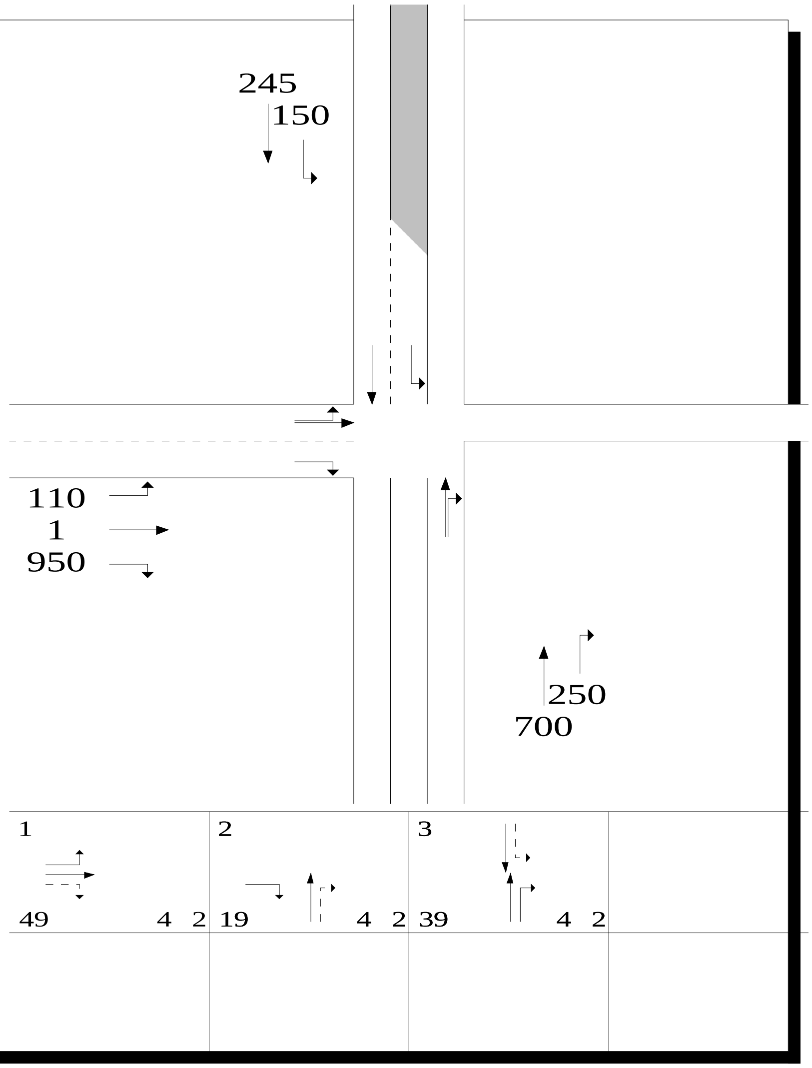
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	LT	696	0.070	0.400	LT	0.174	24.2	C	36.6	D
	* R	932	0.560	0.600	R	0.933	38.4	D		
NB										
	TR	919	0.569	0.520	TR	1.095	89.0	F	89.0	F
SB										
	* L	59	0.891	0.320	L	2.763	881.0	F	357.3	F
	T	585	0.146	0.320	T	0.455	36.4	D		

Intersection: Delay = 115.0 sec/veh Int. LOS=F X_c= 1.58 * Critical Lane Group Σ(v/s)Crit= 1.45

NETSIM Summary Results

No Build Alt 2035	I90 EB Off Ramp/Johnson Lane
R Marvin	10/13/2011
Design Hour PM	Case: EBRAMP~2

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	LT	5 / 9	9.3	0.0
	R	11 / 16	12.7	0.0
	All		12.1	0.0
	All		5.6	25.4
NB	TR	25 / 29	5.6	25.4
	All		1.7	37.8
SB	L	14 / 21	0.5	37.8
	T	5 / 10	3.2	25.3
Intersect.			5.5	



TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/10/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Johnson WB Ramps Nobuild*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *WB Ramps* | North/South Street: *Johnson Lane*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*610*	*200*			*205*	*150*
Peak-Hour Factor, PHF	*0.95*	*0.95*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*642*	*210*	*0*	*0*	*227*	*166*
Percent Heavy Vehicles	*8*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*0*	*1*	*1*
Configuration	*L*	*T*			*T*	*R*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*190*		*110*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.90*	*1.00*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*211*	*0*	*122*
Percent Heavy Vehicles	*0*	*0*	*0*	*8*	*0*	*10*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*			*LR*				
v (veh/h)	*642*			*333*				
C (m) (veh/h)	*1134*			*55*				
v/c	*0.57*			*6.05*				
95% queue length	*3.69*			*38.03*				
Control Delay (s/veh)	*12.2*			*2421*				
LOS	*B*			*F*				
Approach Delay (s/veh)	--	--	*2421*					
Approach LOS	--	--	*F*					

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Coulson & Johnson No Build*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*10/8/2011*	Analysis Year	*2035*
Analysis Time Period	*Design Hour PM*		

Project Description *Billings Bypass*	
East/West Street: *Coulson Road*	North/South Street: *Johnson Lane*
Intersection Orientation: *North-South*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*10*	*55*	*0*	*30*	
Peak-Hour Factor, PHF	*1.00*	*0.60*	*0.60*	*0.60*	*0.60*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*16*	*91*	*0*	*49*	*0*
Percent Heavy Vehicles	*0*	--	--	*5*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*80*		*5*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.60*	*1.00*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*133*	*0*	*8*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*0*		*141*				
C (m) (veh/h)		*1465*		*885*				
v/c		*0.00*		*0.16*				
95% queue length		*0.00*		*0.57*				
Control Delay (s/veh)		*7.5*		*9.8*				
LOS		*A*		*A*				
Approach Delay (s/veh)	--	--	*9.8*					
Approach LOS	--	--	*A*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Peak PM Hour*

Site Information

Intersection	*N Frntg & Johnson*
Jurisdiction	*MDT*
Analysis Year	*NoBuild 2035*

Project Description *Billings Bypass*

East/West Street: *N Frontage Road* | North/South Street: *Johnson Lane*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*200*	*80*	*30*	*5*	*55*	*30*
Peak-Hour Factor, PHF	*0.85*	*0.85*	*0.85*	*0.50*	*0.50*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*235*	*94*	*35*	*10*	*110*	*60*
Percent Heavy Vehicles	*10*	--	--	*4*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*60*	*25*	*275*	*25*	*20*	*5*
Peak-Hour Factor, PHF	*0.85*	*0.85*	*0.85*	*0.50*	*0.50*	*0.50*
Hourly Flow Rate, HFR (veh/h)	*70*	*29*	*323*	*50*	*40*	*10*
Percent Heavy Vehicles	*4*	*4*	*10*	*4*	*4*	*4*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*	*L*		*TR*	*L*		*TR*
v (veh/h)	*235*	*10*	*50*		*50*	*70*		*352*
C (m) (veh/h)	*1360*	*1444*	*126*		*314*	*241*		*749*
v/c	*0.17*	*0.01*	*0.40*		*0.16*	*0.29*		*0.47*
95% queue length	*0.62*	*0.02*	*1.68*		*0.56*	*1.16*		*2.53*
Control Delay (s/veh)	*8.2*	*7.5*	*51.2*		*18.6*	*25.9*		*14.0*
LOS	*A*	*A*	*F*		*C*	*D*		*B*
Approach Delay (s/veh)	--	--	*34.9*			*16.0*		
Approach LOS	--	--	*D*			*C*		

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HCM Analysis Summary

No Build Alt 2035	Old Hardin Road/Johnson lane	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: OLDHAR~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	LT	12.0	R	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	3	1	L	12.0	T	12.0	R	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	270	380	35	35	250	570	25	120	35	750	160	290
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	10	0	0	0	0	0	1	1	0	0	1	10
Lane Groups	L	TR			LT	R	L	TR		L	T	R
Arrival Type	3	3			3	3	3	3		3	3	3
RTOR Vol (vph)	5			80			5			20		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 130.0 Sec   Lost Time Per Cycle: 13.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP		LTP														
WB			LTR		R												
NB							LTP										
SB					LTP		LTP										
Green	23.5		22.5		55.0		11.0										0
Yellow / All Red	4.0	0.0	3.5	1.5	4.0	0.0	3.5	1.5									

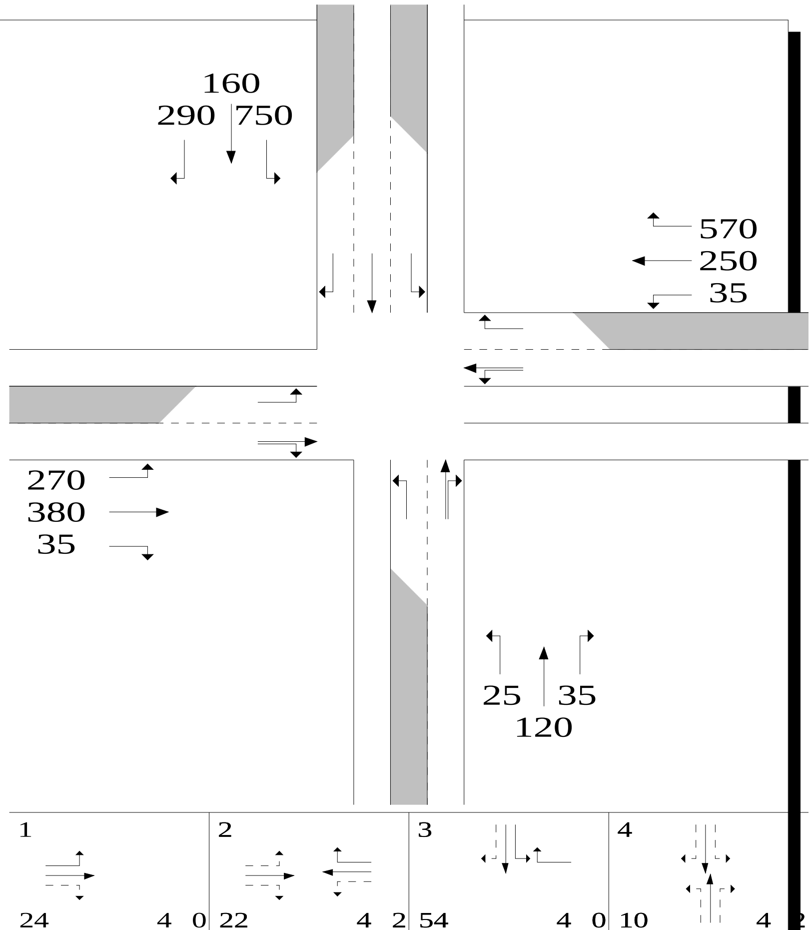
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	Lper	55	0.000	0.212					39.7	D
	* Lpro	297	0.179	0.181	L	0.832	49.3	D		
	TR	722	0.237	0.385	TR	0.618	33.5	C		
WB										
	* LT	292	0.184	0.173	LT	1.062	123.6	F	53.8	D
	R	1025	0.330	0.635	R	0.520	13.2	B		
NB										
	L	103	0.022	0.085	L	0.262	56.2	E	137.3	F
	TR	153	0.090	0.085	TR	1.065	150.7	F		
SB	* Lper	58	0.107	0.123					44.2	D
	* Lpro	764	0.423	0.423	L	0.991	60.1	E		
	T	1013	0.093	0.538	T	0.172	15.3	B		
	R	787	0.201	0.538	R	0.372	17.4	B		

Intersection: Delay = 51.6 sec/veh   Int. LOS=D X_c= 0.99   * Critical Lane Group Σ(v/s)Crit= 0.89

NETSIM Summary Results

No Build Alt 2035	Old Hardin Road/Johnson lane
R Marvin	10/13/2011
PM Design Hour	Case: OLDHAR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	12 / 22	2.6	12.7
	TR	11 / 12	9.6	0.0
	All		5.8	12.7
WB	LT	9 / 20	7.8	3.3
	R	5 / 10	11.6	0.0
	All		8.5	3.3
NB	L	1 / 3	2.2	0.0
	TR	5 / 7	5.8	0.0
	All		5.3	0.0
SB	L	19 / 27	5.9	6.2
	T	3 / 5	15.4	3.7
	R	2 / 5	18.0	0.0
	All		8.4	6.2
Intersect.			7.4	



TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Becraft & Old Hardin Road*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*10/28/2011*	Analysis Year	*2035 No Build*
Analysis Time Period	*Peak PM*		

Project Description *Billings Bypass*

East/West Street: *Old Hardin Road*	North/South Street: *Becraft Lane*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*560*	*570*	*10*	*600*	
Peak-Hour Factor, PHF	*1.00*	*0.92*	*0.92*	*0.92*	*0.92*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*608*	*619*	*10*	*652*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*	*LT*		
Upstream Signal		*1*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*190*		*10*			
Peak-Hour Factor, PHF	*0.85*	*1.00*		*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*223*	*0*	*12*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*LT*		*LR*				
v (veh/h)		*10*		*235*				
C (m) (veh/h)		*420*		*72*				
v/c		*0.02*		*3.26*				
95% queue length		*0.07*		*24.04*				
Control Delay (s/veh)		*13.8*		*1141*				
LOS		*B*		*F*				
Approach Delay (s/veh)	--	--	*1141*					
Approach LOS	--	--	*F*					

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BASIC FREEWAY SEGMENTS WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway/Direction of Travel	*EB*
Agency or Company	*Marvin Associates*	From/To	*N 27th to Lockwood*
Date Performed	*12/5/2011*	Jurisdiction	*MDT*
Analysis Time Period	*PM Design Hour*	Analysis Year	*2035 No Build*

Project Description *Billings Bypass*

☑ Oper.(LOS) ☐ Des.(N) ☐ Planning Data

Flow Inputs

Volume, V	*2240*	veh/h	Peak-Hour Factor, PHF	*0.92*
AADT		veh/day	%Trucks and Buses, P_T	*15*
Peak-Hr Prop. of AADT, K			%RVs, P_R	*4*
Peak-Hr Direction Prop, D			General Terrain:	*Level*
DDHV = AADT x K x D		veh/h	Grade % Length Up/Down %	*mi*

Calculate Flow Adjustments

f_p	*0.95*	E_R	*1.2*
E_T	*1.5*	$f_{HV} = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]$	*0.923*

Speed Inputs			Calc Speed Adj and FFS		
Lane Width		ft			
Rt-Side Lat. Clearance		ft	f_{LW}		mph
Number of Lanes, N	*2*		f_{LC}		mph
Total Ramp Density, TRD		ramps/mi	TRD Adjustment		mph
FFS (measured)	*65.0*	mph	FFS	*65.0*	mph
Base free-flow Speed, BFFS		mph			

LOS and Performance Measures			Design (N)	
			Design (N)	
Operational (LOS)			Design LOS	
v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	*1388*	pc/h/ln	v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	pc/h/ln
S	*65.0*	mph	S	mph
D = v_p / S	*21.4*	pc/mi/ln	D = v_p / S	pc/mi/ln
LOS	*C*		Required Number of Lanes, N	

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design hour volume
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed

Factor Location

E_R - Exhibits 11-10, 11-12
E_T - Exhibits 11-10, 11-11, 11-13
f_p - Page 11-18
LOS, S, FFS, v_p - Exhibits 11-2, 11-3
f_{LW} - Exhibit 11-8
f_{LC} - Exhibit 11-9
TRD - Page 11-11

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BASIC FREEWAY SEGMENTS WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway/Direction of Travel	*EB*
Agency or Company	*Marvin Associates*	From/To	*Lockwood to Johnson*
Date Performed	*12/5/2011*	Jurisdiction	*MDT*
Analysis Time Period	*PM Design Hour*	Analysis Year	*2035 No Build*

Project Description *Billings Bypass*

☑ Oper.(LOS) ☐ Des.(N) ☐ Planning Data

Flow Inputs

Volume, V	*1960*	veh/h	Peak-Hour Factor, PHF	*0.92*
AADT		veh/day	%Trucks and Buses, P_T	*15*
Peak-Hr Prop. of AADT, K			%RVs, P_R	*4*
Peak-Hr Direction Prop, D			General Terrain:	*Level*
DDHV = AADT x K x D		veh/h	Grade % Length Up/Down %	*mi*

Calculate Flow Adjustments

f_p	*0.95*	E_R	*1.2*
E_T	*1.5*	$f_{HV} = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]$	*0.923*

Speed Inputs

Lane Width		ft
Rt-Side Lat. Clearance		ft
Number of Lanes, N	*2*	
Total Ramp Density, TRD		ramps/mi
FFS (measured)	*65.0*	mph
Base free-flow Speed, BFFS		mph

Calc Speed Adj and FFS

f_{LW}		mph
f_{LC}		mph
TRD Adjustment		mph
FFS	*65.0*	mph

LOS and Performance Measures

Operational (LOS)

v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	*1214*	pc/h/ln
S	*65.0*	mph
D = v_p / S	*18.7*	pc/mi/ln
LOS	*C*	

Design (N)

Design (N)

Design LOS		
v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)		pc/h/ln
S		mph
D = v_p / S		pc/mi/ln
Required Number of Lanes, N		

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed
DDHV - Directional design hour volume

Factor Location

E_R - Exhibits 11-10, 11-12
E_T - Exhibits 11-10, 11-11, 11-13
f_p - Page 11-18
LOS, S, FFS, v_p - Exhibits 11-2, 11-3
f_{LW} - Exhibit 11-8
f_{LC} - Exhibit 11-9
TRD - Page 11-11

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BASIC FREEWAY SEGMENTS WORKSHEET

General Information

Analyst	*R Marvin*
Agency or Company	*Marvin Associates*
Date Performed	*12/5/2011*
Analysis Time Period	*PM Design Hour*

Site Information

Highway/Direction of Travel	*EB*
From/To	*Johnson to Pinehills*
Jurisdiction	*MDT*
Analysis Year	*2035 No Build*

Project Description *Billings Bypass*

☑ Oper.(LOS) ☐ Des.(N) ☐ Planning Data

Flow Inputs

Volume, V	*1270*	veh/h	Peak-Hour Factor, PHF	*0.92*
AADT		veh/day	%Trucks and Buses, P_T	*22*
Peak-Hr Prop. of AADT, K			%RVs, P_R	*4*
Peak-Hr Direction Prop, D			General Terrain:	*Level*
DDHV = AADT x K x D		veh/h	Grade % Length Up/Down %	*mi*

Calculate Flow Adjustments

f_p	*0.95*	E_R	*1.2*
E_T	*1.5*	$f_{HV} = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]$	*0.894*

Speed Inputs

Lane Width		ft
Rt-Side Lat. Clearance		ft
Number of Lanes, N	*2*	
Total Ramp Density, TRD		ramps/mi
FFS (measured)	*65.0*	mph
Base free-flow Speed, BFFS		mph

Calc Speed Adj and FFS

f_{LW}		mph
f_{LC}		mph
TRD Adjustment		mph
FFS	*65.0*	mph

LOS and Performance Measures

Operational (LOS)

v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)	*812*	pc/h/ln
S	*65.0*	mph
D = v_p / S	*12.5*	pc/mi/ln
LOS	*B*	

Design (N)

Design (N)

Design LOS		
v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p)		pc/h/ln
S		mph
D = v_p / S		pc/mi/ln
Required Number of Lanes, N		

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design hour volume
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed

Factor Location

E_R - Exhibits 11-10, 11-12
E_T - Exhibits 11-10, 11-11, 11-13
f_p - Page 11-18
LOS, S, FFS, v_p - Exhibits 11-2, 11-3
f_{LW} - Exhibit 11-8
f_{LC} - Exhibit 11-9
TRD - Page 11-11

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Lockwood
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: Yes ☐ On ☐ No ☑ Off ☐; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	500
Freeway Volume, V_F	2240
Ramp Volume, V_R	1100
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: Yes ☐ On ☐ No ☑ Off ☐; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	2240	0.92	Level	15	0	0.930	0.95	2755
Ramp	1100	0.92	Level	10	0	0.952	0.95	1322
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)
P_{FM} = using Equation (Exhibit 13-6)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$

D_R = (pc/mi/ln)
LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)
S_R= mph (Exhibit 13-11)
S_0= mph (Exhibit 13-11)
S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)
P_{FD} = 1.000 using Equation (Exhibit 13-7)
V_{12} = 2755 pc/h
V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	2755	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	1433	Exhibit 13-8	4700	No
V_R	1322	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2755	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$

D_R = 23.4 (pc/mi/ln)
LOS = C (Exhibit 13-2)

Speed Determination

D_s = 0.547 (Exhibit 13-12)
S_R= 52.4 mph (Exhibit 13-12)
S_0= N/A mph (Exhibit 13-12)
S = 52.4 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB On-Ramp
Agency or Company	Marvin Associates	Junction	Lockwood
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	1200
Ramp Volume, V_R	770
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	1200	0.92	Level	15	4	0.923	0.95	1487
Ramp	770	0.92	Level	4	4	0.973	0.95	906
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 1487 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	2393	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	2393	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$

D_R = 17.5 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

M_S = 0.294 (Exhibit 13-11)

S_R= 58.2 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.2 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB On-Ramp
Agency or Company	Marvin Associates	Junction	Lockwood
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp

☐ Yes ☐ On

☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	770
Ramp Volume, V_R	700
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp

☐ Yes ☐ On

☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	770	0.92	Level	15	4	0.923	0.95	954
Ramp	700	0.92	Level	4	4	0.973	0.95	823
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$$V_{12} = V_F (P_{FM})$$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 954 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1777	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1777	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$$

D_R = 12.7 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

M_S = 0.274 (Exhibit 13-11)

S_R= 58.7 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.7 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$$V_{12} = V_R + (V_F - V_R)P_{FD}$$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Lockwood
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	1000
Freeway Volume, V_F	1470
Ramp Volume, V_R	600
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	1470	0.92	Level	15	0	0.930	0.95	1808
Ramp	600	0.92	Level	10	0	0.952	0.95	721
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F\,(P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = using Equation (Exhibit 13-6)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)

S_R= mph (Exhibit 13-11)

S_0= mph (Exhibit 13-11)

S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 1.000 using Equation (Exhibit 13-7)

V_{12} = 1808 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	1808	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	1087	Exhibit 13-8	4700	No
V_R	721	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1808	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = 10.8 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

D_s = 0.493 (Exhibit 13-12)

S_R= 53.7 mph (Exhibit 13-12)

S_0= N/A mph (Exhibit 13-12)

S = 53.7 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Johnson Lane
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	500
Freeway Volume, V_F	1960
Ramp Volume, V_R	1060
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	1960	0.92	Level	15	0	0.930	0.95	2411
Ramp	1060	0.92	Level	15	0	0.930	0.95	1304
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$$V_{12} = V_F (P_{FM})$$

L_{EQ} = (Equation 13-6 or 13-7)
P_{FM} = using Equation (Exhibit 13-6)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$$

D_R = (pc/mi/ln)
LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exibit 13-11)
S_R= mph (Exhibit 13-11)
S_0= mph (Exhibit 13-11)
S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$$V_{12} = V_R + (V_F - V_R)P_{FD}$$

L_{EQ} = (Equation 13-12 or 13-13)
P_{FD} = 1.000 using Equation (Exhibit 13-7)
V_{12} = 2411 pc/h
V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	2411	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	1107	Exhibit 13-8	4700	No
V_R	1304	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2411	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$$

D_R = 20.5 (pc/mi/ln)
LOS = C (Exhibit 13-2)

Speed Determination

D_s = 0.545 (Exhibit 13-12)
S_R= 52.5 mph (Exhibit 13-12)
S_0= N/A mph (Exhibit 13-12)
S = 52.5 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	EB On-Ramp
Agency or Company	Marvin Associates	Junction	Johnson Lane
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp
- ☐ Yes ☐ On
- ☑ No ☐ Off
- L_{up} = ft
- V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	870
Ramp Volume, V_R	400
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp
- ☐ Yes ☐ On
- ☑ No ☐ Off
- L_{down} = ft
- V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	870	0.92	Level	15	4	0.923	0.95	1078
Ramp	400	0.92	Level	12	4	0.936	0.95	489
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 1078 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1567	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1567	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 11.2 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

M_S = 0.270 (Exibit 13-11)

S_R= 58.8 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.8 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB Off-Ramp
Agency or Company	Marvin Associates	Junction	I-90 Johnson Lane
Date Performed	11/16/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{up} = ft; V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	
Deceleration Lane Length L_D	1000
Freeway Volume, V_F	950
Ramp Volume, V_R	300
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	950	0.90	Level	15	0	0.930	0.95	1194
Ramp	300	0.90	Level	25	0	0.889	0.95	395
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = using Equation (Exhibit 13-6)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 13-8		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 13-8		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

M_S = (Exhibit 13-11)

S_R= mph (Exhibit 13-11)

S_0= mph (Exhibit 13-11)

S = mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 1.000 using Equation (Exhibit 13-7)

V_{12} = 1194 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	1194	Exhibit 13-8	4700	No
$V_{FO} = V_F - V_R$	799	Exhibit 13-8	4700	No
V_R	395	Exhibit 13-10	2000	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1194	Exhibit 13-8	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$

D_R = 5.5 (pc/mi/ln)

LOS = A (Exhibit 13-2)

Speed Determination

D_s = 0.464 (Exhibit 13-12)

S_R= 54.3 mph (Exhibit 13-12)

S_0= N/A mph (Exhibit 13-12)

S = 54.3 mph (Exhibit 13-13)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	R Marvin	Freeway/Dir of Travel	WB On-Ramp
Agency or Company	Marvin Associates	Junction	Johnson Lane
Date Performed	12/5/2011	Jurisdiction	MDT
Analysis Time Period	PM Design Hour	Analysis Year	2035 No Build

Project Description Billings Bypass

Inputs

Upstream Adj Ramp

☐ Yes ☐ On

☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Number of Lanes, N	2
Acceleration Lane Length, L_A	1000
Deceleration Lane Length L_D	
Freeway Volume, V_F	710
Ramp Volume, V_R	760
Freeway Free-Flow Speed, S_{FF}	65.0
Ramp Free-Flow Speed, S_{FR}	35.0

Downstream Adj Ramp

☐ Yes ☐ On

☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	710	0.92	Level	15	4	0.923	0.95	880
Ramp	760	0.92	Level	12	4	0.936	0.95	929
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$$V_{12} = V_F (P_{FM})$$

L_{EQ} = (Equation 13-6 or 13-7)

P_{FM} = 1.000 using Equation (Exhibit 13-6)

V_{12} = 880 pc/h

V_3 or V_{av34} 0 pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	1809	Exhibit 13-8		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	1809	Exhibit 13-8	4600:All	No

Level of Service Determination (if not F)

$$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$$

D_R = 12.9 (pc/mi/ln)

LOS = B (Exhibit 13-2)

Speed Determination

M_S = 0.275 (Exhibit 13-11)

S_R= 58.7 mph (Exhibit 13-11)

S_0= N/A mph (Exhibit 13-11)

S = 58.7 mph (Exhibit 13-13)

Diverge Areas

Estimation of v_{12}

$$V_{12} = V_R + (V_F - V_R)P_{FD}$$

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = using Equation (Exhibit 13-7)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 13-14 or 13-17)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 13-16, 13-18, or 13-19)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 13-8		
$V_{FO} = V_F - V_R$		Exhibit 13-8		
V_R		Exhibit 13-10		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 13-8		

Level of Service Determination (if not F)

$$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$$

D_R = (pc/mi/ln)

LOS = (Exhibit 13-2)

Speed Determination

D_s = (Exhibit 13-12)

S_R= mph (Exhibit 13-12)

S_0= mph (Exhibit 13-12)

S = mph (Exhibit 13-13)

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APPENDIX D

Mary Street Alignment Option 1

Year 2035

Existing Street System

Capacity Calculations

HCM Analysis Summary

Mary Option 1 Alt 2035	Wicks Lane/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM	Case: WICKSM~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	320	450	150	520	390	80	350	1370	350	140	820	360
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			30			100			120		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 125.0 Sec   Lost Time Per Cycle: 18.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB							LTR										
WB					LTP												
NB	L		TP														
SB	L		TP														
Green	16.0		38.0		24.0		29.0										0
Yellow / All Red	3.0	0.0	3.5	1.5	3.5	1.5	3.5	1.5									

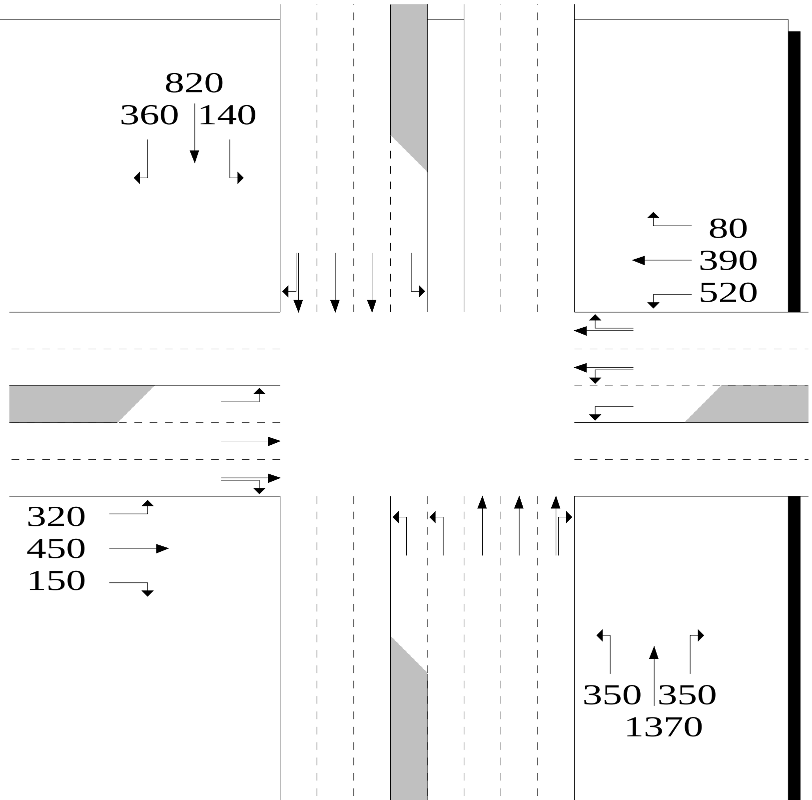
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	419	0.193	0.232	L	0.831	53.6	D	45.0	D
	TR	821	0.160	0.232	TR	0.688	39.7	D		
WB										
	* L	347	0.219	0.192	L	1.138	141.8	F	100.3	F
	LTR	675	0.184	0.192	LTR	0.960	74.9	E		
NB										
	* L	448	0.109	0.128	L	0.848	65.9	E	105.1	F
	* TR	1509	0.355	0.304	TR	1.167	113.5	F		
SB										
	L	231	0.084	0.128	L	0.658	65.7	E	45.2	D
	TR	1507	0.232	0.304	TR	0.764	42.5	D		

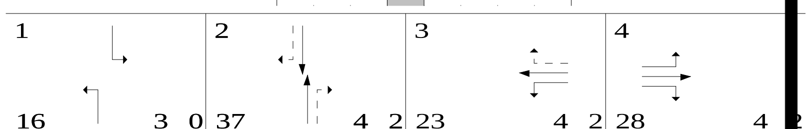
Intersection: Delay = 79.5 sec/veh   Int. LOS=E X_c= 1.02   * Critical Lane Group Σ(v/s)Crit= 0.87

NETSIM Summary Results

Mary Option 1 Alt 2035	Wicks Lane/Main Street
R Marvin	10/12/2011
PM	Case: WICKSM~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	8 / 13	4.9	0.0
	TR	3 / 6	12.8	0.0
	All		8.9	0.0
WB	L	12 / 13	3.8	0.0
	LTR	12 / 15	5.4	0.0
	All		4.9	0.0
NB	L	7 / 9	3.9	0.0
	TR	20 / 29	4.0	7.3
	All		3.9	7.3
SB	L	8 / 10	3.2	0.0
	TR	9 / 15	7.7	0.0
	All		6.7	0.0
Intersect.			5.2	





HCM Analysis Summary

Mary Opt 1 Alt 2035	Airport Road/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: AIRPOR~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	2890	10	70	1700	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)		20			30			0			100	
Peds/Hour		5			0			5			5	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated Operational Analysis Cycle Length: 150.0 Sec Lost Time Per Cycle: 20.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP				R												
WB			LTP														
NB					LTP		TP										
SB							TP		LTR								
Green	39.0		6.0		20.0		56.0		6.0								0
Yellow / All Red	3.5	1.5	3.5	1.5	3.0	0.0	3.5	1.5	3.5	1.5							

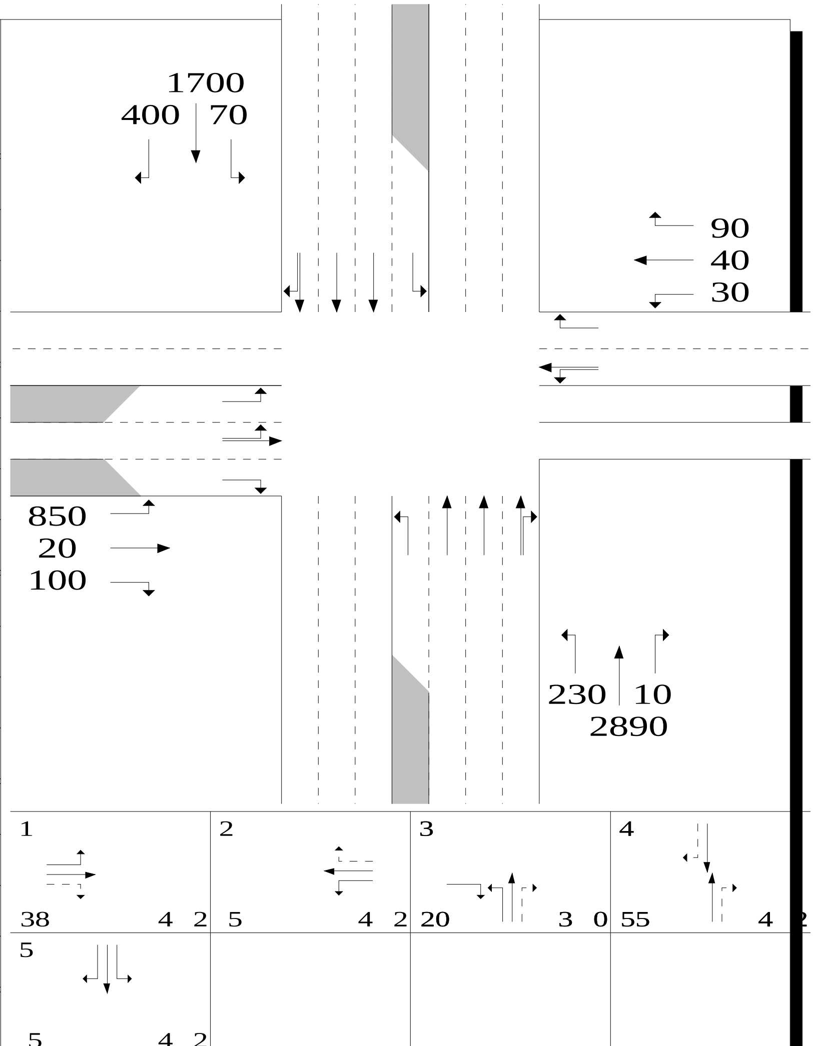
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	460	0.278	0.260	L	1.070	117.3	F	92.5	F
	LT	462	0.238	0.260	LT	0.918	76.8	E		
	R	639	0.054	0.413	R	0.131	27.3	C		
WB										
	* LT	74	0.040	0.040	LT	1.000	176.6	F	177.5	F
	R	64	0.039	0.040	R	0.984	178.5	F		
NB										
	L	236	0.137	0.133	L	1.025	123.7	F	80.8	F
	* TR	2677	0.601	0.527	TR	1.140	77.4	E		
SB										
	* L	72	0.041	0.040	L	1.028	184.0	F	34.0	C
	TR	2219	0.424	0.447	TR	0.949	28.7	C		

Intersection: Delay = 69.2 sec/veh Int. LOS=E X_c= 1.11 * Critical Lane Group Σ(v/s)Crit= 0.96

NETSIM Summary Results

Mary Opt 1 Alt 2035	Airport Road/Main Street
R Marvin	10/12/2011
PM Design Hour	Case: AIRPOR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	18 / 19	4.1	0.0
	LT	17 / 19	5.6	0.0
	R	1 / 2	18.6	0.0
	All		5.2	0.0
WB	LT	3 / 3	5.1	0.0
	R	3 / 4	9.6	0.0
	All		7.4	0.0
NB	L	13 / 16	2.8	0.0
	TR	24 / 30	7.1	11.1
	All		6.5	11.1
SB	L	4 / 7	4.2	0.0
	TR	13 / 18	9.4	0.0
	All		9.0	0.0
Intersect.			6.9	



HCM Analysis Summary

Mary Option 1 Alt 2035	1st Ave N/	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM design Hour	Case: US87MA~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	850	0	0	0	820	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			250			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 130.0 Sec | Lost Time Per Cycle: 15.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		52.0		26.0		37.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App		Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB											
	*	L	2060	0.368	0.400	L	0.920	28.7	C	29.4	C
		T	745	0.339	0.400	T	0.848	31.2	C		
WB											
	*	T	708	0.181	0.200	T	0.907	65.9	E	47.8	D
		R	812	0.407	0.523	R	0.778	29.4	C		
SB											
	*	L	958	0.256	0.285	L	0.901	46.0	D	25.6	C
		R	2015	0.253	0.723	R	0.350	0.5	A		

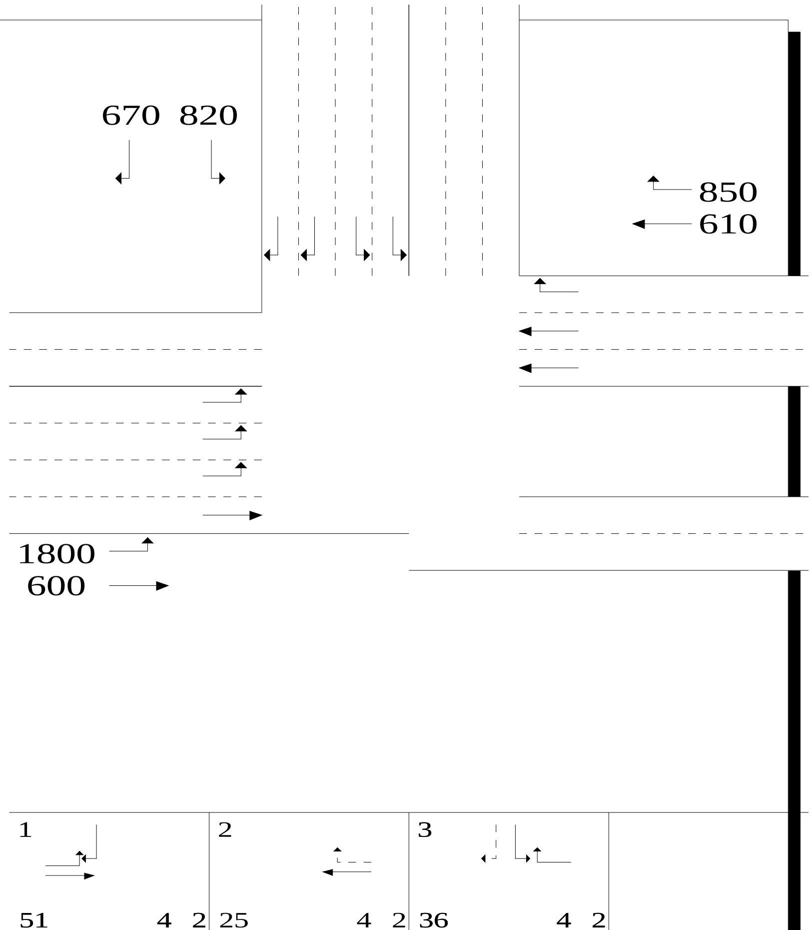
Intersection: Delay = 32.6 sec/veh | Int. LOS=C | X_c= 0.91 | * Critical Lane Group | Σ(v/s)Crit= 0.81

SIG/Cinema v3.08

NETSIM Summary Results

Mary Option 1 Alt 2035	1st Ave N/
R Marvin	10/12/2011
PM design Hour	Case: US87MA~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	17 / 26	4.7	1.2
	T	12 / 17	6.8	0.2
	All		5.1	1.2
WB	T	11 / 13	5.9	0.0
	R	13 / 15	9.6	0.0
	All		7.6	0.0
	All		6.4	0.0
SB	L	16 / 18	4.0	0.0
	R	0 / 1	21.6	0.0
Intersect.			6.0	



HCM Analysis Summary

Mary Op1 Alt 2035	Old US 87/I90 WB On Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: WBRAMP~1	

	Lanes		Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	890	420	220	1000	0	0	0	0	20	1	310
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)		150			0			0			100	
Peds/Hour		0			5			0			0	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 80.0 Sec   Lost Time Per Cycle: 14.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB			TR														
WB	LT		LT														
NB																	
SB					LTR												
Green	10.0		36.0		20.0												0
Yellow / All Red	4.0	0.0	3.5	1.5	3.5	1.5											

	Capacity Analysis Results								Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1493	0.380	0.450	TR	0.844	29.1	C	29.1	C
WB	Lper	94	0.087	0.512					16.4	B
	* Lpro	223	0.125	0.125	L	0.754	33.2	C		
	T	2149	0.316	0.625	T	0.506	12.7	B		
SB										
	* LTR	395	0.159	0.250	LTR	0.635	29.3	C	29.3	C

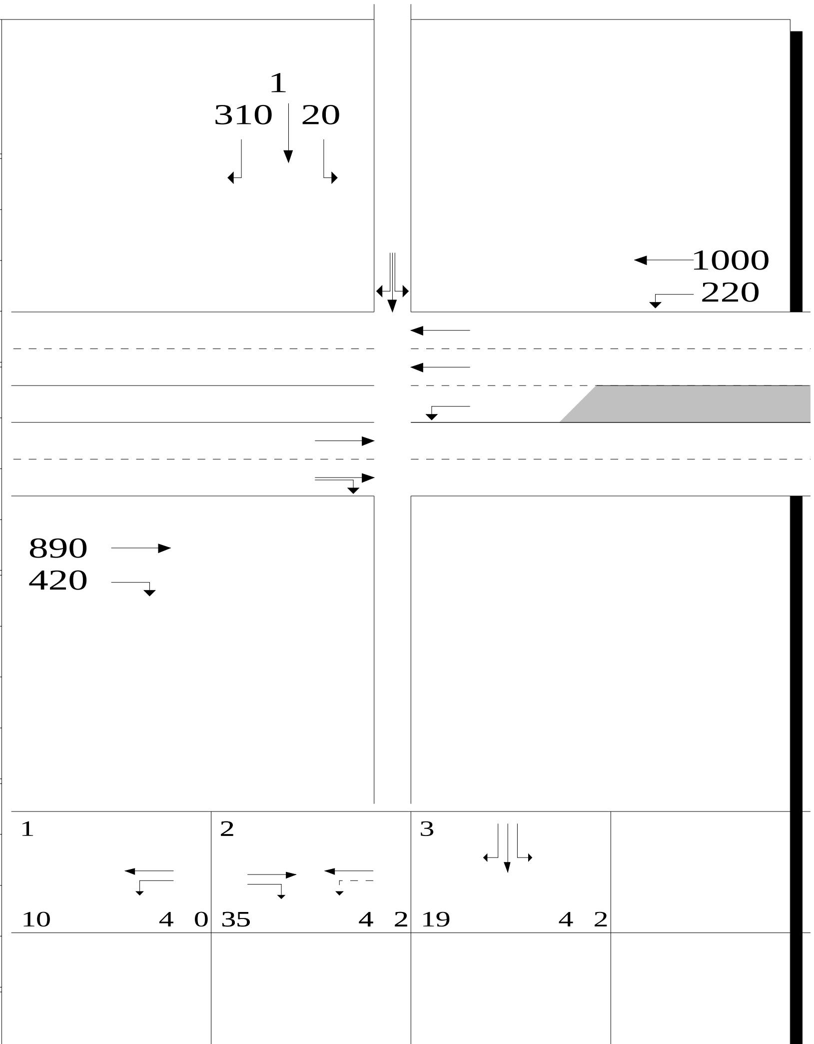
Intersection: Delay = 23.2 sec/veh   Int. LOS=C X_c= 0.80   * Critical Lane Group Σ(v/s)Crit= 0.66

SIG/Cinema v3.08

NETSIM Summary Results

Mary Op1 Alt 2035	Old US 87/I90 WB On Ramp
R Marvin	10/13/2011
PM Design Hour	Case: WBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 13	12.3	0.0
	All		12.3	0.0
WB	L	5 / 7	4.6	0.0
	T	4 / 5	18.3	0.0
	All		14.3	0.0
	All		14.7	0.0
SB	LTR	3 / 5	14.7	0.0
Intersect.			13.3	



HCM Analysis Summary

Mary Opt 1 2035	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: EBRAMP~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	470	440	0	0	600	20	620	350	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 120.0 Sec Lost Time Per Cycle: 9.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LT	LT							
WB		TR							
NB			LTP						
SB									
Green	32.0	25.0	49.0						0
Yellow | All Red	4.0 | 0.0	3.5 | 1.5	3.5 | 1.5						

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	61	0.197	0.250					43.4	D
	* Lpro	463	0.267	0.267	L	0.975	68.0	E		
	T	1817	0.134	0.508	T	0.263	17.1	B		
WB										
	TR	735	0.189	0.208	TR	0.909	63.6	E	63.6	E
NB										
	* L	699	0.393	0.408	L	0.964	59.9	E	54.1	D
	TR	720	0.370	0.408	TR	0.906	48.0	D		

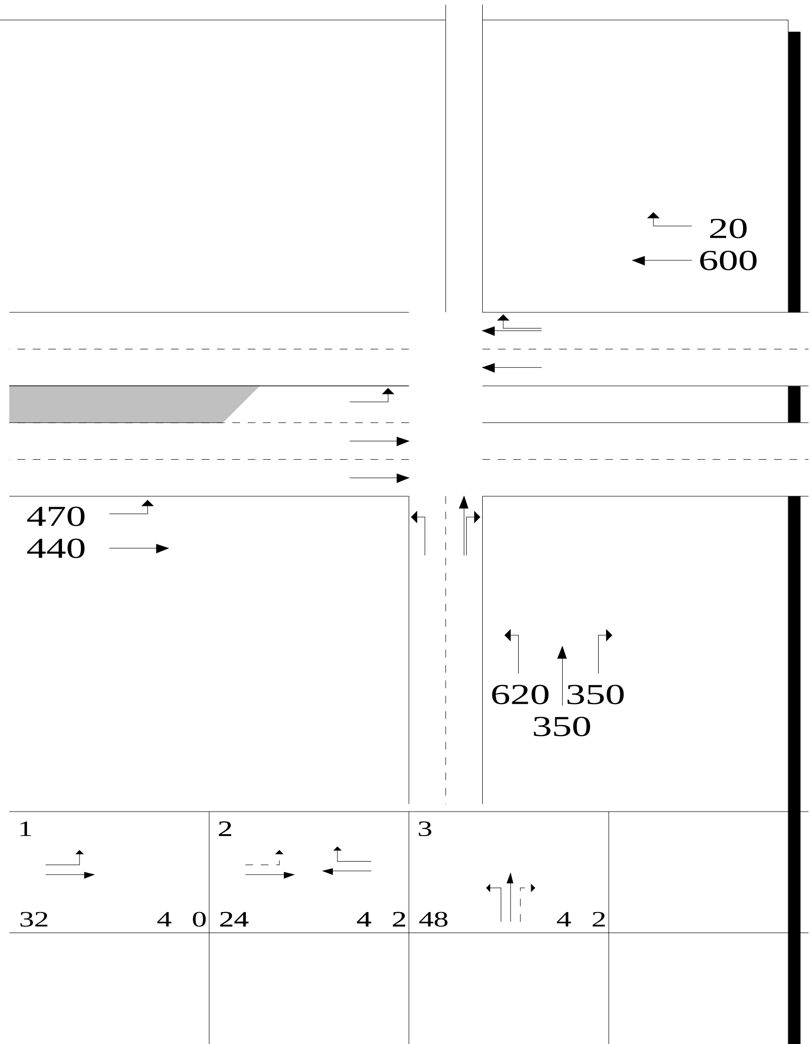
Intersection: Delay = 52.7 sec/veh Int. LOS=D X_c= 0.93 * Critical Lane Group Σ(v/s)Crit= 0.86

NETSIM Summary Results

Mary Opt 1 2035
R Marvin
PM Design Hour

Old US 87/I90 EB Off Ramp
10/13/2011
Case: EBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	20 / 26	2.9	31.2
	T	5 / 7	11.5	0.3
	All		6.4	31.2
WB	TR	9 / 11	6.9	0.0
	All		6.9	0.0
NB	L	24 / 27	4.4	2.3
	TR	25 / 28	4.2	5.4
	All		4.3	5.4
Intersect.			5.3	



APPENDIX E

Mary Street Alignment Option 2

Year 2035

Existing Street System

Capacity Calculations

HCM Analysis Summary

Mary Option 2 Alt 2035	Wicks Lane/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM	Case: WICKSM~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	320	450	150	520	390	80	350	1350	350	140	810	360
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			30			100			120		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 125.0 Sec — Lost Time Per Cycle: 18.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB							LTR										
WB					LTP												
NB	L		TP														
SB	L		TP														
Green	16.0		38.0		24.0		29.0										0
Yellow / All Red	3.0	0.0	3.5	1.5	3.5	1.5	3.5	1.5									

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	419	0.193	0.232	L	0.831	53.6	D	45.0	D
	TR	821	0.160	0.232	TR	0.688	39.7	D		
WB										
	* L	347	0.219	0.192	L	1.138	141.8	F	100.3	F
	LTR	675	0.184	0.192	LTR	0.960	74.9	E		
NB										
	* L	448	0.109	0.128	L	0.848	65.9	E	100.3	F
	* TR	1508	0.350	0.304	TR	1.153	107.8	F		
SB										
	L	231	0.084	0.128	L	0.658	65.7	E	45.0	D
	TR	1506	0.230	0.304	TR	0.758	42.3	D		

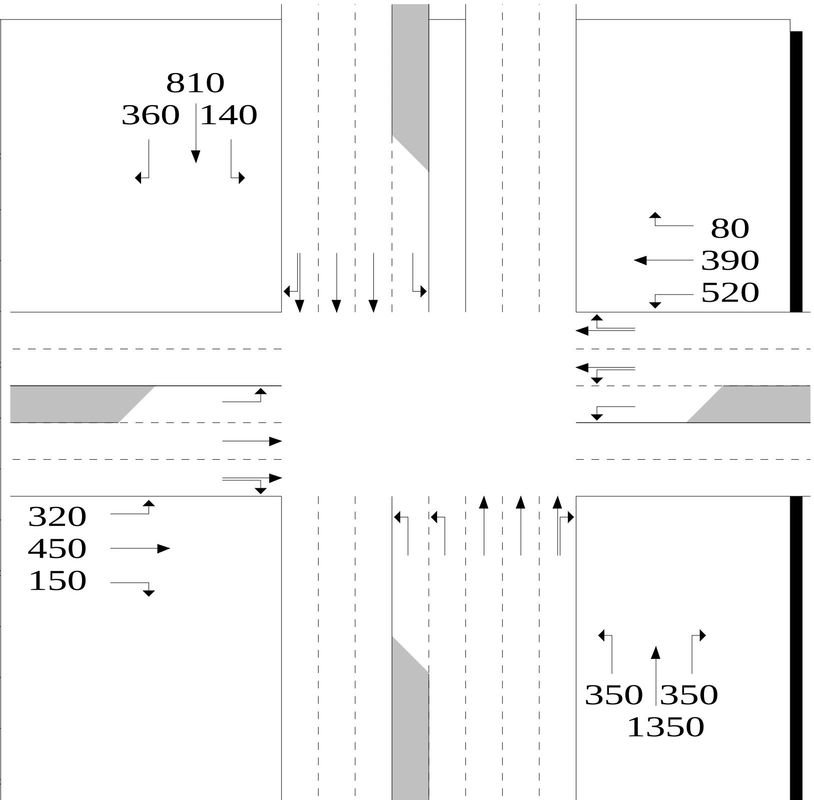
Intersection: Delay = 77.6 sec/veh   Int. LOS=E X_c= 1.02   * Critical Lane Group Σ(v/s)Crit= 0.87

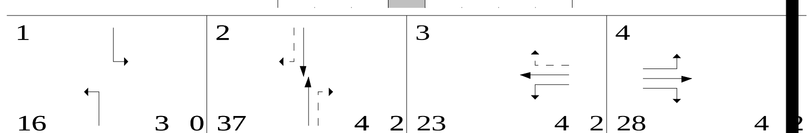
NETSIM Summary Results

Mary Option 2 Alt 2035
R Marvin
PM

Wicks Lane/Main Street
10/12/2011
Case: WICKSM~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	9 / 14	4.7	0.0
	TR	3 / 8	13.6	0.0
	All		9.0	0.0
WB	L	12 / 15	3.9	0.0
	LTR	11 / 14	6.1	0.0
	All		5.4	0.0
NB	L	7 / 10	3.9	0.0
	TR	17 / 29	4.2	2.8
	All		4.2	2.8
SB	L	8 / 10	3.1	0.0
	TR	9 / 20	6.7	0.0
	All		6.0	0.0
Intersect.			5.3	





HCM Analysis Summary

Mary Opt 2 Alt 2035	Airport Road/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: AIRPOR~1	

	Lanes		Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	2910	10	70	1710	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 150.0 Sec   Lost Time Per Cycle: 20.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP				R												
WB			LTP														
NB					LTP		TP										
SB							TP		LTR								
Green	39.0		6.0		20.0		56.0		6.0								0
Yellow / All Red	3.5	1.5	3.5	1.5	3.0	0.0	3.5	1.5	3.5	1.5							

App		Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB											
	*	L	460	0.278	0.260	L	1.070	117.3	F	92.5	F
		LT	462	0.238	0.260	LT	0.918	76.8	E		
		R	639	0.054	0.413	R	0.131	27.3	C		
WB											
	*	LT	74	0.040	0.040	LT	1.000	176.6	F	177.5	F
		R	64	0.039	0.040	R	0.984	178.5	F		
NB											
		L	236	0.137	0.133	L	1.025	123.7	F	83.9	F
	*	TR	2677	0.605	0.527	TR	1.148	80.7	F		
SB											
	*	L	72	0.041	0.040	L	1.028	184.0	F	34.6	C
		TR	2219	0.426	0.447	TR	0.954	29.4	C		

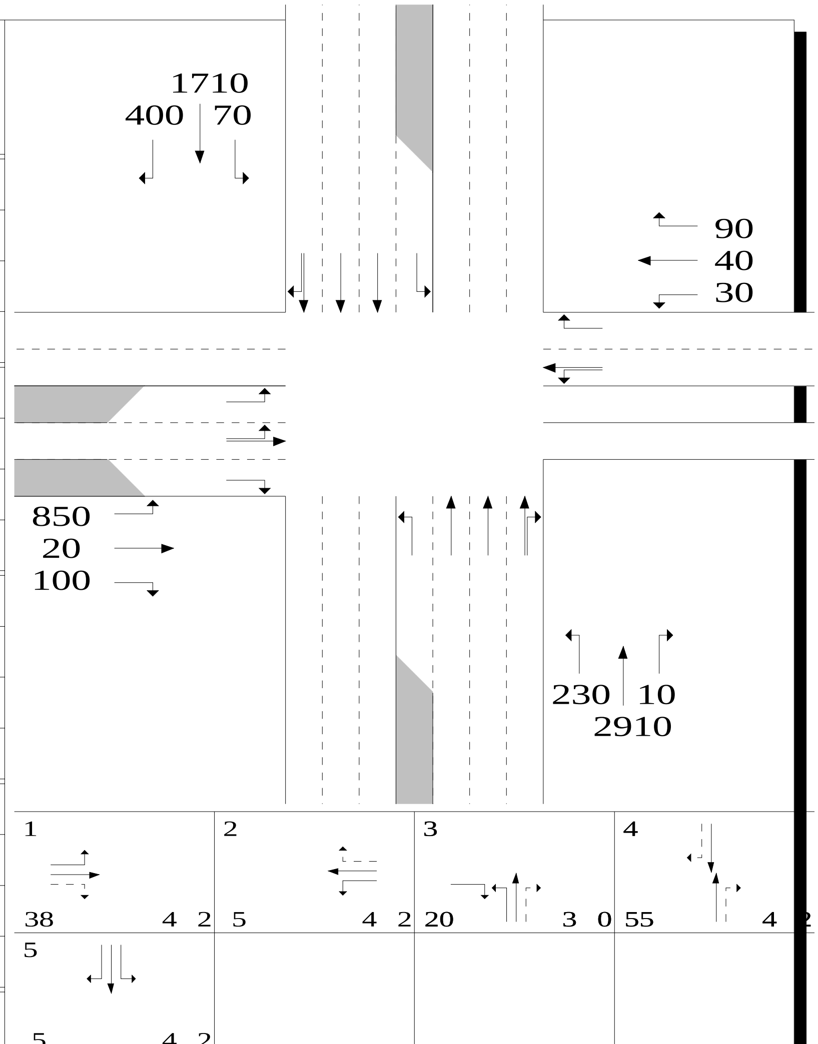
Intersection: Delay = 70.9 sec/veh   Int. LOS=E X_c = 1.11   * Critical Lane Group Σ(v/s)Crit= 0.96

SIG/Cinema v3.08

NETSIM Summary Results

Mary Opt 2 Alt 2035	Airport Road/Main Street
R Marvin	10/12/2011
PM Design Hour	Case: AIRPOR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	18 / 19	4.0	0.0
	LT	17 / 19	5.3	0.0
	R	1 / 2	17.9	0.0
	All		5.0	0.0
WB	LT	3 / 3	5.1	0.0
	R	3 / 4	9.5	0.0
	All		7.4	0.0
NB	L	13 / 16	2.9	0.0
	TR	25 / 30	7.0	12.9
	All		6.4	12.9
SB	L	4 / 6	7.2	0.0
	TR	11 / 18	10.0	0.0
	All		9.8	0.0
Intersect.			6.9	



HCM Analysis Summary

Mary Option 2 Alt 2035	1st Ave N/	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM design Hour	Case: US87MA~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	880	0	0	0	840	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			250			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated | Operational Analysis | Cycle Length: 130.0 Sec | Lost Time Per Cycle: 15.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		52.0		26.0		37.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

Capacity Analysis Results										Approach:	
App		Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB											
	*	L	2060	0.368	0.400	L	0.920	28.7	C	29.4	C
		T	745	0.339	0.400	T	0.848	31.2	C		
WB											
	*	T	708	0.181	0.200	T	0.907	65.9	E	48.6	D
		R	812	0.427	0.523	R	0.817	31.9	C		
SB											
	*	L	958	0.263	0.285	L	0.923	48.7	D	27.3	C
		R	2015	0.253	0.723	R	0.350	0.5	A		

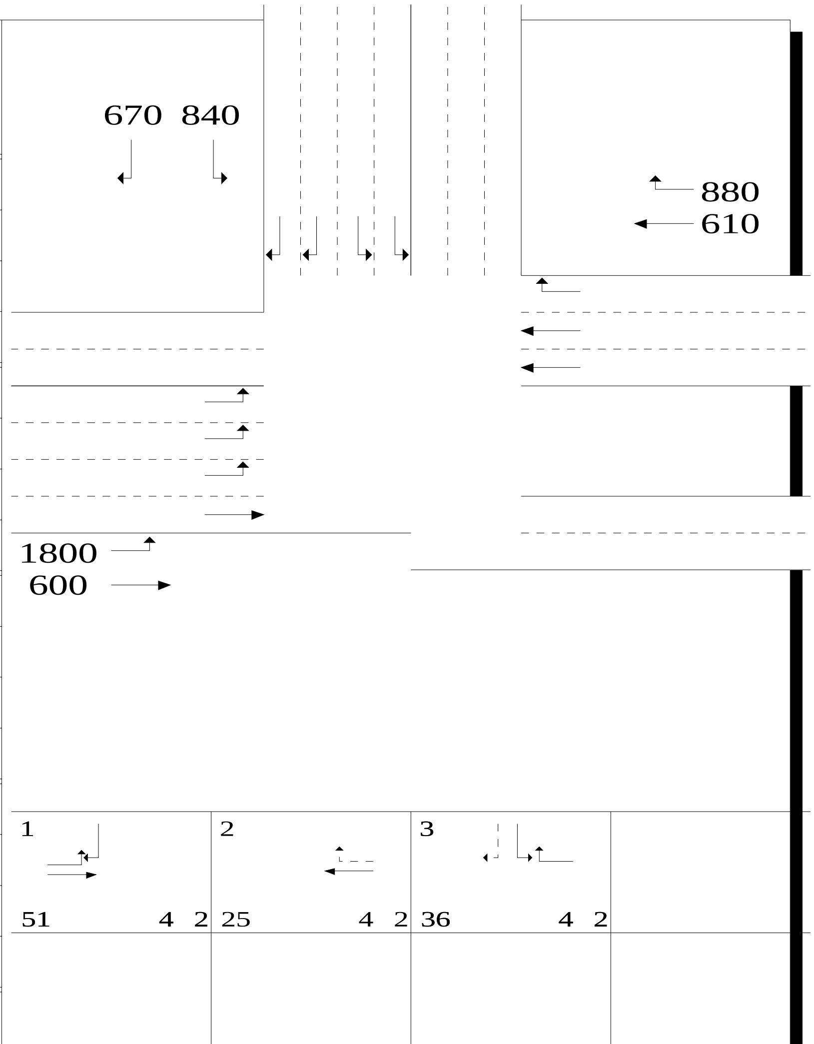
Intersection: Delay = 33.4 sec/veh   Int. LOS=C X_c= 0.92   * Critical Lane Group Σ(v/s)Crit= 0.81

NETSIM Summary Results

Mary Option 2 Alt 2035
R Marvin
PM design Hour

1st Ave N/
10/12/2011
Case: US87MA~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	17 / 24	4.6	1.7
	T	12 / 17	6.8	0.2
	All		5.0	1.7
WB	T	11 / 14	5.6	0.0
	R	22 / 27	5.4	2.6
	All		5.5	2.6
	All		6.5	0.0
SB	L	16 / 18	4.0	0.0
	R	1 / 3	22.0	0.0
Intersect.			5.5	



HCM Analysis Summary

Mary Op2 Alt 2035	Old US 87/I90 WB On Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: WBRAMP~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	920	420	220	1020	0	0	0	0	20	1	320
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)		150			0			0			100	
Peds/Hour		0			5			0			0	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 80.0 Sec — Lost Time Per Cycle: 14.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB			TR														
WB	LT		LT														
NB																	
SB					LTR												
Green	10.0		36.0		20.0												0
Yellow / All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1494	0.389	0.450	TR	0.865	30.4	C	30.4	C
WB	Lper	94	0.087	0.512					16.5	B
	* Lpro	223	0.125	0.125	L	0.754	33.4	C		
	T	2149	0.323	0.625	T	0.516	12.9	B		
SB										
	* LTR	395	0.166	0.250	LTR	0.663	30.3	C	30.3	C

Intersection: Delay = 24.0 sec/veh — Int. LOS=C — X_c= 0.82 — * Critical Lane Group — Σ(v/s)Crit= 0.68

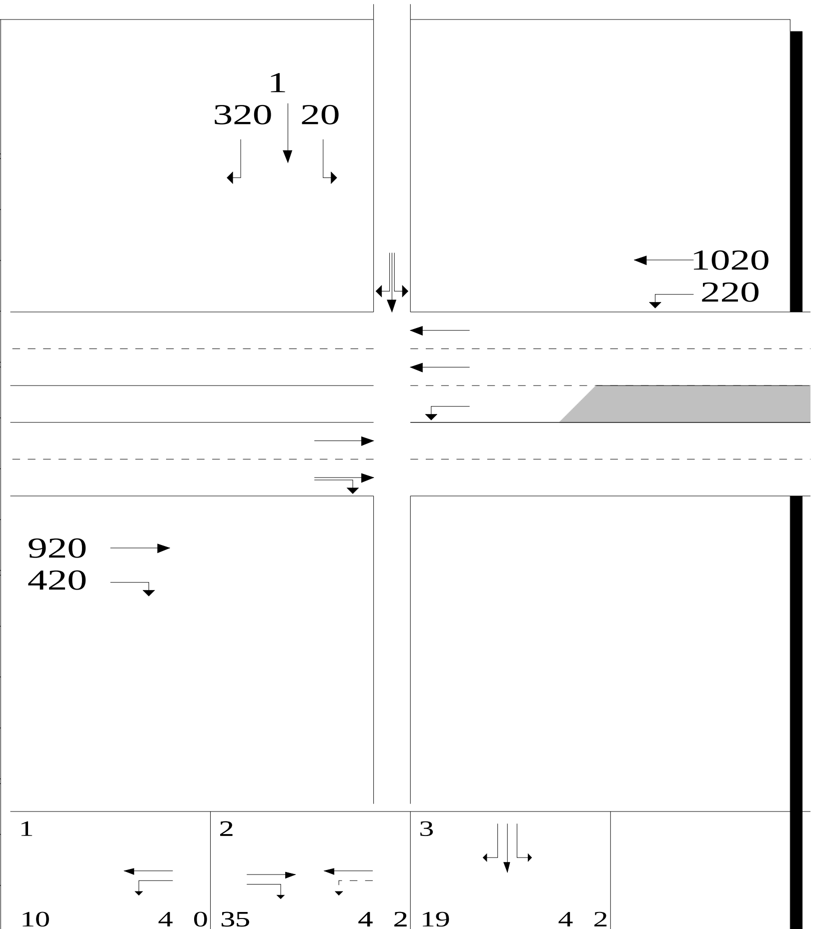
SIG/Cinema v3.08

NETSIM Summary Results

Mary Op2 Alt 2035
R Marvin
PM Design Hour

Old US 87/I90 WB On Ramp
10/13/2011
Case: WBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 14	12.1	0.0
	All		12.1	0.0
WB	L	5 / 6	5.0	0.0
	T	4 / 6	17.6	0.0
	All		14.5	0.0
	All		13.1	0.0
SB	LTR	4 / 7	13.1	0.0
Intersect.			13.1	



HCM Analysis Summary

Mary Opt 2 2035	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: EBRAMP~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	480	460	0	0	620	20	620	5	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 120.0 Sec Lost Time Per Cycle: 9.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LT	LT							
WB		TR							
NB			LTP						
SB									
Green	32.0	25.0	49.0						0
Yellow / All Red	4.0 / 0.0	3.5 / 1.5	3.5 / 1.5						

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	61	0.242	0.250					45.9	D
	* Lpro	463	0.267	0.267	L	0.996	73.3	E		
	T	1817	0.140	0.508	T	0.275	17.2	B		
WB										
	TR	735	0.196	0.208	TR	0.939	68.0	E	68.0	E
NB										
	* L	699	0.393	0.408	L	0.964	59.9	E	49.9	D
	TR	648	0.174	0.408	TR	0.427	25.6	C		

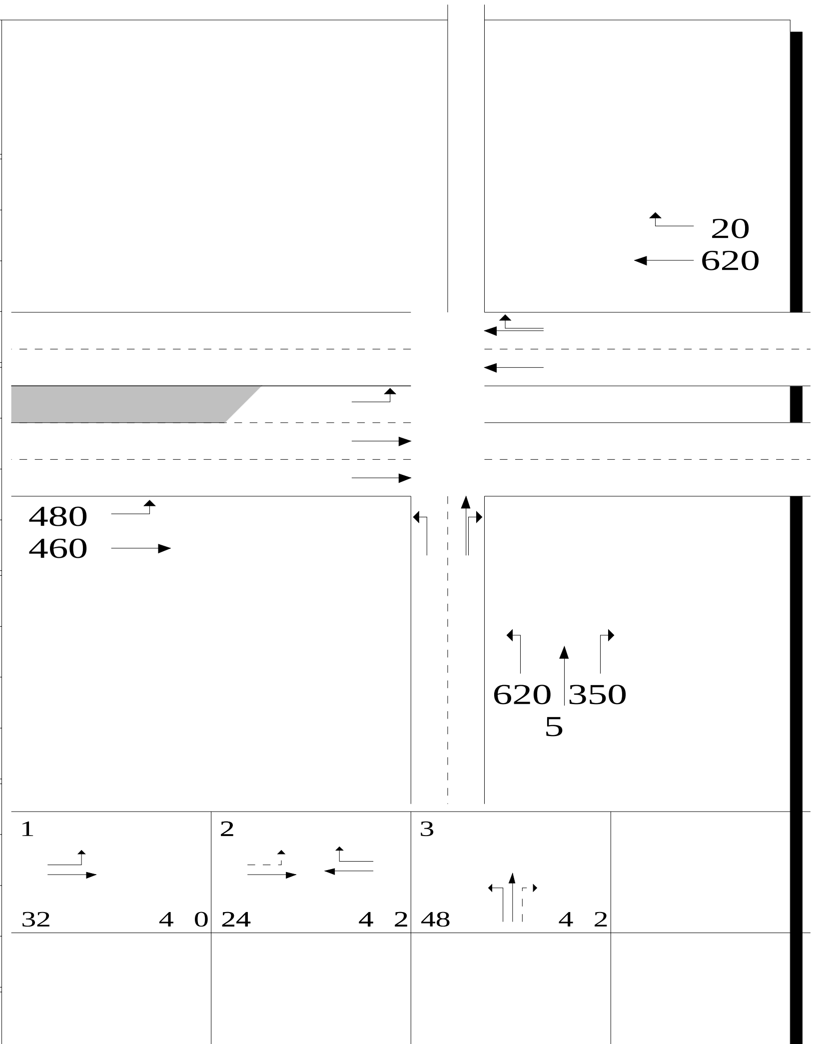
Intersection: Delay = 53.0 sec/veh Int. LOS=D X_c= 0.98 * Critical Lane Group Σ(v/s)Crit= 0.90

NETSIM Summary Results

Mary Opt 2 2035
R Marvin
PM Design Hour

Old US 87/I90 EB Off Ramp
10/13/2011
Case: EBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	24 / 28	2.8	42.9
	T	6 / 11	7.7	8.6
	All		5.2	42.9
WB	TR	9 / 11	6.8	0.0
	All		6.8	0.0
NB	L	17 / 24	6.2	0.8
	TR	4 / 9	16.5	0.0
	All		8.0	0.8
Intersect.			6.5	



APPENDIX F

Five Mile Road Alignment

Year 2035

Existing Street System

Capacity Calculations

HCM Analysis Summary

Five Mile Alt 2035	Wicks Lane/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM	Case: WICKSM~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	260	450	160	520	390	80	400	1450	380	140	920	290
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)		80			30			100			100	
Peds/Hour		0			5			5			5	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated | Operational Analysis | Cycle Length: 130.0 Sec | Lost Time Per Cycle: 18.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB				LTR					
WB			LTP						
NB	L	TP							
SB	L	TP							
Green	19.0	43.0	25.0	25.0					0
Yellow / All Red	3.0 / 0.0	3.5 / 1.5	3.5 / 1.5	3.5 / 1.5					

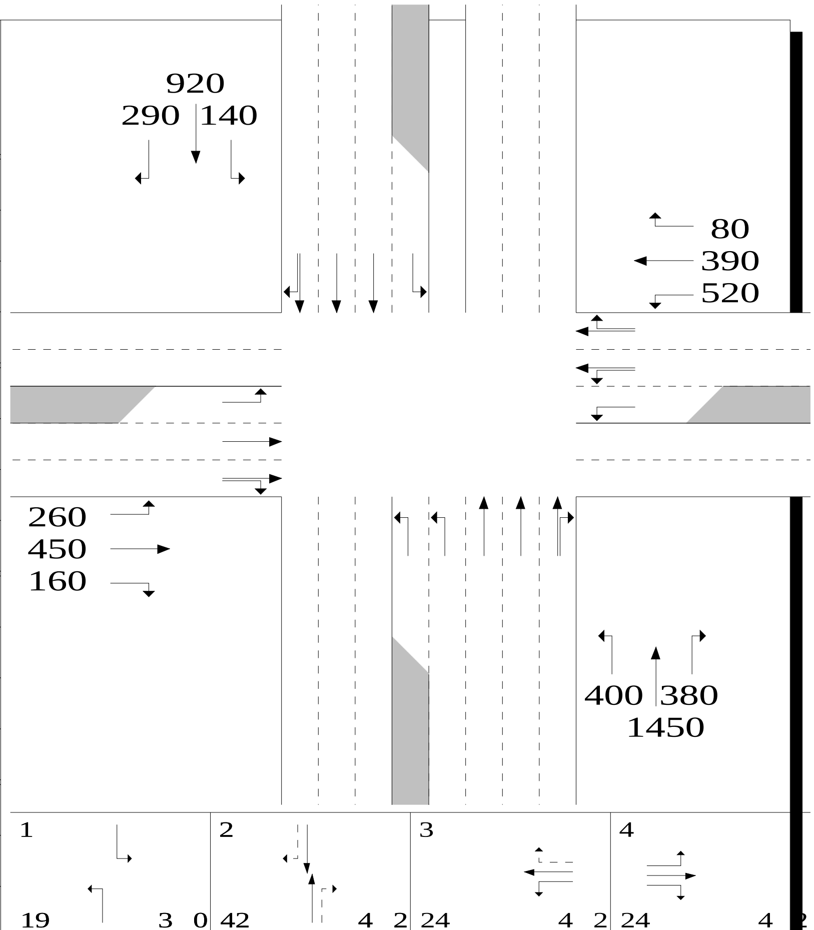
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	347	0.157	0.192	L	0.816	61.0	E	57.2	E
	* TR	678	0.163	0.192	TR	0.850	55.3	E		
WB										
	* L	347	0.219	0.192	L	1.138	143.8	F	102.0	F
	LTR	676	0.184	0.192	LTR	0.959	76.5	E		
NB										
	* L	512	0.124	0.146	L	0.850	64.0	E	95.4	F
	* TR	1640	0.379	0.331	TR	1.146	102.7	F		
SB										
	L	264	0.084	0.146	L	0.576	60.6	E	42.3	D
	TR	1638	0.244	0.331	TR	0.737	40.0	D		

Intersection: Delay = 77.8 sec/veh Int. LOS=E X_c= 1.03 * Critical Lane Group Σ(v/s)Crit= 0.89

NETSIM Summary Results

Five Mile Alt 2035	Wicks Lane/Main Street
R Marvin	10/12/2011
PM	Case: WICKSM~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	9 / 14	4.1	0.0
	TR	4 / 6	11.1	0.0
	All		7.8	0.0
WB	L	12 / 13	3.6	0.0
	LTR	11 / 13	6.2	0.0
	All		5.3	0.0
NB	L	8 / 9	3.5	0.0
	TR	15 / 28	5.0	2.1
	All		4.6	2.1
SB	L	9 / 11	3.1	0.0
	TR	9 / 14	7.2	0.0
	All		6.4	0.0
Intersect.			5.5	



HCM Analysis Summary

Five Mile Alt 2035	Airport Road/Main Street	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: AIRPOR~1	

	Lanes		Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	3050	10	70	1820	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated Operational Analysis Cycle Length: 150.0 Sec Lost Time Per Cycle: 20.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP		R						
WB		LTP							
NB			LTP	TP					
SB				TP	LTR				
Green	39.0	6.0	17.0	59.0	6.0				0
Yellow / All Red	3.5 / 1.5	3.5 / 1.5	3.0 / 0.0	3.5 / 1.5	3.5 / 1.5				

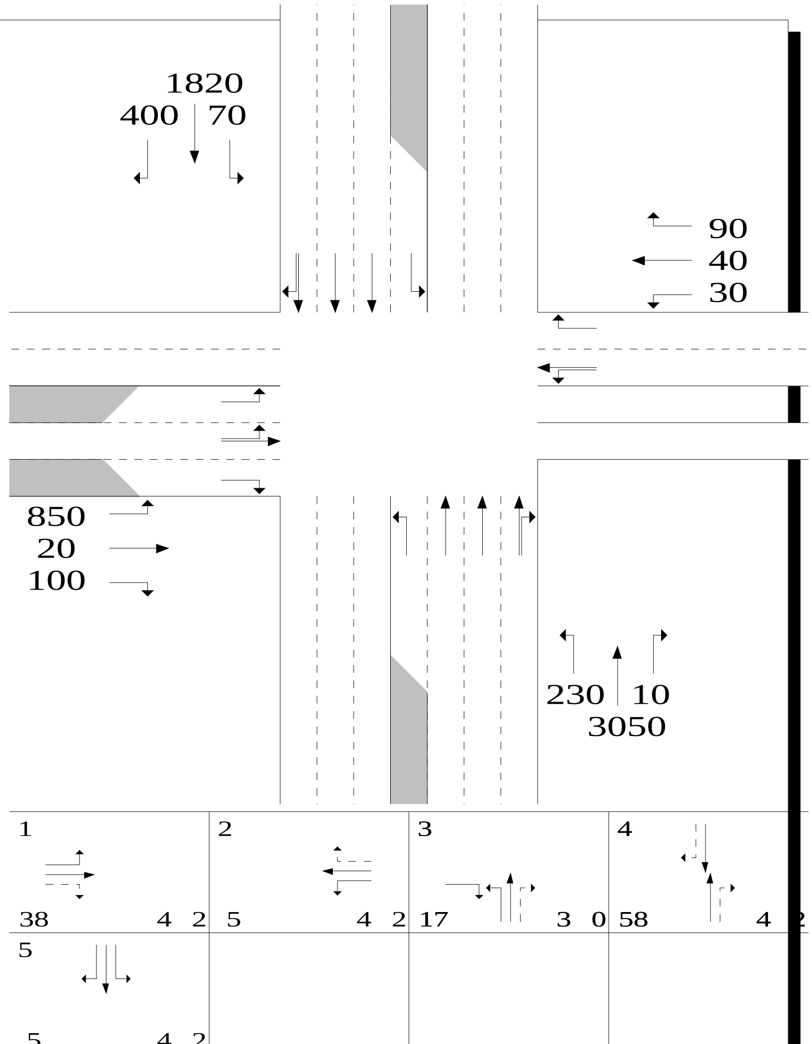
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	460	0.278	0.260	L	1.070	117.3	F	92.7	F
	LT	462	0.238	0.260	LT	0.918	76.8	E		
	R	608	0.054	0.393	R	0.138	29.2	C		
WB										
	* LT	74	0.040	0.040	LT	1.000	176.6	F	177.5	F
	R	64	0.039	0.040	R	0.984	178.5	F		
NB										
	L	201	0.137	0.113	L	1.204	190.1	F	110.6	F
	* TR	2677	0.634	0.527	TR	1.204	104.6	F		
SB										
	* L	72	0.041	0.040	L	1.028	184.0	F	32.7	C
	TR	2322	0.449	0.467	TR	0.961	27.7	C		

Intersection: Delay = 83.3 sec/veh Int. LOS=F X_c= 1.15 * Critical Lane Group Σ(v/s)Crit= 0.99

NETSIM Summary Results

Five Mile Alt 2035	Airport Road/Main Street
R Marvin	10/12/2011
PM Design Hour	Case: AIRPOR~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	17 / 18	4.3	0.0
	LT	16 / 17	5.8	0.0
	R	1 / 2	17.9	0.0
	All		5.4	0.0
WB	LT	3 / 3	5.1	0.0
	R	3 / 4	9.4	0.0
	All		7.4	0.0
NB	L	17 / 20	1.7	0.0
	TR	28 / 30	6.0	28.3
	All		5.2	28.3
SB	L	6 / 9	2.8	0.0
	TR	11 / 17	10.5	0.0
	All		9.6	0.0
Intersect.			6.3	



HCM Analysis Summary

Mary Five Mile Alt 2035	1st Ave N/	Area Type: Non CBD
R Marvin	10/12/2011	Analysis Duration: 15 mins.
PM design Hour	Case: US87MA~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	1000	0	0	0	970	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			250			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 140.0 Sec — Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		54.0		28.0		43.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

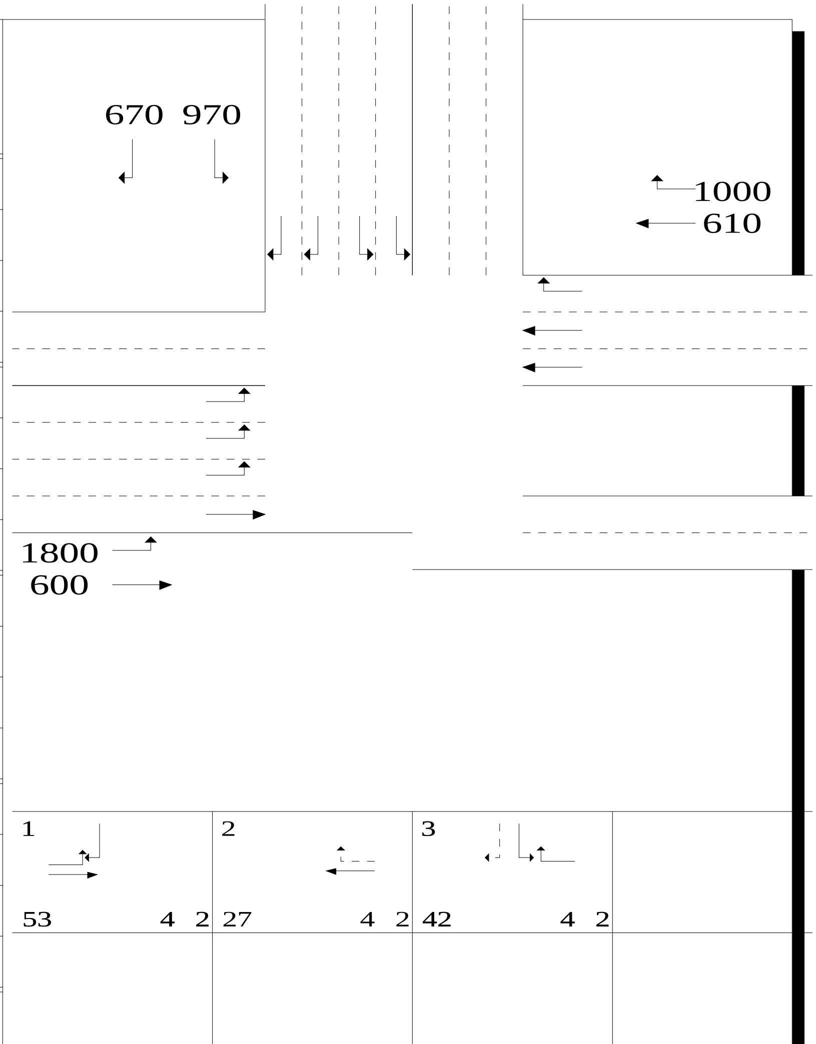
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	1986	0.368	0.386	L	0.954	36.2	D	36.6	D
	T	719	0.339	0.386	T	0.879	37.6	D		
WB										
	T	708	0.181	0.200	T	0.907	69.8	E	57.2	E
	* R	843	0.508	0.543	R	0.936	47.0	D		
SB										
	L	1034	0.303	0.307	L	0.987	59.1	E	35.2	D
	R	2031	0.253	0.729	R	0.347	0.5	A		

Intersection: Delay = 41.3 sec/veh — Int. LOS=D — X_c= 0.94 — * Critical Lane Group — Σ(v/s)Crit= 0.88

NETSIM Summary Results

Mary Five Mile Alt 2035 — 1st Ave N/
R Marvin — 10/12/2011
PM design Hour — Case: US87MA~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	20 / 30	4.3	15.2
	T	13 / 21	6.5	0.0
	All		4.8	15.2
WB	T	11 / 13	6.0	0.0
	R	28 / 30	4.0	28.4
	All		4.6	28.4
	All		5.8	0.0
SB	L	20 / 22	3.6	0.0
	R	1 / 1	22.4	0.0
Intersect.			5.0	



HCM Analysis Summary

Five Mile Alt 2035
R Marvin
PM Design Hour

Old US 87/I90 WB On Ramp
10/13/2011
Case: WBRAMP~1

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	990	460	220	1130	0	0	0	0	20	1	320
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)	150			0			0			100		
Peds/Hour	0			5			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 80.0 Sec Lost Time Per Cycle: 14.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB		TR							
WB	LT	LT							
NB									
SB			LTR						
Green	10.0	37.0	19.0						0
Yellow / All Red	4.0 / 0.0	3.5 / 1.5	3.5 / 1.5						

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1533	0.426	0.463	TR	0.922	34.7	C	34.7	C
WB	Lper	94	0.089	0.525					16.5	B
	* Lpro	223	0.125	0.125	L	0.754	34.3	C		
	T	2192	0.357	0.637	T	0.560	13.1	B		
SB										
	* LTR	375	0.166	0.237	LTR	0.699	32.7	C	32.7	C

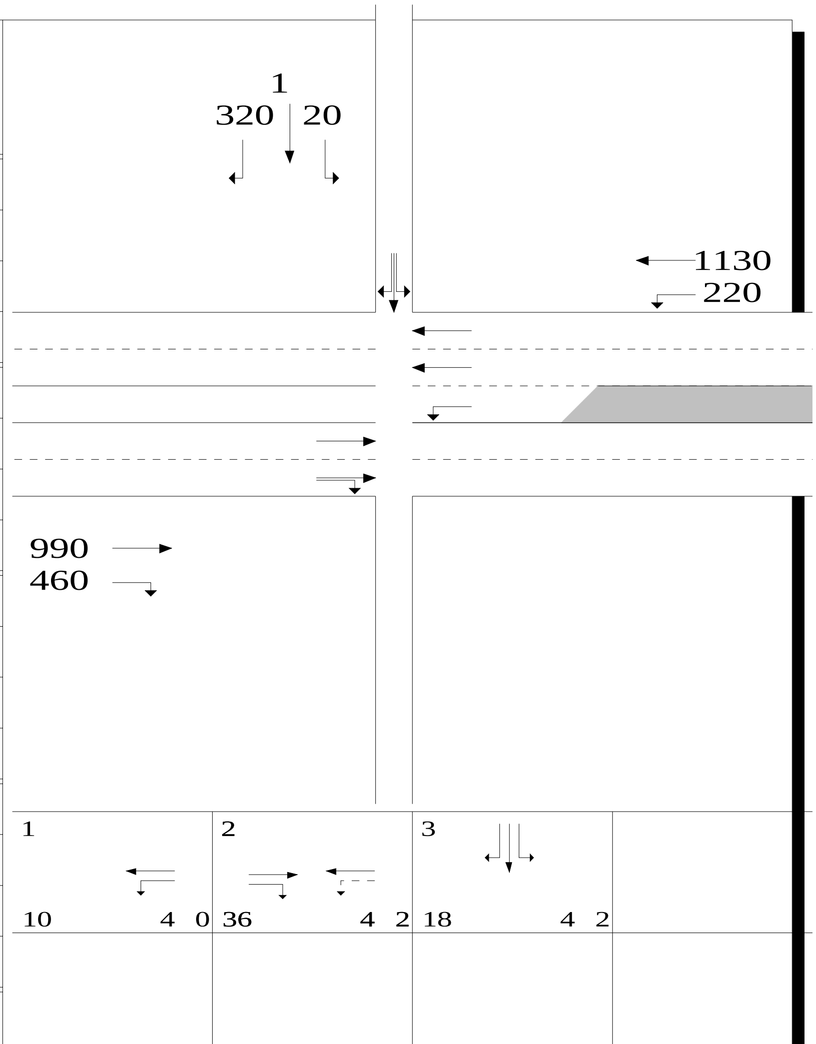
Intersection: Delay = 26.1 sec/veh Int. LOS=C X_c= 0.87 * Critical Lane Group Σ(v/s)Crit= 0.72

NETSIM Summary Results

Five Mile Alt 2035
R Marvin
PM Design Hour

Old US 87/I90 WB On Ramp
10/13/2011
Case: WBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 14	12.5	0.0
	All		12.5	0.0
WB	L	5 / 7	4.8	0.0
	T	6 / 7	17.5	0.0
	All		14.3	0.0
	All		12.0	0.0
SB	LTR	4 / 7	12.0	0.0
Intersect.			13.1	



HCM Analysis Summary

Five Mile Alt 2035
R Marvin
PM Design Hour

Old US 87/I90 EB Off Ramp
10/13/2011
Case: EBRAMP~1

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	480	530	0	0	690	20	660	5	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 120.0 Sec   Lost Time Per Cycle: 9.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT		LT														
WB				TR														
NB						LTP												
SB																		
Green		32.0		28.0		46.0												0
Yellow	All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	61	0.267	0.275					43.4	D
	* Lpro	463	0.267	0.267	L	0.996	73.7	E		
	T	1906	0.161	0.533	T	0.302	16.0	B		
WB										
	TR	823	0.217	0.233	TR	0.931	63.5	E	63.5	E
NB										
	* L	656	0.419	0.383	L	1.093	100.2	F	80.0	F
	TR	609	0.174	0.383	TR	0.455	27.8	C		

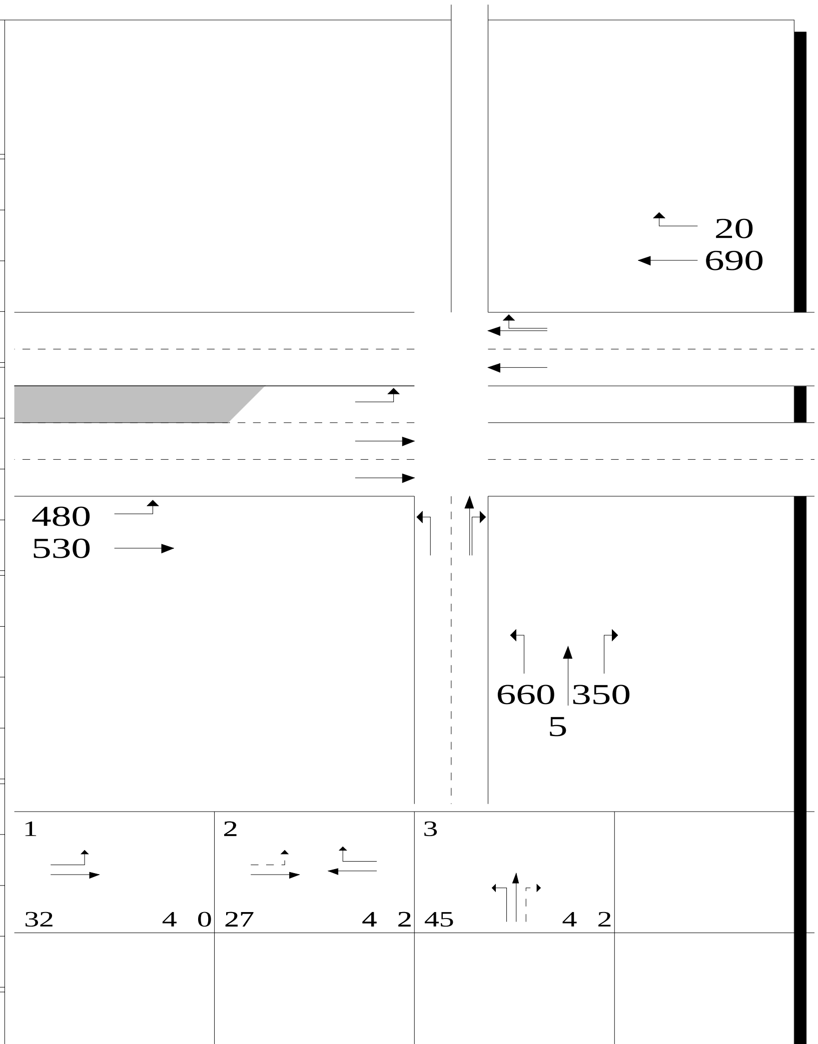
Intersection: Delay = 61.5 sec/veh   Int. LOS=E X_c= 1.03   * Critical Lane Group Σ(v/s)Crit= 0.95

NETSIM Summary Results

Five Mile Alt 2035
R Marvin
PM Design Hour

Old US 87/I90 EB Off Ramp
10/13/2011
Case: EBRAMP~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	26 / 29	2.3	49.6
	T	5 / 8	8.3	7.3
	All		5.2	49.6
WB	TR	10 / 12	7.0	0.0
	All		7.0	0.0
NB	L	25 / 29	4.1	23.6
	TR	5 / 10	14.1	0.0
	All		5.4	23.6
Intersect.			5.7	



APPENDIX G

Alternative Alignment

Intersection Designs

Year 2035 Capacity Calculations

TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Mary Opt 1 & Johnson N*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*10/8/2011*	Analysis Year	*2035*
Analysis Time Period	*Design Hour PM*		

Project Description *Billings Bypass*	
East/West Street: *Mary Option 1*	North/South Street: *Johnson Lane N*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*10*	*1010*			*730*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*11*	*1122*	*0*	*0*	*811*	*5*
Percent Heavy Vehicles	*4*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*0*	*2*	*0*
Configuration	*L*	*T*			*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*0*		*30*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.60*	*1.00*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*0*	*0*	*49*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*11*						*49*	
C (m) (veh/h)	*795*						*632*	
v/c	*0.01*						*0.08*	
95% queue length	*0.04*						*0.25*	
Control Delay (s/veh)	*9.6*						*11.2*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*11.2*		
Approach LOS	--	--				*B*		

 *HCS+*TM Version 5.6 Generated: 12/19/2011 3:27 PM

TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary Opt 1 & Coulson Rd*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Option 1* | North/South Street: *Coulson Road*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*55*	*955*			*650*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*61*	*1061*	*0*	*0*	*722*	*5*
Percent Heavy Vehicles	*4*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*0*	*2*	*0*
Configuration	*L*	*T*			*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*5*		*80*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.70*	*1.00*	*0.70*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*7*	*0*	*114*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*61*						*121*	
C (m) (veh/h)	*859*						*534*	
v/c	*0.07*						*0.23*	
95% queue length	*0.23*						*0.86*	
Control Delay (s/veh)	*9.5*						*13.7*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*13.7*		
Approach LOS	--	--				*B*		

 *HCS+*TM Version 5.6 Generated: 12/19/2011 3:28 PM

LANE SUMMARY

Site: Mary Alignment Option 1
Intersection with Five Mile adn
Mary Street

Mary Alignment Option 1
Intersection of Mary Alignment with Mary Street & Five Mile Road
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Mary Street NB																
Lane 1	5	54	22	82	0.0	681	0.120	100	8.2	LOS A	0.5	12.0	1600	–	0.0	0.0
Approach	5	54	22	82	0.0		0.120		8.2	LOS A	0.5	12.0				
East: Mary Alignment WB																
Lane 1	22	460	0	482	3.8	1335	0.361	100	5.1	LOS A	2.6	67.0	1600	–	0.0	0.0
Lane 2	0	301	250	551	3.1	1528	0.361	100	5.3	LOS A	2.6	67.6	1600	–	0.0	0.0
Approach	22	761	250	1033	3.4		0.361		5.2	LOS A	2.6	67.6				
North: Five Mile Road SB																
Lane 1	185	11	5	201	1.9	627	0.321	100	15.9	LOS B	1.4	35.0	1600	–	0.0	0.0
Approach	185	11	5	201	1.9		0.321		15.9	LOS B	1.4	35.0				
West: Mary Alignment EB																
Lane 1	5	220	0	226	3.9	1101	0.205	100	5.8	LOS A	1.2	31.5	1600	–	0.0	0.0
Lane 2	0	247	5	252	3.9	1231	0.205	100	5.4	LOS A	1.3	32.2	1600	–	0.0	0.0
Approach	5	467	5	478	3.9		0.205		5.6	LOS A	1.3	32.2				
Intersection				1793	3.2		0.361		6.6	LOS A	2.6	67.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/3/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Dover & Five Mile Mary Opt 1*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Dover Road* North/South Street: *Five Mile Road*

Intersection Orientation: *North-South* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	30	240	50	5	160	5
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	33	266	55	5	177	5
Percent Heavy Vehicles	3	--	--	3	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration	LTR			LTR		
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	5	90	20	30	60	5
Peak-Hour Factor, PHF	0.80	0.80	0.80	0.80	0.80	0.80
Hourly Flow Rate, HFR (veh/h)	6	112	24	37	74	6
Percent Heavy Vehicles	0	3	0	0	3	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	LTR	LTR		LTR			LTR	
v (veh/h)	33	5		117			142	
C (m) (veh/h)	1387	1233		385			449	
v/c	0.02	0.00		0.30			0.32	
95% queue length	0.07	0.01		1.26			1.34	
Control Delay (s/veh)	7.7	7.9		18.4			16.7	
LOS	A	A		C			C	
Approach Delay (s/veh)	--	--	18.4			16.7		
Approach LOS	--	--	C			C		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary & Hawthrone Option 1*
Jurisdiction	*MDT*
Analysis Year	*Year 2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* | North/South Street: *Bitteroot*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	5	20	5	10	35	10
Peak-Hour Factor, PHF	0.60	0.60	0.60	0.60	0.60	0.60
Hourly Flow Rate, HFR (veh/h)	8	33	8	16	58	16
Percent Heavy Vehicles	0	--	--	0	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration	LTR			LTR		
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	15	95	30	5	65	10
Peak-Hour Factor, PHF	0.70	0.70	0.70	0.70	0.70	0.70
Hourly Flow Rate, HFR (veh/h)	21	135	42	7	92	14
Percent Heavy Vehicles	0	0	0	0	0	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	LTR	LTR		LTR			LTR	
v (veh/h)	8	16		113			198	
C (m) (veh/h)	1538	1581		742			766	
v/c	0.01	0.01		0.15			0.26	
95% queue length	0.02	0.03		0.54			1.03	
Control Delay (s/veh)	7.4	7.3		10.7			11.3	
LOS	A	A		B			B	
Approach Delay (s/veh)	--	--	10.7			11.3		
Approach LOS	--	--	B			B		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Assoc*
Date Performed	*9/28/2011*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*Mary Align & Hawthorne Opt 1*
Jurisdiction	*City Billings*
Analysis Year	*2035*

Project Description *Billings Bypass EIS*

East/West Street: *Mary Align* North/South Street: *Hawthorne*

Intersection Orientation: *East-West* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*420*	*5*	*50*	*640*	
Peak-Hour Factor, PHF	*1.00*	*0.90*	*0.90*	*0.90*	*0.90*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*466*	*5*	*55*	*711*	*0*
Percent Heavy Vehicles	*0*	*--*	*--*	*0*	*--*	*--*
Median Type	*Two Way Left Turn Lane*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*1*	*1*	*0*
Configuration			*TR*	*L*	*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*5*		*40*			
Peak-Hour Factor, PHF	*0.80*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*6*	*0*	*49*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)		*0*			*0*	
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*L*		*LR*				
v (veh/h)		*55*		*55*				
C (m) (veh/h)		*1101*		*541*				
v/c		*0.05*		*0.10*				
95% queue length		*0.16*		*0.34*				
Control Delay (s/veh)		*8.4*		*12.4*				
LOS		*A*		*B*				
Approach Delay (s/veh)	*--*	*--*	*12.4*					
Approach LOS	*--*	*--*	*B*					

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Mary Opt 2 & Johnson N*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*10/8/2011*	Analysis Year	*2035*
Analysis Time Period	*Design Hour PM*		

Project Description *Billings Bypass*

East/West Street: *Mary Option 2* — North/South Street: *Johnson Lane N*

Intersection Orientation: *East-West* — Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*10*	*995*			*705*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*11*	*1105*	*0*	*0*	*783*	*5*
Percent Heavy Vehicles	*4*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*0*	*2*	*0*
Configuration	*L*	*T*			*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*0*		*30*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.60*	*1.00*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*0*	*0*	*49*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*11*						*49*	
C (m) (veh/h)	*814*						*644*	
v/c	*0.01*						*0.08*	
95% queue length	*0.04*						*0.25*	
Control Delay (s/veh)	*9.5*						*11.0*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*11.0*		
Approach LOS	--	--				*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary Opt 2 & Coulson Rd*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Option 1*

North/South Street: *Coulson Road*

Intersection Orientation: *East-West*

Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*55*	*940*			*625*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*61*	*1044*	*0*	*0*	*694*	*5*
Percent Heavy Vehicles	*4*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*0*	*2*	*0*
Configuration	*L*	*T*			*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*5*		*80*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.70*	*1.00*	*0.70*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*7*	*0*	*114*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*61*						*121*	
C (m) (veh/h)	*880*						*548*	
v/c	*0.07*						*0.22*	
95% queue length	*0.22*						*0.84*	
Control Delay (s/veh)	*9.4*						*13.4*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*13.4*		
Approach LOS	--	--				*B*		

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LANE SUMMARY

Site: Mary Alignment Option 2
Intersection with Five Mile & Mary Street

Mary Alignment Option 2
Intersection of Mary Alignment with Mary Street & Five Mile Road
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Mary Street NB																
Lane 1	5	54	22	82	0.0	676	0.121	100	8.2	LOS A	0.5	12.1	1600	–	0.0	0.0
Approach	5	54	22	82	0.0		0.121		8.2	LOS A	0.5	12.1				
East: Mary Alignment WB																
Lane 1	22	450	0	471	3.8	1335	0.353	100	5.1	LOS A	2.5	65.1	1600	–	0.0	0.0
Lane 2	0	289	250	539	3.1	1527	0.353	100	5.3	LOS A	2.6	65.7	1600	–	0.0	0.0
Approach	22	739	250	1011	3.4		0.353		5.2	LOS A	2.6	65.7				
North: Five Mile Road SB																
Lane 1	185	11	5	201	1.9	634	0.317	100	15.8	LOS B	1.4	34.3	1600	–	0.0	0.0
Approach	185	11	5	201	1.9		0.317		15.8	LOS B	1.4	34.3				
West: Mary Alignment EB																
Lane 1	5	225	0	231	3.9	1101	0.210	100	5.8	LOS A	1.3	32.3	1600	–	0.0	0.0
Lane 2	0	253	5	258	3.9	1232	0.210	100	5.4	LOS A	1.3	33.1	1600	–	0.0	0.0
Approach	5	478	5	489	3.9		0.210		5.6	LOS A	1.3	33.1				
Intersection				1783	3.2		0.353		6.6	LOS A	2.6	65.7				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/3/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Dover & Five Mile Mary Opt 2*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Dover Road* | North/South Street: *Five Mile Road*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	30	200	50	5	150	5
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	33	222	55	5	166	5
Percent Heavy Vehicles	3	--	--	3	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration	LTR			LTR		
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	5	90	20	30	60	5
Peak-Hour Factor, PHF	0.80	0.80	0.80	0.80	0.80	0.80
Hourly Flow Rate, HFR (veh/h)	6	112	24	37	74	6
Percent Heavy Vehicles	0	3	0	0	3	0
Percent Grade (%)		0			0	
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	LTR	LTR		LTR			LTR	
v (veh/h)	33	5		117			142	
C (m) (veh/h)	1400	1280		419			481	
v/c	0.02	0.00		0.28			0.30	
95% queue length	0.07	0.01		1.13			1.22	
Control Delay (s/veh)	7.6	7.8		16.9			15.6	
LOS	A	A		C			C	
Approach Delay (s/veh)	--	--	16.9			15.6		
Approach LOS	--	--	C			C		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary & Hawthrone Option 2*
Jurisdiction	*MDT*
Analysis Year	*Year 2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* | North/South Street: *Bitteroot*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*5*	*20*	*5*	*10*	*35*	*10*
Peak-Hour Factor, PHF	*0.60*	*0.60*	*0.60*	*0.60*	*0.60*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*8*	*33*	*8*	*16*	*58*	*16*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration	*LTR*			*LTR*		
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*15*	*95*	*30*	*5*	*65*	*10*
Peak-Hour Factor, PHF	*0.70*	*0.70*	*0.70*	*0.70*	*0.70*	*0.70*
Hourly Flow Rate, HFR (veh/h)	*21*	*135*	*42*	*7*	*92*	*14*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*LTR*	*LTR*		*LTR*			*LTR*	
v (veh/h)	*8*	*16*		*113*			*198*	
C (m) (veh/h)	*1538*	*1581*		*742*			*766*	
v/c	*0.01*	*0.01*		*0.15*			*0.26*	
95% queue length	*0.02*	*0.03*		*0.54*			*1.03*	
Control Delay (s/veh)	*7.4*	*7.3*		*10.7*			*11.3*	
LOS	*A*	*A*		*B*			*B*	
Approach Delay (s/veh)	--	--	*10.7*			*11.3*		
Approach LOS	--	--	*B*			*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Assoc*
Date Performed	*9/28/2011*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*Mary Align & Hawthorne Opt 2*
Jurisdiction	*City Billings*
Analysis Year	*2035*

Project Description *Billings Bypass EIS*	
East/West Street: *Mary Align*	North/South Street: *Hawthorne*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*410*	*5*	*50*	*610*	
Peak-Hour Factor, PHF	*1.00*	*0.90*	*0.90*	*0.90*	*0.90*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*455*	*5*	*55*	*677*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Two Way Left Turn Lane*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*1*	*1*	*0*
Configuration			*TR*	*L*	*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*5*		*40*			
Peak-Hour Factor, PHF	*0.80*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*6*	*0*	*49*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)		*0*			*0*	
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*L*		*LR*				
v (veh/h)		*55*		*55*				
C (m) (veh/h)		*1112*		*551*				
v/c		*0.05*		*0.10*				
95% queue length		*0.16*		*0.33*				
Control Delay (s/veh)		*8.4*		*12.3*				
LOS		*A*		*B*				
Approach Delay (s/veh)	--	--		*12.3*				
Approach LOS	--	--		*B*				

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*5 Mile Align & Johnson N*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Five Mile Align* North/South Street: *Johnson Lane N*

Intersection Orientation: *East-West* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*10*	*835*			*595*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*11*	*927*	*0*	*0*	*661*	*5*
Percent Heavy Vehicles	*4*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*0*	*2*	*0*
Configuration	*L*	*T*			*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*0*		*30*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.60*	*1.00*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*0*	*0*	*49*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*11*						*49*	
C (m) (veh/h)	*906*						*698*	
v/c	*0.01*						*0.07*	
95% queue length	*0.04*						*0.23*	
Control Delay (s/veh)	*9.0*						*10.5*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*10.5*		
Approach LOS	--	--				*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*5 Mile Align & Coulson Rd*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Five Mile Align* | North/South Street: *Coulson Road*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*55*	*780*			*520*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*61*	*866*	*0*	*0*	*577*	*5*
Percent Heavy Vehicles	*4*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*0*	*2*	*0*
Configuration	*L*	*T*			*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*5*		*80*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.70*	*1.00*	*0.70*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*7*	*0*	*114*
Percent Heavy Vehicles	*0*	*0*	*0*	*5*	*0*	*5*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration					*LR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*61*						*121*	
C (m) (veh/h)	*975*						*624*	
v/c	*0.06*						*0.19*	
95% queue length	*0.20*						*0.71*	
Control Delay (s/veh)	*8.9*						*12.2*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*12.2*		
Approach LOS	--	--				*B*		

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LANE SUMMARY

Site: Five Mile Road Alignment
Mary Street Intersection

Five Mile Road Alignment
Mary Street Intersection Year 2035 PM Design Hour
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Five Mile Align NWB																
Lane 1	543	0	0	543	4.0	1600	0.340	100	12.5	LOS B	2.4	61.6	1600	–	0.0	0.0
Lane 2	0	304	0	304	3.0	1320	0.231	68 [5]	4.5	LOS A	1.4	36.0	1600	–	0.0	0.0
Approach	543	304	0	848	3.6		0.340		9.7	LOS A	2.4	61.6				
North West: Five Mile Align SEB																
Lane 1	0	109	0	109	2.0	853	0.128	100	7.5	LOS A	0.7	17.8	1600	–	0.0	0.0
Lane 2	0	98	33	130	1.7	1018	0.128	100	7.3	LOS A	0.7	18.7	1600	–	0.0	0.0
Approach	0	207	33	239	1.9		0.128		7.4	LOS A	0.7	18.7				
South West: Mary Street NEB																
Lane 1	33	0	0	33	1.0	638	0.051	100	14.0	LOS B	0.2	5.1	200	–	0.0	0.0
Lane 2	0	0	359	359	3.0	1087	0.330	100	6.8	LOS A	1.8	46.1	200	–	0.0	0.0
Approach	33	0	359	391	2.8		0.330		7.4	LOS A	1.8	46.1				
Intersection				1478	3.1		0.340		8.7	LOS A	2.4	61.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/3/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Dover & 5 Mile 5 Mile Align*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Dover Road* | North/South Street: *Five Mile Road*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*30*	*240*	*50*	*5*	*160*	*5*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*33*	*266*	*55*	*5*	*177*	*5*
Percent Heavy Vehicles	*3*	--	--	*3*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration	*LTR*			*LTR*		
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*10*	*85*	*20*	*30*	*65*	*10*
Peak-Hour Factor, PHF	*0.80*	*0.80*	*0.80*	*0.80*	*0.80*	*0.80*
Hourly Flow Rate, HFR (veh/h)	*12*	*106*	*24*	*37*	*81*	*12*
Percent Heavy Vehicles	*0*	*3*	*0*	*0*	*3*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*LTR*	*LTR*		*LTR*			*LTR*	
v (veh/h)	*33*	*5*		*130*			*142*	
C (m) (veh/h)	*1387*	*1233*		*398*			*444*	
v/c	*0.02*	*0.00*		*0.33*			*0.32*	
95% queue length	*0.07*	*0.01*		*1.40*			*1.36*	
Control Delay (s/veh)	*7.7*	*7.9*		*18.4*			*16.9*	
LOS	*A*	*A*		*C*			*C*	
Approach Delay (s/veh)	--	--	*18.4*			*16.9*		
Approach LOS	--	--	*C*			*C*		

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HCM Analysis Summary

Five Mile Align 2035 Secondary Imp | Mary Street/Bitteroot | Area Type: Non CBD
R Marvin | 12/19/2011 | Analysis Duration: 15 mins.
Pm Design Hour | Case: FIVEMI~1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	1	1	LTR	12.0										
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	20	310	50	80	390	60	50	100	80	40	60	10
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	4	0	0	4	0	0	1	0	0	1	0
Lane Groups	L	TR		L	TR			LTR			LTR	
Arrival Type	3	3		3	3			3			3	
RTOR Vol (vph)	10			10			30			5		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		33.0		17.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	L	437	0.028	0.550	L	0.050	6.5	A	8.7	A
	TR	997	0.210	0.550	TR	0.381	8.8	A		
WB										
	L	521	0.092	0.550	L	0.167	7.4	A	9.5	A
	* TR	997	0.264	0.550	TR	0.479	9.9	A		
NB										
	* LTR	465	0.132	0.283	LTR	0.467	18.0	B	18.0	B
SB										
	LTR	442	0.072	0.283	LTR	0.256	16.7	B	16.7	B

Capacity Analysis Results

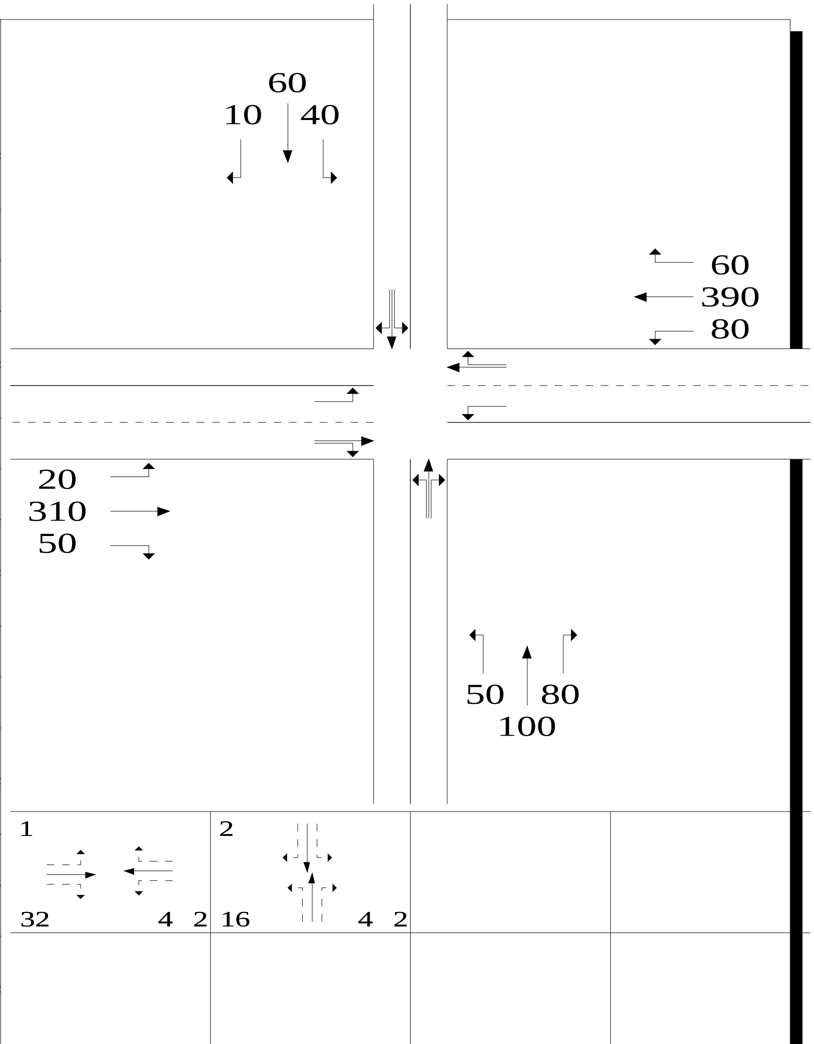
Intersection: Delay = 11.3 sec/veh Int. LOS=B X_c= 0.48 * Critical Lane Group Σ(v/s)Crit= 0.40

NETSIM Summary Results

Five Mile Align 2035 Secondary Imp
R Marvin
Pm Design Hour

Mary Street/Bitteroot
12/19/2011
Case: FIVEMI~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 1	24.7	0.0
	TR	4 / 5	16.7	0.0
	All		17.0	0.0
WB	L	1 / 2	17.8	0.0
	TR	5 / 6	17.2	0.0
	All		17.2	0.0
NB	LTR	2 / 3	14.3	0.0
	All		14.3	0.0
SB	LTR	2 / 2	12.2	0.0
	All		12.2	0.0
Intersect.			16.0	



TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Assoc*
Date Performed	*9/28/2011*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*5 Mile ALign Mary Hawthorne*
Jurisdiction	*City Billings*
Analysis Year	*2035*

Project Description *Billings Bypass EIS*

East/West Street: *Mary Street* | North/South Street: *Hawthorne*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*380*	*35*	*30*	*450*	
Peak-Hour Factor, PHF	*1.00*	*0.90*	*0.90*	*0.90*	*0.90*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*422*	*38*	*33*	*500*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Two Way Left Turn Lane*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*1*	*1*	*0*
Configuration			*TR*	*L*	*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*20*		*20*			
Peak-Hour Factor, PHF	*0.80*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*24*	*0*	*24*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*L*		*LR*				
v (veh/h)		*33*		*48*				
C (m) (veh/h)		*1112*		*481*				
v/c		*0.03*		*0.10*				
95% queue length		*0.09*		*0.33*				
Control Delay (s/veh)		*8.3*		*13.3*				
LOS		*A*		*B*				
Approach Delay (s/veh)	--	--	*13.3*					
Approach LOS	--	--	*B*					

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LANE SUMMARY

Site: Five Mile Align US87/312/ Main/Bench/Mary

Five Mile Align US87/312/Main/Bench/Mary
Secondary Improvements
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Bench NB																
Lane 1	11	120	168	299	0.0	394	0.759	100	20.6	LOS C	5.5	138.3	1600	–	0.0	0.0
Approach	11	120	168	299	0.0		0.759		20.6	LOS C	5.5	138.3				
South East: Mary Street NWB																
Lane 1	391	0	0	391	1.3	543	0.721	100	24.5	LOS C	6.1	153.6	1600	–	0.0	0.0
Lane 2	0	239	11	250	4.0	400	0.625	87 [5]	16.3	LOS B	4.1	105.0	1600	–	0.0	0.0
Approach	391	239	11	641	2.4		0.721		21.3	LOS C	6.1	153.6				
North East: HWY 312 SWB																
Lane 1	71	164	0	234	1.7	472	0.496	100	15.6	LOS B	3.3	84.1	1600	–	0.0	0.0
Lane 2	0	271	11	282	2.0	568	0.496	100	12.6	LOS B	3.6	91.2	1600	–	0.0	0.0
Approach	71	435	11	516	1.9		0.496		13.9	LOS B	3.6	91.2				
North West: US 87 SEB																
Lane 1	11	109	103	223	2.1	570	0.391	100	8.8	LOS A	2.1	54.1	1600	–	0.0	0.0
Approach	11	109	103	223	2.1		0.391		8.8	LOS A	2.1	54.1				
South West: Main Street NE Bound																
Lane 1	457	160	0	617	1.0	1002	0.615	100	14.6	LOS B	6.0	152.2	1600	–	0.0	0.0
Lane 2	0	514	239	753	1.3	1223	0.615	100	7.3	LOS A	6.2	155.4	1600	–	0.0	0.0
Approach	457	674	239	1370	1.2		0.615		10.6	LOS B	6.2	155.4				
Intersection				3049	1.5		0.759		14.3	LOS B	6.2	155.4				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

SIDRA INTERSECTION

APPENDIX H

Johnson Lane Interchange

Design Options

Figures & Capacity Calculations

APPENDIX H

Johnson Lane Interchange

Design Option Figures

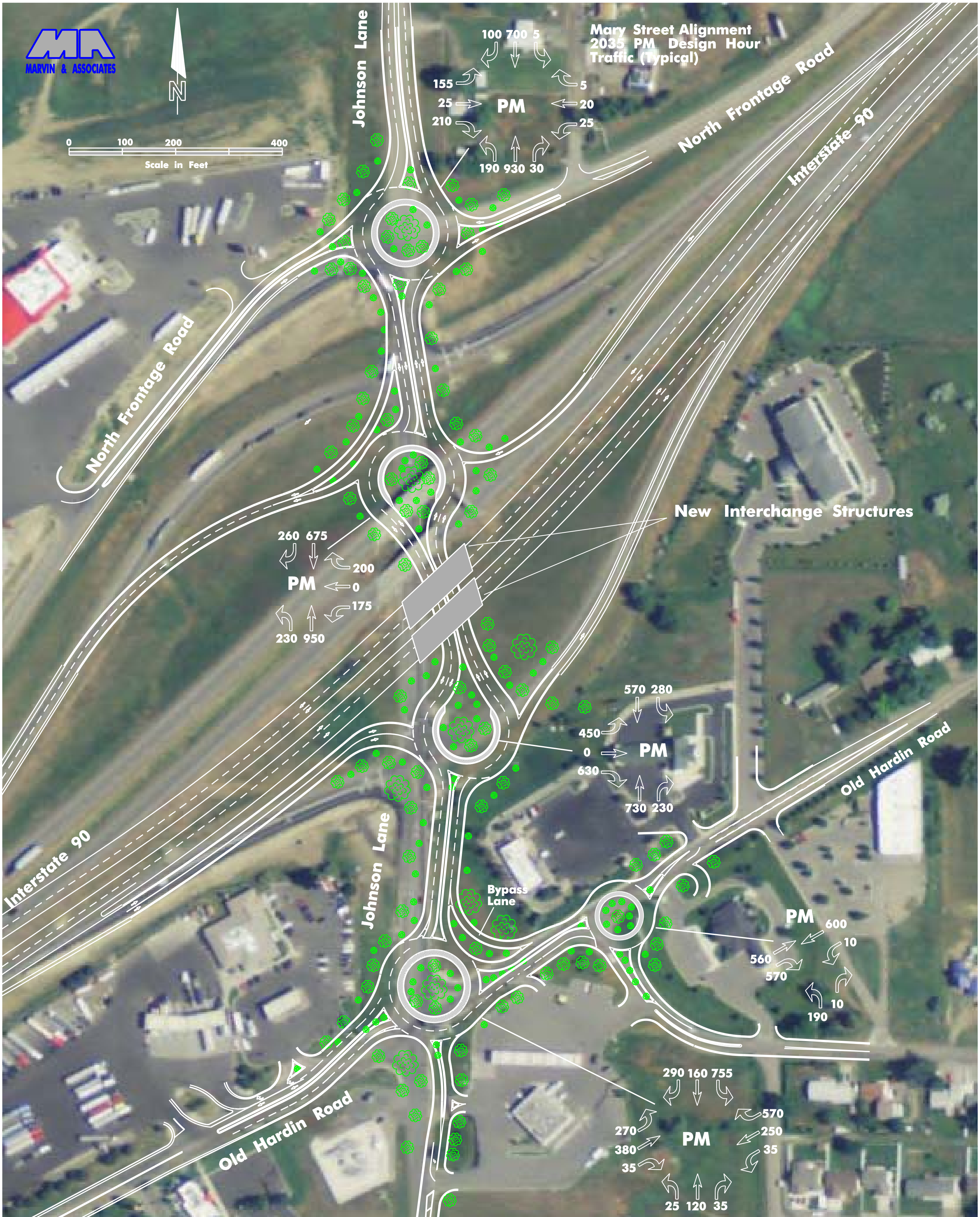


Figure H1. Option 1 – Modified Diamond with Roundabouts

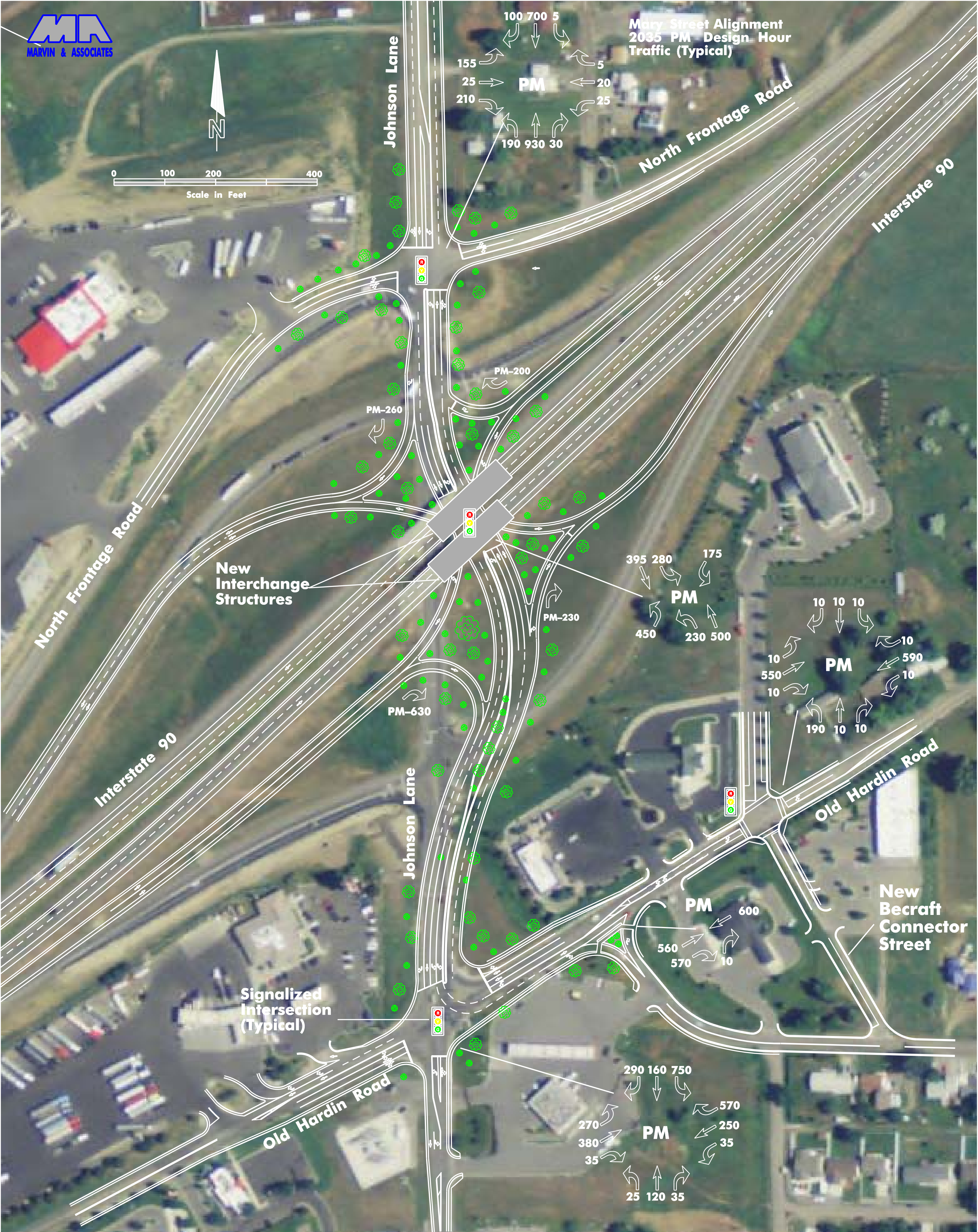


Figure H2. Single–Point Urban Interchange

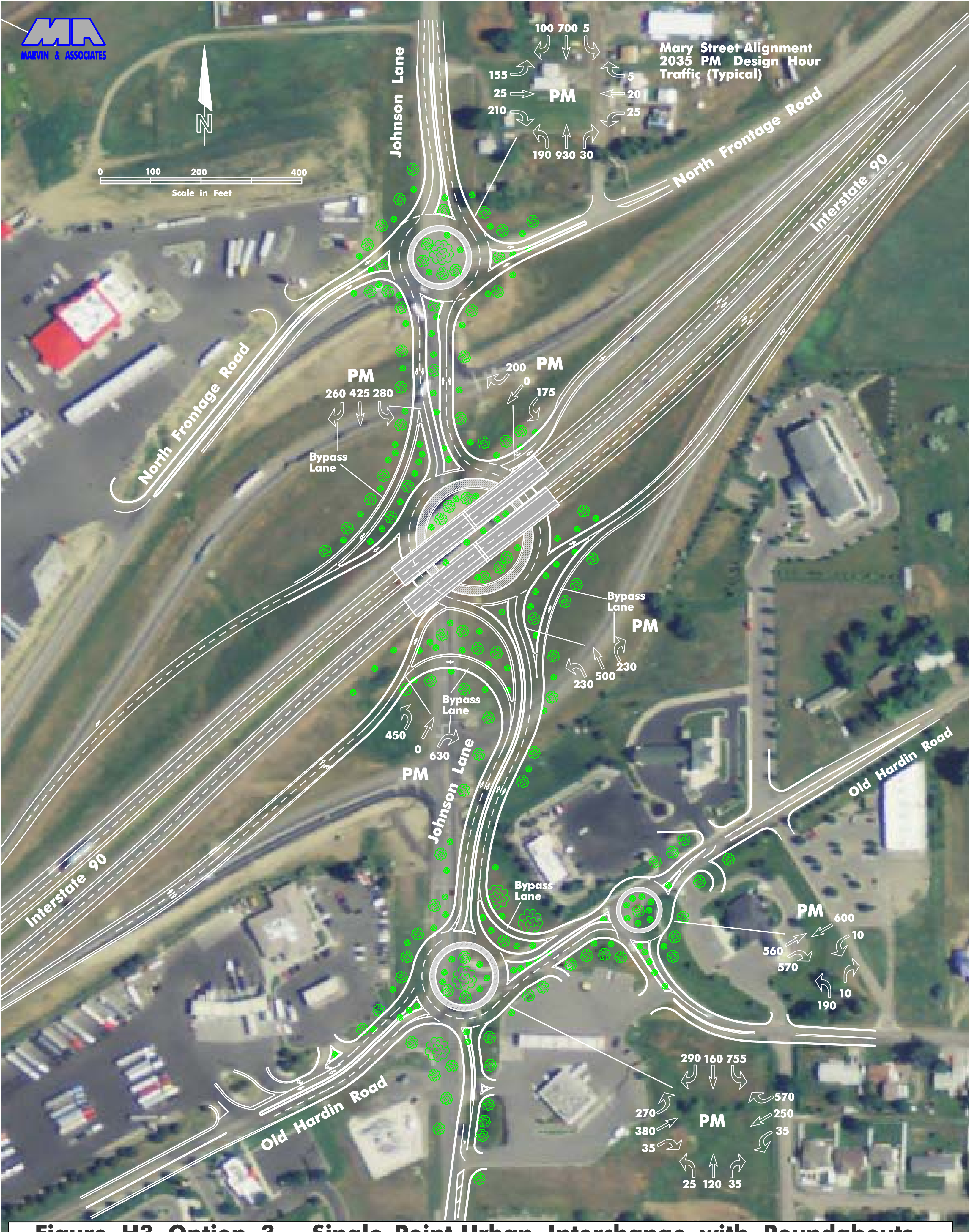


Figure H3. Option 3 – Single–Point Urban Interchange with Roundabouts

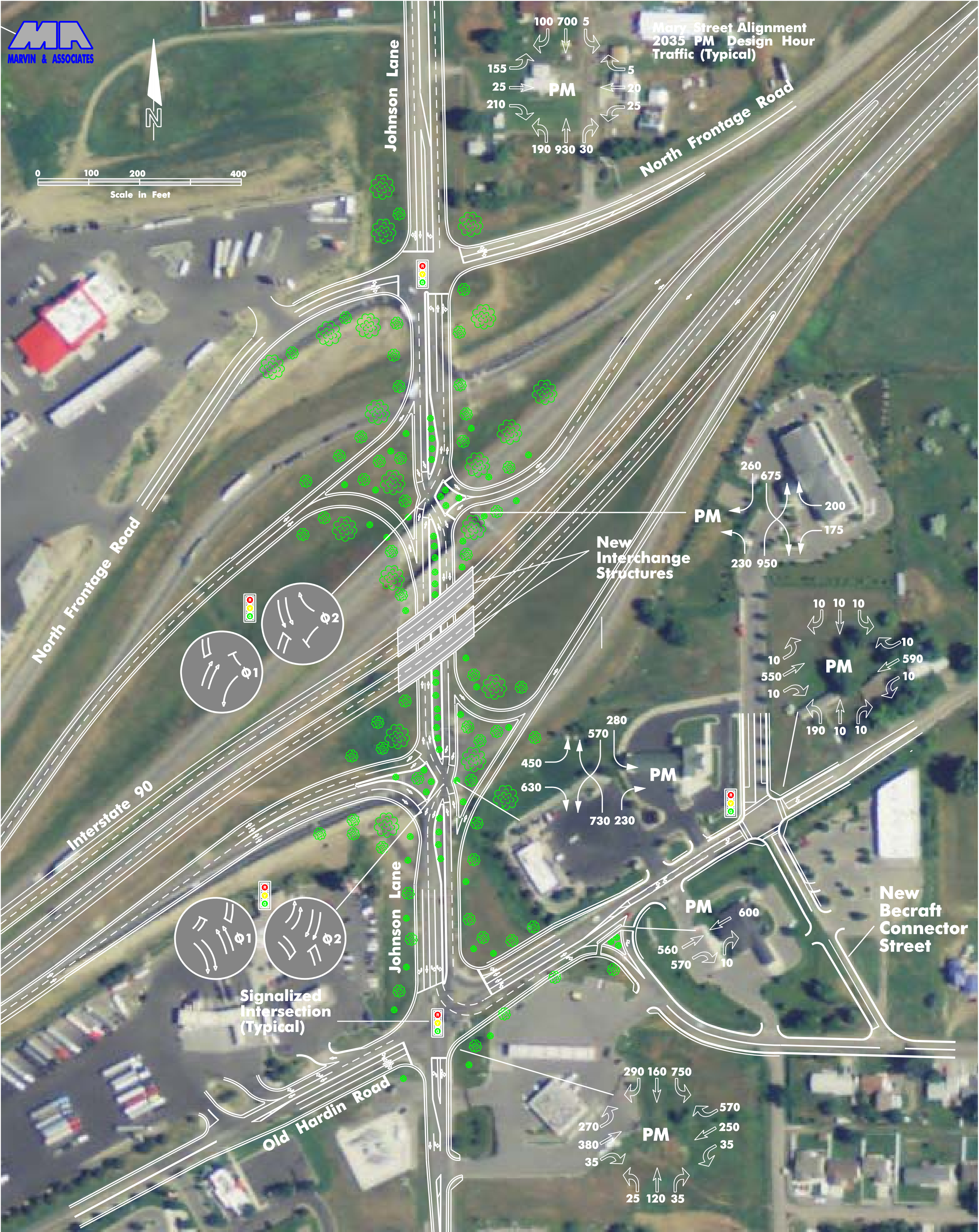


Figure H4. Option 4 – Double Crossover Diamond with Traffic Signals

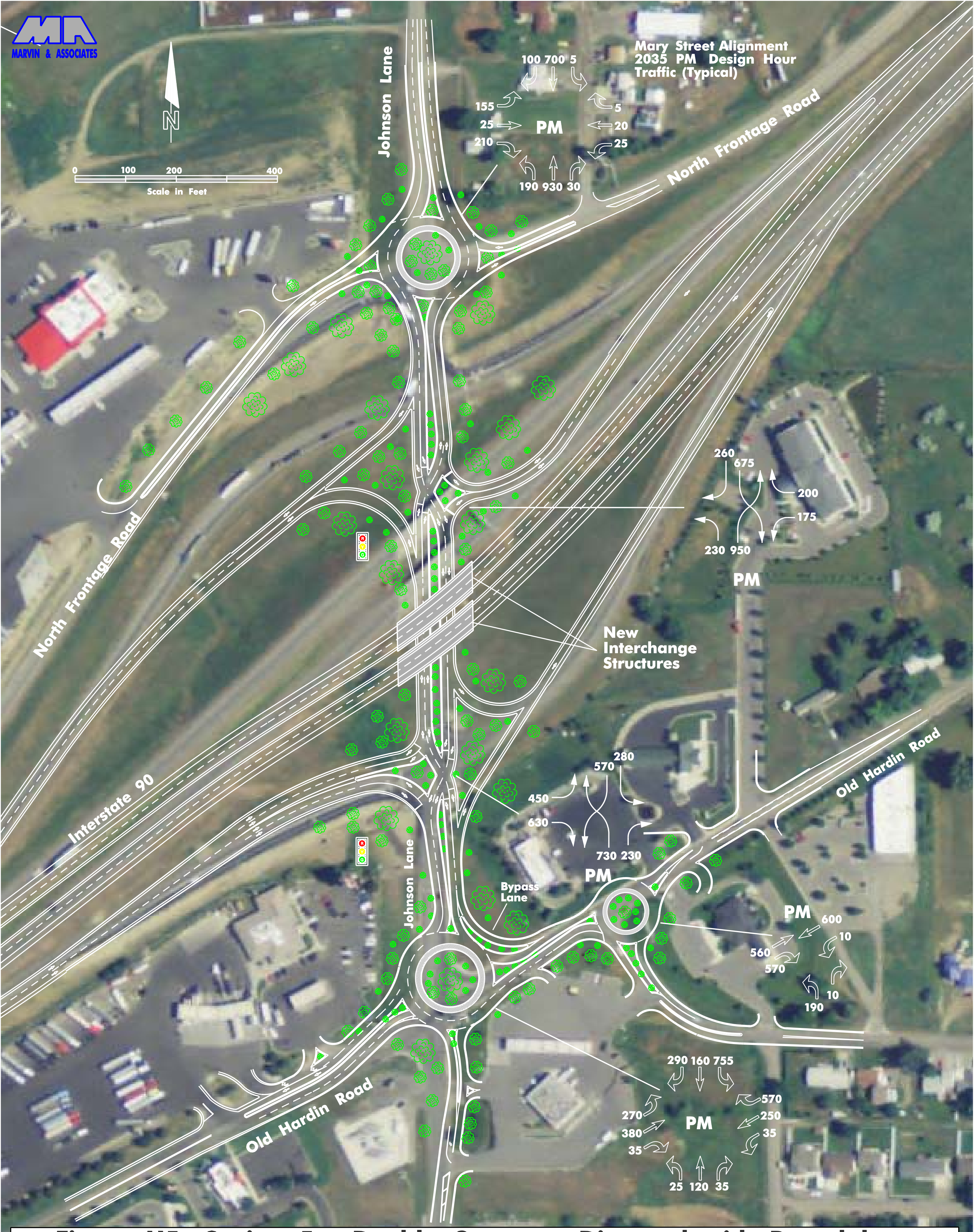


Figure H5. Option 5 – Double Crossover Diamond with Roundabouts

APPENDIX H

Johnson Lane Interchange

Design Options

Capacity Calculations

HCM Analysis Summary

Year 2035 Mary Op1 Alternate | Old Hardin Road/Johnson Lane | Area Type: Non CBD
R Marvin | 10/20/11 | Analysis Duration: 15 mins.
Peak PM Hour | Case: Old Hardin Johnson 2035 PM 102011

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	4	2	L	12.0	T	12.0	T	12.0	R	12.0				
NB	2	2	L	12.0	TR	12.0								
SB	4	1	L	12.0	L	12.0	T	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	270	380	35	35	250	570	25	120	35	750	160	290
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
% Heavy Vehicles	10	1	0	0	1	1	1	1	0	0	1	10
Lane Groups	L	TR		L	T	R	L	TR		L	T	R
Arrival Type	3	3		3	3	3	3	3		3	3	3
RTOR Vol (vph)	5			80			5			60		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 80.0 Sec | Lost Time Per Cycle: 18.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	L		LTP														
WB	L		LTR		R												
NB							LTP										
SB	R				LTP												
Green	13.0		14.0		23.0		12.0										0
Yellow / All Red	3.0	0.0	3.5	1.5	3.5	1.5	3.5	1.5									

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	Lper	172	0.024	0.237					28.5	C
	* Lpro	267	0.163	0.162	L	0.647	20.3	C		
	* TR	618	0.122	0.175	TR	0.699	34.0	C		
WB	Lper	112	0.000	0.237					19.3	B
	Lpro	293	0.020	0.162	L	0.091	15.3	B		
	T	625	0.074	0.175	T	0.421	29.6	C		
	R	839	0.323	0.525	R	0.615	14.3	B		
NB										
	L	268	0.015	0.150	L	0.097	29.4	C	33.0	C
	* TR	274	0.087	0.150	TR	0.577	33.6	C		
SB										
	* L	1007	0.225	0.287	L	0.784	30.0	C	25.4	C
	T	541	0.089	0.287	T	0.311	22.4	C		
	R	714	0.165	0.488	R	0.339	12.7	B		

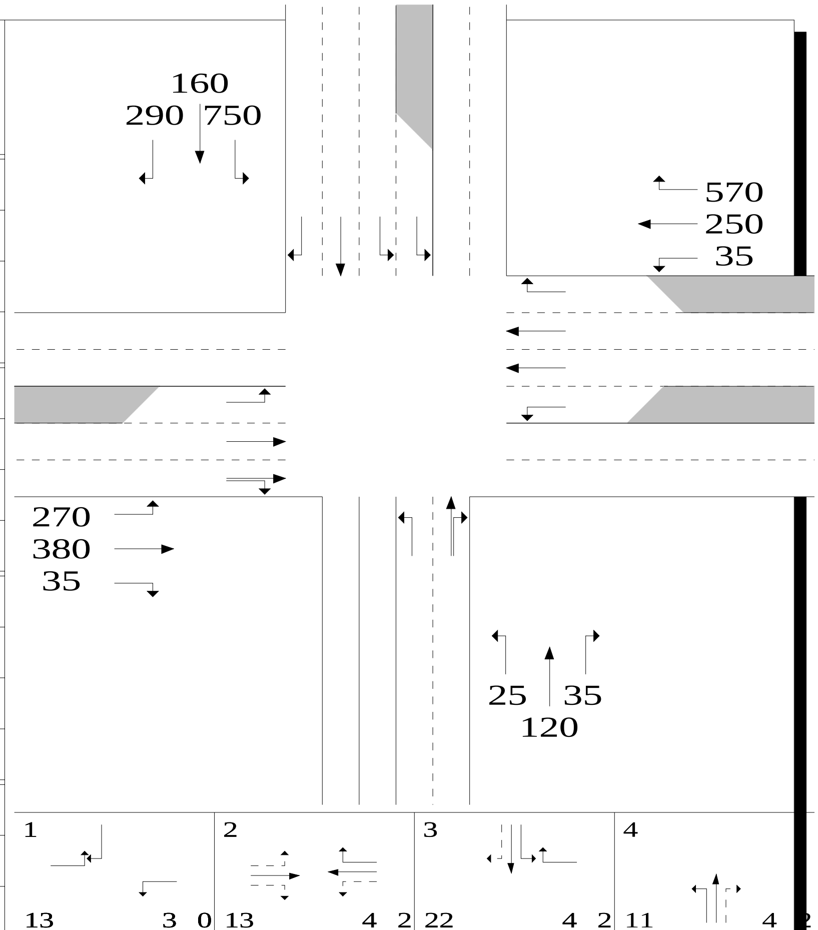
Intersection: Delay = 24.9 sec/veh | Int. LOS=C | X_c= 0.77 | * Critical Lane Group | Σ(v/s)Crit= 0.60

NETSIM Summary Results

Year 2035 Mary Op1 Alternate
R Marvin
Peak PM Hour

Old Hardin Road/Johnson Lane
10/20/11
Case: Old Hardin Johnson 2035 PM 102011

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	6 / 10	8.6	0.0
	TR	4 / 6	10.5	0.0
	All		9.8	0.0
WB	L	1 / 2	7.4	0.0
	T	2 / 4	13.2	0.0
	R	2 / 3	21.2	0.0
	All		15.7	0.0
NB	L	1 / 3	8.0	0.0
	TR	2 / 4	10.7	0.0
	All		10.2	0.0
SB	L	6 / 9	9.9	0.0
	T	3 / 5	10.0	0.0
	R	2 / 3	22.0	0.0
	All		11.5	0.0
Intersect.			11.8	



LANE SUMMARY

Site: Old Hardin & Johnson Year 2035 PM

Old Hardin Road & Johnson Lane Year 2035 PM Hour
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Johnson NB																
Lane 1	27	130	38	196	0.8	285	0.687	100	31.5	LOS C	5.1	128.1	1600	–	0.0	0.0
Approach	27	130	38	196	0.8		0.687		31.5	LOS C	5.1	128.1				
East: Old Hardin WB																
Lane 1	38	272	0	310	0.0	788	0.393	100	6.0	LOS A	2.6	65.7	1600	–	0.0	0.0
Lane 2	0	0	620	620	0.0	1610	0.385	100	2.4	X	X	X	1600	–	0.0	X
Approach	38	272	620	929	0.0		0.393		3.6	LOS A	2.6	65.7				
North: Johnson SB																
Lane 1	821	0	0	821	0.0	1150	0.714	100	12.6	LOS B	9.0	224.4	1600	–	0.0	0.0
Lane 2	0	174	315	489	4.2	882	0.555	100	6.3	LOS A	4.7	121.8	1600	–	0.0	0.0
Approach	821	174	315	1310	1.6		0.714		10.2	LOS B	9.0	224.4				
West: Old Hardin EB																
Lane 1	293	47	0	341	5.2	474	0.719	100	20.3	LOS C	5.8	152.0	1600	–	0.0	0.0
Lane 2	0	366	38	404	0.1	562	0.719	100	13.0	LOS B	6.3	157.9	1600	–	0.0	0.0
Approach	293	413	38	745	2.4		0.719		16.3	LOS B	6.3	157.9				
Intersection				3179	1.3		0.719		11.0	LOS B	9.0	224.4				

X: Not applicable for Continuous lane.

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

HCM Analysis Summary

Becraft Connection & Old Hardin	Old Hardin Road/Becraft Connect Area Type: Non CBD
R Marvin	10/21/2011 Analysis Duration: 15 mins.
Year 2035 PM	Case: Becraft Connection Old Hardin 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	1	1	LTR	12.0										
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	10	550	10	10	590	10	190	10	10	10	10	10
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	0	0	0	0	0
Lane Groups	L	TR		L	TR			LTR			LTR	
Arrival Type	3	3		3	3			3			3	
RTOR Vol (vph)	0			0			0			0		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 80.0 Sec   Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3	4	5	6	7	8	Ped Only
EB		LTP										
WB		LTP										
NB				LTP								
SB				LTP								
Green		50.0		20.0								0
Yellow	All Red	3.5	1.5	3.5	1.5							

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	L	376	0.018	0.625	L	0.029	5.9	A	9.8	A
	TR	1184	0.321	0.625	TR	0.514	9.9	A		
WB										
	L	408	0.017	0.625	L	0.027	5.8	A	10.3	B
	* TR	1184	0.344	0.625	TR	0.551	10.4	B		
NB										
	* LTR	338	0.169	0.250	LTR	0.678	31.5	C	31.5	C
SB										
	LTR	402	0.021	0.250	LTR	0.082	23.0	C	23.0	C

Capacity Analysis Results

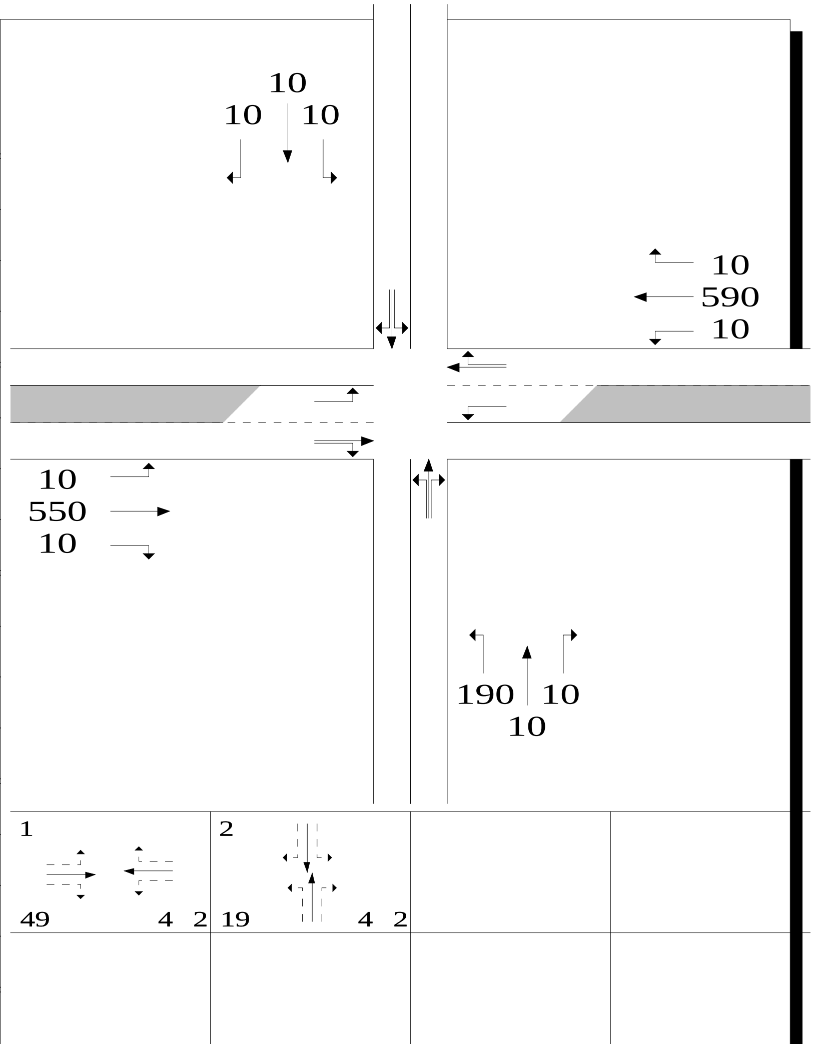
Intersection: Delay = 13.5 sec/veh   Int. LOS=B X_c= 0.59   * Critical Lane Group Σ(v/s)Crit= 0.51

NETSIM Summary Results

Becraft Connection & Old Hardin
R Marvin
Year 2035 PM

Old Hardin Road/Becraft Connect
10/21/2011
Case: Becraft Connection Old Hardin 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 1	9.4	0.0
	TR	6 / 7	17.2	0.0
	All		17.1	0.0
WB	L	0 / 1	9.8	0.0
	TR	6 / 7	17.5	0.0
	All		17.3	0.0
NB	LTR	3 / 4	10.2	0.0
	All		10.2	0.0
SB	LTR	1 / 1	11.0	0.0
	All		11.0	0.0
Intersect.			15.5	



LANE SUMMARY

Site: Becraft & Old Hardin Year 2035 PM

Becraft & Old Hardin Road Year 2035 PM
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Becraft Lane																
Lane 1	207	0	11	217	0.0	699	0.311	100	13.0	LOS B	1.8	44.8	1600	–	0.0	0.0
Approach	207	0	11	217	0.0		0.311		13.0	LOS B	1.8	44.8				
East: Old Hardin WB																
Lane 1	11	652	0	663	0.0	1032	0.643	100	4.4	LOS A	6.3	158.7	1600	–	0.0	0.0
Approach	11	652	0	663	0.0		0.643		4.4	LOS A	6.3	158.7				
West: Old Hardin EB																
Lane 1	0	609	0	609	0.0	1504	0.405	100	1.9	LOS A	3.4	84.9	1600	–	0.0	0.0
Lane 2	0	0	620	620	0.0	1405	0.441	100	2.8	LOS A	3.9	97.0	250	–	0.0	0.0
Approach	0	609	620	1228	0.0		0.441		2.3	LOS A	3.9	97.0				
Intersection				2109	0.0		0.643		4.1	LOS A	6.3	158.7				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

LANE SUMMARY

Site: Johnson Lane & WB Ramps Year 2035 PM

Johnson Lane & Westbound Ramps Year 2035 PM
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	T veh/h	R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Johnson NB																
Lane 1	250	351	0	601	4.0	1453	0.414	100	3.7	LOS A	0.0	0.0	1600	–	0.0	0.0
Lane 2	0	681	0	681	4.0	1647	0.414	100	0.7	LOS A	0.0	0.0	1600	–	0.0	0.0
Approach	250	1033	0	1283	4.0		0.414		2.1	LOS A	0.0	0.0				
East: WB Off Ramp																
Lane 1	190	1	217	409	4.5	538	0.759	100	19.1	LOS B	5.5	143.4	1600	–	0.0	0.0
Approach	190	1	217	409	4.5		0.759		19.1	LOS B	5.5	143.4				
North: Johnson SB																
Lane 1	0	337	0	337	4.0	901	0.374	100	3.8	LOS A	2.4	63.0	1600	–	0.0	0.0
Lane 2	0	397	1	398	4.0	1064	0.374	100	3.3	LOS A	2.6	66.2	1600	–	0.0	0.0
Approach	0	734	1	735	4.0		0.374		3.5	LOS A	2.6	66.2				
Intersection				2426	4.1		0.759		5.4	LOS A	5.5	143.4				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

LANE SUMMARY

Site: Johnson Lane EB Ramps
2035 PM

Johnson Lane & Eaastbound Ramps Year 2035 PM
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Johnson NB																
Lane 1	0	462	0	462	4.0	594	0.779	100	20.7	LOS C	10.5	270.9	1600	–	0.0	0.0
Lane 2	0	331	250	581	4.4	746	0.779	100	18.6	LOS B	11.9	307.2	600	–	0.0	0.0
Approach	0	793	250	1043	4.2		0.779		19.5	LOS B	11.9	307.2				
North: SB Johnson																
Lane 1	304	117	0	422	4.7	1498	0.281	100	5.9	LOS A	0.0	0.0	1600	–	0.0	0.0
Lane 2	0	502	0	502	4.0	1785	0.281	100	0.8	LOS A	0.0	0.0	1600	–	0.0	0.0
Approach	304	620	0	924	4.3		0.281		3.1	LOS A	0.0	0.0				
West: I90 EB Off Ramp																
Lane 1	489	5	0	495	4.0	814	0.607	100	13.9	LOS B	3.8	98.9	1600	–	0.0	0.0
Lane 2	0	0	5	5	4.0	432	0.013	100	8.0	LOS A	0.0	1.0	1600	–	0.0	0.0
Approach	489	5	5	500	4.0		0.607		13.8	LOS B	3.8	98.9				
Intersection				2467	4.2		0.779		12.2	LOS B	11.9	307.2				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

LANE SUMMARY

Site: North Frontage Road & Johnson Lane Year 2035 PM

N Frontage Johnson Lane Year 2035 PM
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	T veh/h	R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Johnson NB																
Lane 1	207	385	0	591	4.3	1075	0.550	100	6.0	LOS A	4.8	124.2	1600	–	0.0	0.0
Lane 2	0	626	33	659	4.0	1198	0.550	100	3.6	LOS A	4.9	127.4	1600	–	0.0	0.0
Approach	207	1011	33	1250	4.1		0.550		4.7	LOS A	4.9	127.4				
East: N Frontage WB																
Lane 1	27	22	5	54	1.0	369	0.147	100	11.9	LOS B	0.6	15.5	1600	–	0.0	0.0
Approach	27	22	5	54	1.0		0.147		11.9	LOS B	0.6	15.5				
North: Johnson SB																
Lane 1	5	411	0	417	4.0	1033	0.404	100	3.9	LOS A	2.8	72.3	1600	–	0.0	0.0
Lane 2	0	350	109	458	4.0	1135	0.404	100	3.9	LOS A	2.9	73.9	1600	–	0.0	0.0
Approach	5	761	109	875	4.0		0.404		3.9	LOS A	2.9	73.9				
West: N Frontage EB																
Lane 1	168	33	228	429	4.3	532	0.807	100	18.0	LOS B	7.0	180.6	1600	–	0.0	0.0
Approach	168	33	228	429	4.3		0.807		18.0	LOS B	7.0	180.6				
Intersection				2609	4.0		0.807		6.8	LOS A	7.0	180.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

HCM Analysis Summary

Year 2035 Mary Op1 Alt	N Frontage Rd/Johnson Lane	Area Type: Non CBD
R Marvin	10/20/11	Analysis Duration: 15 mins.
Peak PM	Case: N Frtg Johnson Mary Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	3	2	L	12.0	T	12.0	TR	12.0						
SB	3	2	L	12.0	T	12.0	TR	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	155	25	210	25	20	5	190	930	30	5	700	100
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	4	2	8	2	2	2	8	4	2	2	4	2
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	40			0			5			30		
Peds/Hour	0			5			5			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 80.0 Sec Lost Time Per Cycle: 8.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP																
WB	LTP																
NB			LTR		LTP												
SB					LTP												
Green	24.0		12.0		36.0												0
Yellow / All Red	0.0	0.0	3.0	0.0	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	389	0.130	0.300	L	0.432	22.8	C	22.9	C
	* TR	463	0.137	0.300	TR	0.458	23.0	C		
WB										
	L	241	0.034	0.300	L	0.112	20.4	C	20.1	C
	TR	543	0.015	0.300	TR	0.050	19.9	B		
NB	Lper	198	0.000	0.512					8.6	A
	* Lpro	251	0.124	0.150	L	0.461	10.5	B		
	TR	2204	0.300	0.637	TR	0.471	8.2	A		
SB										
	L	231	0.010	0.450	L	0.022	12.4	B	17.4	B
	* TR	1541	0.244	0.450	TR	0.543	17.4	B		

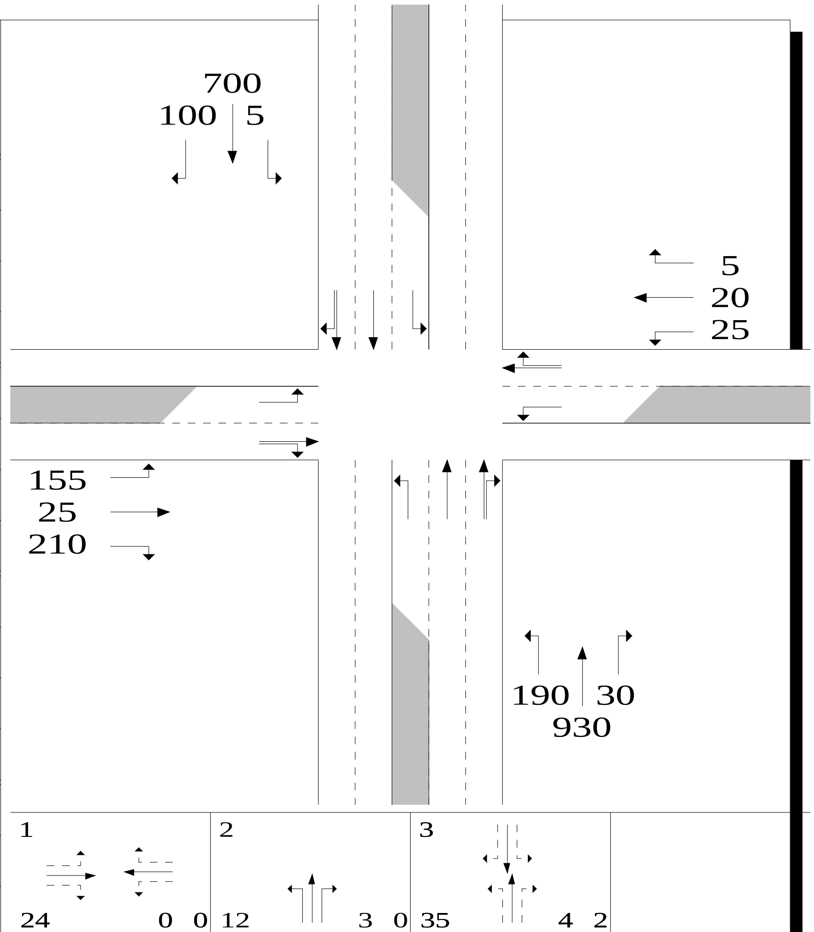
Intersection: Delay = 13.9 sec/veh Int. LOS=B X_c= 0.56 * Critical Lane Group Σ(v/s)Crit= 0.51

NETSIM Summary Results

Year 2035 Mary Op1 Alt
R Marvin
Peak PM

N Frontage Rd/Johnson Lane
10/20/11
Case: N Frtg Johnson Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	4 / 6	6.3	0.0
	TR	2 / 4	20.8	0.0
	All		13.2	0.0
WB	L	0 / 1	6.9	0.0
	TR	1 / 1	15.1	0.0
	All		12.2	0.0
NB	L	3 / 5	9.0	0.0
	TR	5 / 7	17.4	0.0
	All		15.6	0.0
SB	L	0 / 1	19.7	0.0
	TR	5 / 7	14.2	0.0
	All		14.3	0.0
Intersect.			14.6	



HCM Analysis Summary

Johnson SPUI Mary Op1 2035 | EB Off Ramp/Johnson Lane | Area Type: Non CBD
R Marvin | 10/20/11 | Analysis Duration: 15 mins.
PM | Case: Johnson SPUI Mary Op1 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	1	1	L	12.0										
WB	1	1	L	12.0										
NB	3	2	L	12.0	T	12.0	T	12.0						
SB	3	2	L	12.0	T	12.0	T	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	450	0	0	175	0	0	230	500	0	280	395	0
PHF	0.92	0.90	0.90	0.92	0.90	0.90	0.92	0.92	0.90	0.92	0.92	0.90
% Heavy Vehicles	4	2	2	4	2	2	2	2	2	4	2	2
Lane Groups	L			L			L	T		L	T	
Arrival Type	3			3			3	3		3	3	
RTOR Vol (vph)	0			0			0			0		
Peds/Hour	0			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 80.0 Sec | Lost Time Per Cycle: 13.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	L																
WB	L																
NB			L		LT												
SB			L		LT												
Green	30.0		19.0		18.0												0
Yellow / All Red	3.5	1.5	3.0	0.0	3.5	1.5											

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	* L	651	0.282	0.375	L	0.751	26.1	C	26.1	C
WB										
	L	651	0.109	0.375	L	0.292	17.6	B	17.6	B
NB	Lper	165	0.000	0.287					26.9	C
	Lpro	420	0.141	0.237	L	0.427	13.5	B		
	* T	796	0.153	0.225	T	0.682	33.1	C		
SB	Lper	116	0.000	0.287					24.5	C
	* Lpro	412	0.175	0.237	L	0.576	16.8	B		
	T	796	0.121	0.225	T	0.539	30.0	C		

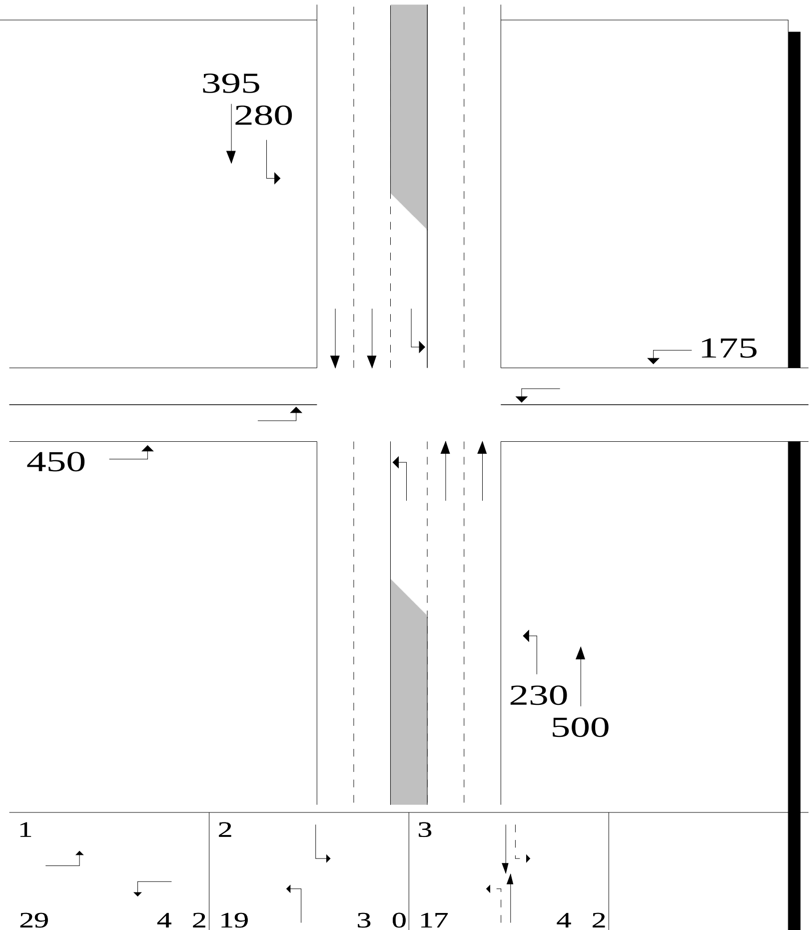
Intersection: Delay = 25.1 sec/veh | Int. LOS=C | X_c= 0.73 | * Critical Lane Group | Σ(v/s)Crit= 0.61

NETSIM Summary Results

Johnson SPUI Mary Op1 2035
R Marvin
PM

EB Off Ramp/Johnson Lane
10/20/11
Case: Johnson SPUI Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	8 / 8	10.7	0.0
	All		10.7	0.0
WB	L	3 / 3	12.5	0.0
	All		12.5	0.0
NB	L	3 / 7	9.5	0.0
	T	5 / 8	11.2	0.0
	All		10.8	0.0
SB	L	4 / 7	8.7	0.0
	T	4 / 7	12.5	0.0
	All		11.5	0.0
Intersect.			11.1	



LANE SUMMARY

Site: Johnson Lane SPUI Roundabout 2035 PM

Johnson Lane SPUI Roundabout 2035 PM
Roundabout

Lane Use and Performance																
	Demand Flows L veh/h	T veh/h	R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Johnson NB																
Lane 1	250	86	0	336	4.7	608	0.553	100	14.6	LOS B	5.1	133.2	600	–	0.0	0.0
Lane 2	0	457	5	463	4.0	837	0.553	100	7.6	LOS A	5.8	150.7	600	–	0.0	0.0
Approach	250	543	5	799	4.3		0.553		10.5	LOS B	5.8	150.7				
North East: WB Off Ramp																
Lane 1	191	0	0	191	5.0	427	0.449	100	15.8	LOS B	2.8	71.6	600	–	0.0	0.0
Lane 2	0	0	217	217	5.0	538	0.404	100	9.3	LOS A	2.6	67.9	600	–	0.0	0.0
Approach	191	0	217	409	5.0		0.449		12.3	LOS B	2.8	71.6				
North: Johnson SB																
Lane 1	304	0	0	304	5.0	918	0.331	100	8.9	LOS A	2.2	57.0	600	–	0.0	0.0
Lane 2	0	462	5	467	4.0	1198	0.390	100	2.3	LOS A	2.9	75.8	600	–	0.0	0.0
Approach	304	462	5	772	4.4		0.390		4.9	LOS A	2.9	75.8				
South West: EB Off Ramp																
Lane 1	490	0	12	502	4.9	562	0.893	100	25.5	LOS C	10.7	278.2	600	–	0.0	0.0
Approach	490	0	12	502	4.9		0.893		25.5	LOS C	10.7	278.2				
Intersection				2482	4.6		0.893		12.1	LOS B	10.7	278.2				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

FREEWAY WEAVING WORKSHEET

General Information

Analyst	R Marvin
Agency/Company	Marvin & Associates
Date Performed	8/4/2011
Analysis Time Period	PM

Site Information

Freeway/Dir of Travel	Southbound
Weaving Seg Location	EB Off Ramp to Old Hardin Rd
Jurisdiction	Billings
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	35
Weaving number of lanes, N	4
Weaving seg length, L (ft)	500
Terrain	Level
Weaving type	A
Volume ratio, VR	0.50
Weaving ratio, R	0.36

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	360	0.92	1	1	1.5	1.2	0.993	1.00	394
V_{o2}	237	0.92	5	1	1.5	1.2	0.974	1.00	264
V_{w1}	388	0.92	1	0	1.5	1.2	0.995	1.00	423
V_{w2}	220	0.92	1	0	1.5	1.2	0.995	1.00	240
V_w				663	V_{nw}				658
V									1321

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)			0.35	0.0020
b (Exhibit 24-6)			2.20	4.00
c (Exhibit 24-6)			0.97	1.30
d (Exhibit 24-6)			0.80	0.75
Weaving intensity factor, Wi			1.65	0.18
Weaving and non-weaving speeds, Si (mi/h)			24.44	36.17

Number of lanes required for unconstrained operation, Nw 1.94
Maximum number of lanes, Nw (max) 1.40

☐ If Nw < Nw(max) unconstrained operation ☑ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	29.15
Weaving segment density, D (pc/mi/ln)	11.33
Level of service, LOS	B
Capacity of base condition, c_b (pc/h)	5440
Capacity as a 15-minute flow rate, c (veh/h)	5402
Capacity as a full-hour volume, c_h (veh/h)	4970

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

 HCS+™ Version 5.4 Generated: 8/4/2011 11:24 AM

HCM Analysis Summary

Double Cross Johnson Mary Op1	EB Ramp Right/Johnson	Area Type: Non CBD
R Marvin	09/08/2011	Analysis Duration: 15 mins.
PM Hour YR 2035	Case: Double Cross EB Ramp Johnson Mary Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	0	R	12.0	R	12.0								
WB	2	0	R	12.0	R	12.0								
NB	2	2	T	12.0	T	12.0								
SB	2	2	T	12.0	T	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	0	630	0	0	450	0	730	0	0	230	0
PHF	0.90	0.90	0.92	0.90	0.90	0.92	0.90	0.92	0.90	0.90	0.92	0.90
% Heavy Vehicles	2	2	5	2	2	5	2	4	2	2	4	2
Lane Groups			R			R		T			T	
Arrival Type			3			3		4			4	
RTOR Vol (vph)	100			80			0			0		
Peds/Hour	0			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 80.0 Sec   Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		P																
WB				P														
NB		T																
SB				T														
Green		37.0		33.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	R	1252	0.213	0.463	R	0.460	15.9	B	15.9	B
WB										
	* R	1117	0.149	0.412	R	0.360	17.1	B	17.1	B
NB										
	* T	1605	0.228	0.463	T	0.494	13.4	B	13.4	B
SB										
	T	1432	0.072	0.412	T	0.175	13.4	B	13.4	B

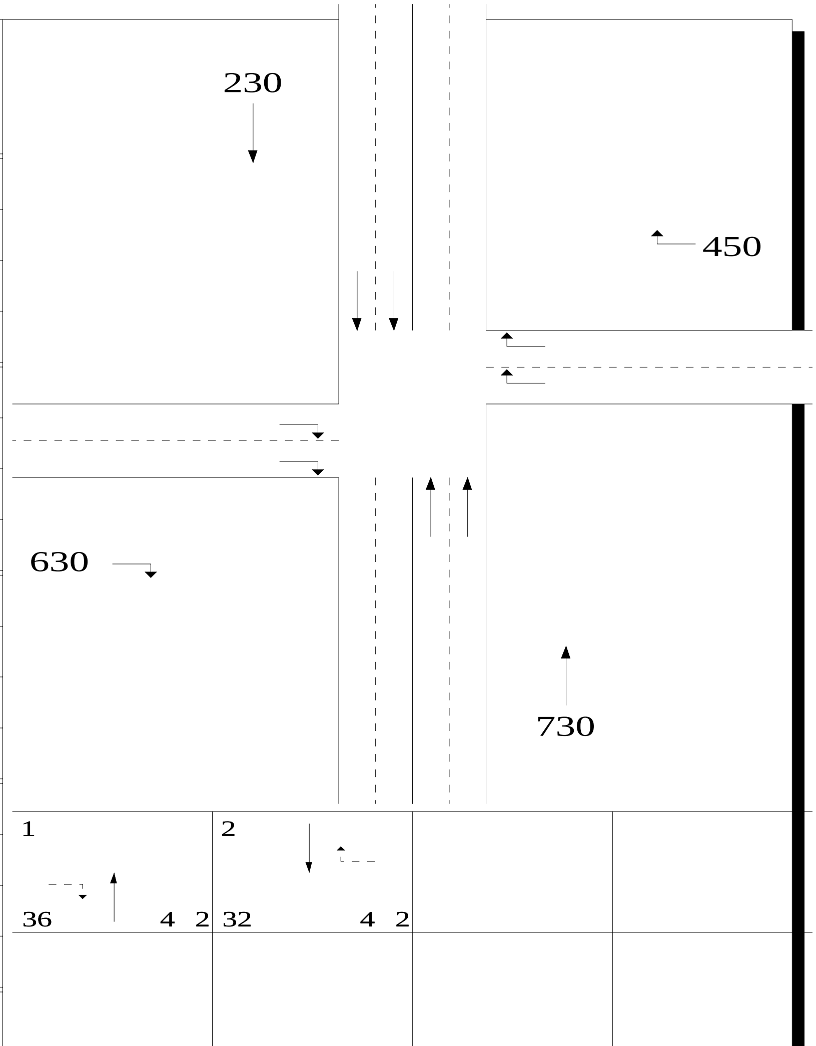
Intersection: Delay = 14.8 sec/veh   Int. LOS=B X_c= 0.43   * Critical Lane Group Σ(v/s)Crit= 0.38

NETSIM Summary Results

Double Cross Johnson Mary Op1
R Marvin
PM Hour YR 2035

EB Ramp Right/Johnson
09/08/2011
Case: Double Cross EB Ramp Johnson Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	R	3 / 4	19.2	0.0
	All		19.2	0.0
WB	R	3 / 5	15.3	0.0
	All		15.3	0.0
NB	T	2 / 3	17.6	0.0
	All		17.6	0.0
SB	T	0 / 0	25.9	0.0
	All		25.9	0.0
Intersect.			18.1	



HCM Analysis Summary

Double Cross Johnson Mary Op1	WB Ramp Left/Johnson	Area Type: Non CBD
R Marvin	09/08/2011	Analysis Duration: 15 mins.
PM Hour YR 2035	Case: Double Cross WB Ramp Johnson Mary Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	0	R	12.0	R	12.0								
WB	2	0	R	12.0	R	12.0								
NB	2	2	T	12.0	T	12.0								
SB	2	2	T	12.0	T	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	0	175	0	0	200	0	950	0	0	675	0
PHF	0.90	0.90	0.92	0.90	0.90	0.92	0.90	0.92	0.90	0.90	0.92	0.90
% Heavy Vehicles	2	2	5	2	2	5	2	4	2	2	4	2
Lane Groups			R			R		T			T	
Arrival Type			3			3		4			4	
RTOR Vol (vph)	30			25			0			0		
Peds/Hour	0			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 80.0 Sec — Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		P																
WB				P														
NB		T																
SB				T														
Green		37.0		33.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	R	1252	0.058	0.463	R	0.126	12.5	B	12.5	B
WB										
	R	1117	0.070	0.412	R	0.170	15.2	B	15.2	B
NB										
	* T	1605	0.298	0.463	T	0.644	15.5	B	15.5	B
SB										
	* T	1432	0.211	0.412	T	0.513	16.7	B	16.7	B

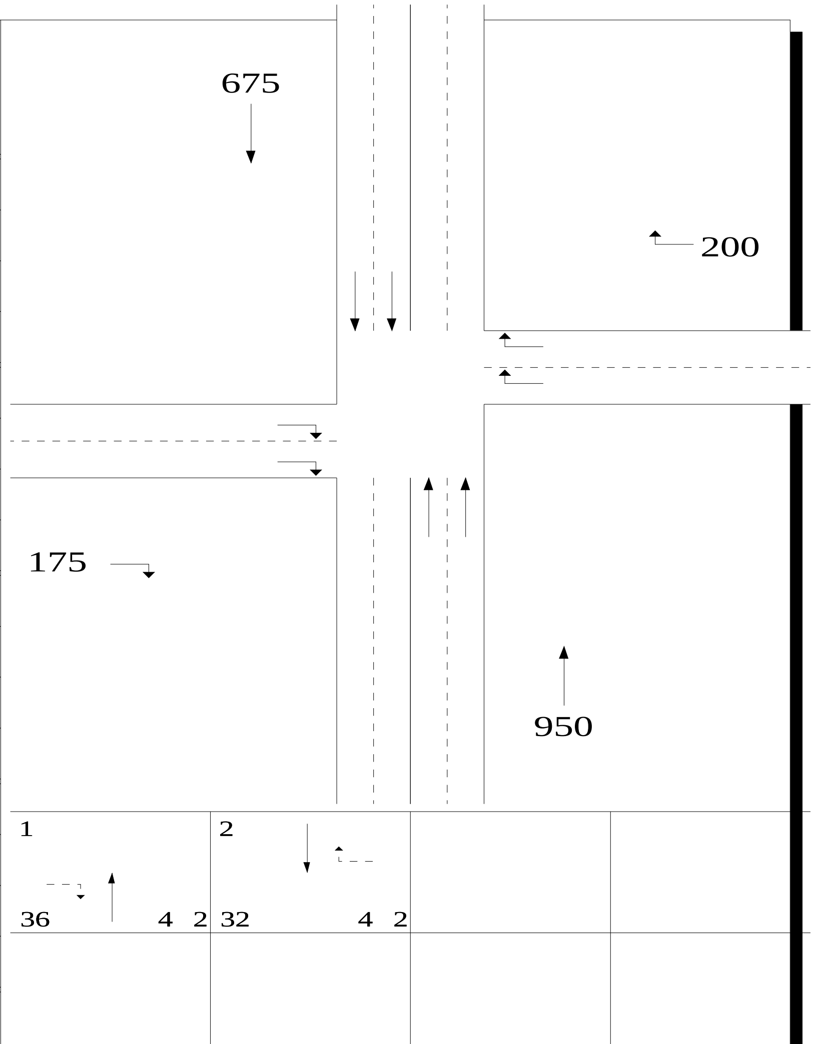
Intersection: Delay = 15.7 sec/veh Int. LOS=B X_c= 0.58 * Critical Lane Group Σ(v/s)Crit= 0.51

NETSIM Summary Results

Double Cross Johnson Mary Op1
R Marvin
PM Hour YR 2035

WB Ramp Left/Johnson
09/08/2011
Case: Double Cross WB Ramp Johnson Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	R	1 / 2	17.4	0.0
	All		17.4	0.0
WB	R	1 / 2	15.4	0.0
	All		15.4	0.0
NB	T	5 / 7	13.3	0.0
	All		13.3	0.0
SB	T	2 / 4	17.3	0.0
	All		17.3	0.0
Intersect.			14.9	



HCM Analysis Summary

Double Cross Adjacent RA Mary OP1 | EB Ramp Right/Johnson | Area Type: Non CBD
R Marvin | 09/08/2011 | Analysis Duration: 15 mins.
PM Hour YR 2035 | Case: Double Cross EB Ramp Johns Adjacent RA 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	0	R	12.0	R	12.0								
WB	2	0	R	12.0	R	12.0								
NB	2	2	T	12.0	T	12.0								
SB	2	2	T	12.0	T	12.0								

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	0	630	0	0	450	0	730	0	0	230	0
PHF	0.90	0.90	0.92	0.90	0.90	0.92	0.90	0.92	0.90	0.90	0.92	0.90
% Heavy Vehicles	2	2	5	2	2	5	2	4	2	2	4	2
Lane Groups			R			R		T			T	
Arrival Type			3			3		3			3	
RTOR Vol (vph)	100			100			0			0		
Peds/Hour	0			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 50.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		P																
WB				P														
NB		T																
SB				T														
Green		22.0		18.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	R	1191	0.213	0.440	R	0.484	11.4	B	11.4	B
WB										
	* R	975	0.140	0.360	R	0.390	13.1	B	13.1	B
NB										
	* T	1527	0.228	0.440	T	0.519	10.3	B	10.3	B
SB										
	T	1250	0.072	0.360	T	0.200	11.1	B	11.1	B

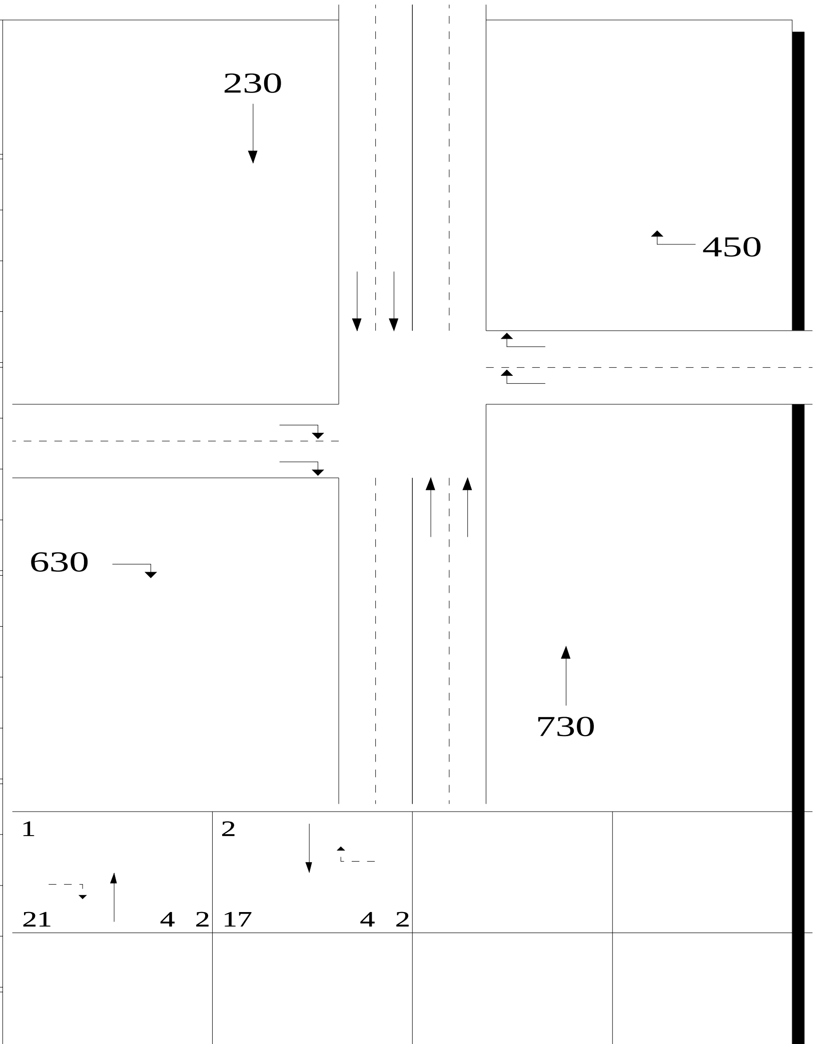
Intersection: Delay = 11.2 sec/veh | Int. LOS=B | X_c= 0.46 | * Critical Lane Group | Σ(v/s)Crit= 0.37

NETSIM Summary Results

Double Cross Adjacent RA Mary OP1
R Marvin
PM Hour YR 2035

EB Ramp Right/Johnson
09/08/2011
Case: Double Cross EB Ramp Johns Adjacent RA 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	R	2 / 3	19.9	0.0
	All		19.9	0.0
WB	R	2 / 3	17.9	0.0
	All		17.9	0.0
NB	T	4 / 5	16.5	0.0
	All		16.5	0.0
SB	T	1 / 2	18.5	0.0
	All		18.5	0.0
Intersect.			18.0	



HCM Analysis Summary

Double Cross WB Ramps Adjacent RA — WB Ramp Left/Johnson — Area Type: Non CBD
R Marvin — 09/08/2011 — Analysis Duration: 15 mins.
PM Hour YR 2035 — Case: Double Cross WB Ramp Adjacent RA 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	0	R	12.0	R	12.0								
WB	2	0	R	12.0	R	12.0								
NB	2	2	T	12.0	T	12.0								
SB	2	2	T	12.0	T	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	0	175	0	0	200	0	950	0	0	675	0
PHF	0.90	0.90	0.92	0.90	0.90	0.92	0.90	0.92	0.90	0.90	0.92	0.90
% Heavy Vehicles	2	2	5	2	2	5	2	4	2	2	4	2
Lane Groups			R			R		T			T	
Arrival Type			3			3		3			3	
RTOR Vol (vph)	30			25			0			0		
Peds/Hour	0			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 50.0 Sec — Lost Time Per Cycle: 10.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	P								
WB		P							
NB	T								
SB		T							
Green	22.0	18.0							0
Yellow / All Red	3.5 / 1.5	3.5 / 1.5							

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	R	1191	0.058	0.440	R	0.133	8.6	A	8.6	A
WB										
	R	975	0.070	0.360	R	0.195	11.5	B	11.5	B
NB										
	* T	1527	0.298	0.440	T	0.676	12.2	B	12.2	B
SB										
	* T	1250	0.211	0.360	T	0.587	13.5	B	13.5	B

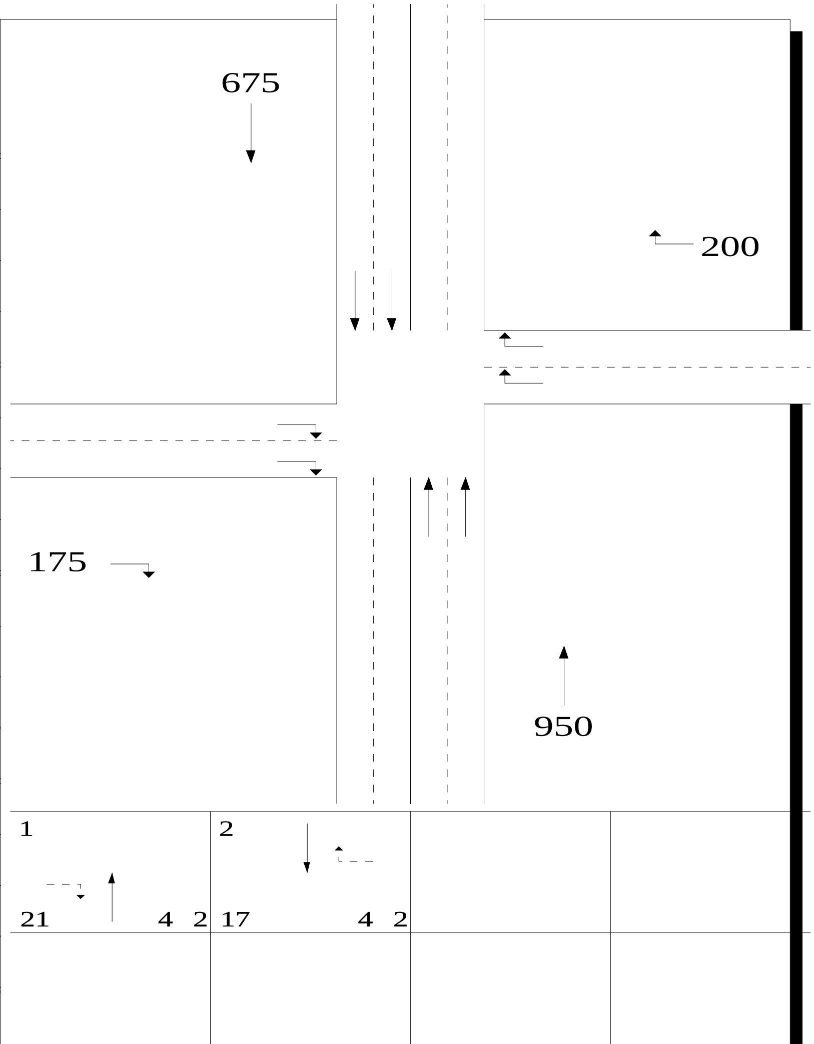
Intersection: Delay = 12.3 sec/veh   Int. LOS=B X_c= 0.64   * Critical Lane Group Σ(v/s)Crit= 0.51

NETSIM Summary Results

Double Cross WB Ramps Adjacent RA
R Marvin
PM Hour YR 2035

WB Ramp Left/Johnson
09/08/2011
Case: Double Cross WB Ramp Adjacent RA 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	R	1 / 2	18.0	0.0
	All		18.0	0.0
WB	R	1 / 2	18.6	0.0
	All		18.6	0.0
NB	T	5 / 6	15.3	0.0
	All		15.3	0.0
SB	T	3 / 5	16.0	0.0
	All		16.0	0.0
Intersect.			16.1	



Appendix I

US 87/Old Hwy 312 Intersection

Design Options

Figures & Capacity Calculations

Appendix I

US 87/Old Hwy 312 Intersection

Design Option Figures

Figure I–1. Option 1 – Main Street Roundabouts with Access to Mary St/Bench Blvd. T–intersection

Figure I–2. Option 2 – Primary & Secondary Roundabouts

Figure I–3. Option 3 – Dual Roundabouts

Appendix I

US 87/Old Hwy 312 Intersection

Design Options

Capacity Calculations

LANE SUMMARY

Site: Rou 4-way 2-Lane & 1-Lane Exits US

Mary Street Alignment US87/312/Bench/Mary
Design Option 1
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Mary Alignment NW Bound																
Lane 1	418	21	0	439	2.4	518	0.847	100	26.4	LOS C	7.8	197.8	1600	–	0.0	0.0
Lane 2	0	474	5	479	4.0	566	0.847	100	17.5	LOS B	8.1	207.9	1600	–	0.0	0.0
Approach	418	495	5	918	3.2		0.847		21.8	LOS C	8.1	207.9				
North East: Highway 312 SW Bound																
Lane 1	179	107	0	287	2.4	392	0.731	100	26.7	LOS C	5.6	143.6	1600	–	0.0	0.0
Lane 2	0	322	11	333	3.0	455	0.731	100	20.0	LOS C	6.1	155.3	1600	–	0.0	0.0
Approach	179	429	11	620	2.7		0.731		23.1	LOS C	6.1	155.3				
North West: US 87 SE Bound																
Lane 1	11	190	5	207	3.8	451	0.458	100	13.0	LOS B	2.6	66.6	700	–	0.0	0.0
Approach	11	190	5	207	3.8		0.458		13.0	LOS B	2.6	66.6				
South West: Main Street NE Bound																
Lane 1	451	145	0	596	1.8	897	0.664	100	17.2	LOS B	7.2	182.7	1600	–	0.0	0.0
Lane 2	0	486	217	703	1.6	1058	0.664	100	10.4	LOS B	7.5	189.2	1600	–	0.0	0.0
Approach	451	630	217	1299	1.7		0.664		13.5	LOS B	7.5	189.2				
Intersection				3043	2.5		0.847		17.9	LOS B	8.1	207.9				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Mary Alignment & Bench*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*12/21/2011*	Analysis Year	*2035 Option 1*
Analysis Time Period	*PM Design Hour*		

Project Description *Billings Bypass*

East/West Street: *Mary Street Alignment* | North/South Street: *Bench Blvd*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*305*			*465*	
Peak-Hour Factor, PHF	*1.00*	*0.92*	*1.00*	*1.00*	*0.92*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*331*	*0*	*0*	*505*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Raised curb*					
RT Channelized			*0*			*0*
Lanes	*0*	*2*	*0*	*0*	*2*	*0*
Configuration		*T*			*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*380*		*60*			
Peak-Hour Factor, PHF	*0.92*	*1.00*		*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*413*	*0*	*60*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*0*	*1*	*0*	*0*	*0*
Configuration	*L*		*R*			

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration			*L*		*R*			
v (veh/h)			*413*		*60*			
C (m) (veh/h)			*540*		*884*			
v/c			*0.76*		*0.07*			
95% queue length			*6.82*		*0.22*			
Control Delay (s/veh)			*30.1*		*9.4*			
LOS			*D*		*A*			
Approach Delay (s/veh)	--	--	*27.5*					
Approach LOS	--	--	*D*					

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	R Marvin	Intersection	Mary & Bench
Agency/Co.	Marvin Associates	Jurisdiction	MDT
Date Performed	12/21/2011	Analysis Year	2035 Option 1
Analysis Time Period	Pm Design Hour		
Project Description	Billings Bypass		
East/West Street:	Mary Street (exist)	North/South Street:	Bench Blvd
Intersection Orientation:	North-South	Study Period (hrs):	0.25

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		440				
Peak-Hour Factor, PHF	1.00		1.00	1.00	1.00	1.00
Hourly Flow Rate, HFR (veh/h)	0	440	0	0	0	0
Percent Heavy Vehicles	0	--	--	0	--	--
Median Type	Raised curb					
RT Channelized			0			0
Lanes	0	2	0	0	0	0
Configuration		T				
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				95		30
Peak-Hour Factor, PHF	1.00	1.00	1.00	0.92	1.00	0.92
Hourly Flow Rate, HFR (veh/h)	0	0	0	103	0	32
Percent Heavy Vehicles	0	0	0	0	0	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	0	0	0	0	0
Configuration					LR	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration				LR				
v (veh/h)				135				
C (m) (veh/h)				629				
v/c				0.21				
95% queue length				0.81				
Control Delay (s/veh)				12.3				
LOS				B				
Approach Delay (s/veh)	--	--	12.3					
Approach LOS	--	--	B					

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LANE SUMMARY

Site: Mary Alignment US87/312/ Main/Bench/Mary Design Opt 2

US87/312/Main/Bench Mary Street Alignment Design Option 2
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Bench NB																
Lane 1	22	125	0	147	0.0	408	0.359	100	16.2	LOS B	1.8	45.7	600	–	0.0	0.0
Lane 2	0	0	332	332	0.0	576	0.576	100	9.1	LOS A	4.0	99.7	200	–	0.0	0.0
Approach	22	125	332	478	0.0		0.576		11.3	LOS B	4.0	99.7				
South East: Mary Street Alignment NWB																
Lane 1	397	0	0	397	1.5	601	0.660	100	21.2	LOS C	4.9	123.8	1600	–	0.0	0.0
Lane 2	0	228	5	234	4.0	428	0.546	83[5]	13.6	LOS B	3.1	80.6	1600	–	0.0	0.0
Approach	397	228	5	630	2.4		0.660		18.4	LOS B	4.9	123.8				
North East: HWY 312 SWB																
Lane 1	179	103	0	282	1.2	487	0.580	100	19.3	LOS B	4.4	109.8	1600	–	0.0	0.0
Lane 2	0	326	11	337	3.0	581	0.580	100	14.8	LOS B	4.7	121.2	1600	–	0.0	0.0
Approach	179	429	11	620	2.2		0.580		16.8	LOS B	4.7	121.2				
North West: US 87 SEB																
Lane 1	11	109	87	207	2.3	528	0.391	100	9.4	LOS A	2.2	55.0	1600	–	0.0	0.0
Approach	11	109	87	207	2.3		0.391		9.4	LOS A	2.2	55.0				
South West: Main Street NE Bound																
Lane 1	451	139	0	590	1.0	979	0.603	100	15.3	LOS B	5.8	146.3	1600	–	0.0	0.0
Lane 2	0	492	245	736	1.3	1222	0.603	100	7.6	LOS A	6.0	150.9	1600	–	0.0	0.0
Approach	451	630	245	1326	1.1		0.603		11.0	LOS B	6.0	150.9				
Intersection				3261	1.5		0.660		13.5	LOS B	6.0	150.9				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

SIDRA INTERSECTION

LANE SUMMARY

Site: Rou 4-way 1-Lane US

Mary Street Alignment Single Lane Roundabout Bench and Mary Street South of Main Street US87
Option 2 Design
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Mary Street WB																
Lane 1	103	0	33	136	0.0	732	0.186	100	10.6	LOS B	1.0	24.7	1600	–	0.0	0.0
Approach	103	0	33	136	0.0		0.186		10.6	LOS B	1.0	24.7				
North: Main US 87 Connect SB																
Lane 1	33	0	342	375	0.0	1109	0.338	100	3.2	LOS A	2.3	58.0	600	–	0.0	0.0
Approach	33	0	342	375	0.0		0.338		3.2	LOS A	2.3	58.0				
South West: Bench Blvd EB																
Lane 1	446	0	152	598	0.0	1106	0.541	100	7.1	LOS A	5.0	124.9	1600	–	0.0	0.0
Approach	446	0	152	598	0.0		0.541		7.1	LOS A	5.0	124.9				
Intersection				1109	0.0		0.541		6.2	LOS A	5.0	124.9				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

LANE SUMMARY

Site: Mary Street Alignment US87/312/Bench Design Option 3

Mary Street Alignment US87/312/Bench
Design Option 3
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Mary Alignment NW Bound																
Lane 1	326	120	0	446	1.5	543	0.822	100	20.9	LOS C	7.3	183.8	600	–	0.0	0.0
Lane 2	0	233	272	505	1.9	614	0.822	100	14.3	LOS B	7.6	194.1	600	–	0.0	0.0
Approach	326	353	272	951	1.7		0.822		17.4	LOS B	7.6	194.1				
North East: Highway 312 SW Bound																
Lane 1	179	105	0	284	2.0	484	0.588	100	20.3	LOS C	4.2	107.4	1600	–	0.0	0.0
Lane 2	0	313	11	324	2.0	552	0.588	100	14.0	LOS B	4.5	113.8	1600	–	0.0	0.0
Approach	179	418	11	609	2.0		0.588		17.0	LOS B	4.5	113.8				
North West: US 87 SE Bound																
Lane 1	11	190	5	207	3.8	508	0.406	100	10.7	LOS B	2.2	55.6	700	–	0.0	0.0
Approach	11	190	5	207	3.8		0.406		10.7	LOS B	2.2	55.6				
South West: Main Street NE Bound																
Lane 1	451	156	0	607	1.7	983	0.618	100	14.7	LOS B	6.0	152.8	1600	–	0.0	0.0
Lane 2	0	474	245	719	1.3	1164	0.618	100	8.1	LOS A	6.1	154.4	1600	–	0.0	0.0
Approach	451	630	245	1326	1.5		0.618		11.1	LOS B	6.1	154.4				
Intersection				3092	1.8		0.822		14.2	LOS B	7.6	194.1				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

LANE SUMMARY

Site: Mary Street Alignment Bench/ Mary Intersection Design Option 3

Mary Street Alignment Bench/Mary Intersection
Design Option 3
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	T veh/h	R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Mary Street NB																
Lane 1	103	33	5	141	0.0	612	0.231	100	12.0	LOS B	1.5	36.3	1600	–	0.0	0.0
Approach	103	33	5	141	0.0		0.231		12.0	LOS B	1.5	36.3				
East: Mary Street Alignment WB																
Lane 1	5	92	0	98	0.0	787	0.124	100	7.8	LOS A	0.7	17.9	1600	–	0.0	0.0
Lane 2	0	0	538	538	3.0	1577	0.341	100	5.3	X	X	X	1600	–	0.0	X
Approach	5	92	538	636	2.5		0.341		5.7	LOS A	0.7	17.9				
North: Bench Connect SB																
Lane 1	326	11	0	337	3.9	1135	0.297	100	9.1	LOS A	1.9	48.0	600	–	0.0	0.0
Lane 2	0	0	370	370	0.0	1318	0.280	95[5]	3.5	LOS A	1.8	44.5	600	–	0.0	0.0
Approach	326	11	370	707	1.8		0.297		6.2	LOS A	1.9	48.0				
West: Bench Blvd EB																
Lane 1	380	65	152	598	0.0	928	0.644	100	10.8	LOS B	6.6	164.5	1600	–	0.0	0.0
Approach	380	65	152	598	0.0		0.644		10.8	LOS B	6.6	164.5				
Intersection				2082	1.4		0.644		7.7	LOS A	6.6	164.5				

X: Not applicable for Continuous lane.

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

SIDRA INTERSECTION

APPENDIX J

Five Mile Road/Old Hwy 312

Design Options

Figures & Capacity Calculations

APPENDIX J

Five Mile Road/Old Hwy 312

Design Option Figures

Figure J1. Option A – Signal Five Mile Road–Old Hwy 312

Figure J2. Option A –Roundabout Five Mile Road–Old Hwy 312

Figure J3. Option B – Signal Five Mile Road–Old Hwy 312

Figure J4. Option B – Signal Five Mile Road–Old Hwy 312

APPENDIX J

Five Mile Road/Old Hwy 312

Design Options

Capacity Calculations

HCM Analysis Summary

Five Mile Align HWY 312 | Highway 312/Five Mile Align | Area Type: Non CBD
R Marvin | 12/01/2011 | Analysis Duration: 15 mins.
PM design Hour | Case: Five Mile Align 312 PM 2035

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	3	1	L	12.0	T	12.0	R	12.0						
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	5	470	20	160	310	5	30	5	230	5	5	5
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	3	1	2	3	1	3	1	3	1	1	1
Lane Groups	L	TR		L	TR		L	T	R		LTR	
Arrival Type	3	3		3	3		3	3	3		3	
RTOR Vol (vph)	0			0			100			0		
Peds/Hour	0			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 11.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		35.0		14.0														0
Yellow	All Red	4.0	2.0	3.5	1.5													

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	595	0.006	0.583	L	0.010	5.3	A	6.5	A
	TR	2032	0.156	0.583	TR	0.268	6.5	A		
WB										
	* L	488	0.213	0.583	L	0.365	8.7	A	6.9	A
	TR	2039	0.100	0.583	TR	0.172	6.0	A		
NB										
	L	321	0.024	0.233	L	0.103	18.1	B	19.3	B
	T	439	0.003	0.233	T	0.014	17.7	B		
	* R	366	0.092	0.233	R	0.393	19.7	B		
SB										
	LTR	393	0.011	0.233	LTR	0.046	17.8	B	17.8	B

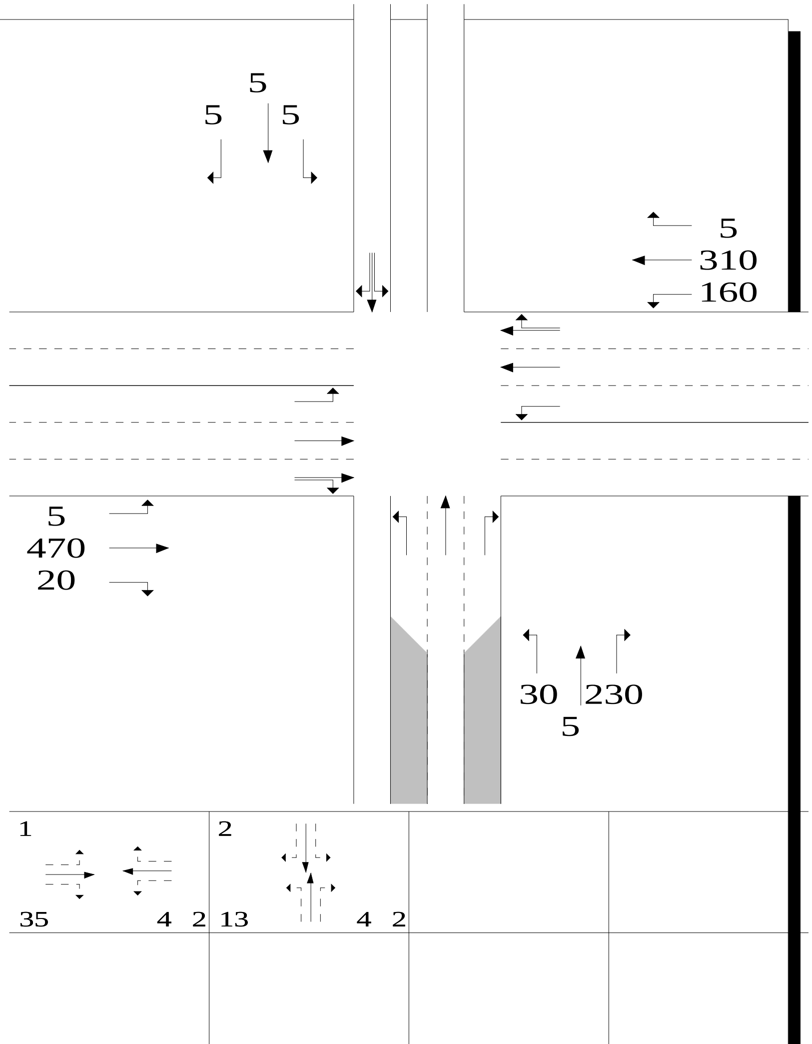
Intersection: Delay = 8.7 sec/veh | Int. LOS=A | X_c= 0.37 | * Critical Lane Group | Σ(v/s)Crit= 0.30

NETSIM Summary Results

Five Mile Align HWY 312
R Marvin
PM design Hour

Highway 312/Five Mile Align
12/01/2011
Case: Five Mile Align 312 PM 2035

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	31.5	0.0
	TR	2 / 3	19.6	0.0
	All		19.6	0.0
WB	L	1 / 2	17.3	0.0
	TR	2 / 3	19.7	0.0
	All		19.0	0.0
NB	L	0 / 1	8.1	0.0
	T	0 / 1	24.6	0.0
	R	1 / 3	16.2	0.0
	All		18.2	0.0
SB	LTR	0 / 1	11.8	0.0
	All		11.8	0.0
Intersect.			19.0	



LANE SUMMARY

Site: Five Mile Road Alignment HWY 312 Intersection

Five Mile Road Alignment
Highway 312 Intersection Year 2035 PM Design Hour
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Five Mile Road NWB																
Lane 1	33	5	0	38	3.6	480	0.079	28 [5]	15.4	LOS B	0.3	7.3	1600	–	0.0	0.0
Lane 2	0	0	250	250	3.0	891	0.281	100	7.9	LOS A	1.2	31.8	1600	–	0.0	0.0
Approach	33	5	250	288	3.1		0.281		8.9	LOS A	1.2	31.8				
North East: HWY 312 SWB																
Lane 1	174	74	0	248	3.0	1335	0.186	100	10.2	LOS B	1.1	28.1	1600	–	0.0	0.0
Lane 2	0	263	5	268	3.0	1445	0.186	100	4.5	LOS A	1.1	28.4	1600	–	0.0	0.0
Approach	174	337	5	516	3.0		0.186		7.3	LOS A	1.1	28.4				
North West: Access Road SEB																
Lane 1	5	5	5	16	1.0	753	0.022	100	8.1	LOS A	0.1	1.9	1600	–	0.0	0.0
Approach	5	5	5	16	1.0		0.022		8.1	LOS A	0.1	1.9				
South West: HWY 312 NEB																
Lane 1	5	249	0	254	3.0	1172	0.217	100	5.5	LOS A	1.2	31.0	1600	–	0.0	0.0
Lane 2	0	262	22	284	3.0	1310	0.217	100	5.3	LOS A	1.2	31.5	200	–	0.0	0.0
Approach	5	511	22	538	3.0		0.217		5.4	LOS A	1.2	31.5				
Intersection				1359	3.0		0.281		6.9	LOS A	1.2	31.8				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

SIDRA INTERSECTION

HCM Analysis Summary

5 Mile & HWY 312 Secondary Imps — Highway 312/Five Mile Align — Area Type: Non CBD
R Marvin — 12/01/2011 — Analysis Duration: 15 mins.
PM Design Hour — Case: MARYAL~1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	LT	12.0	R	12.0								
SB	1	1	LTR	12.0										

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	5	470	20	150	300	5	30	5	210	5	5	5
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	3	1	2	3	1	3	1	3	1	1	1
Lane Groups	L	TR		L	TR			LT	R		LTR	
Arrival Type	3	3		3	3			3	3		3	
RTOR Vol (vph)	0			0			100			0		
Peds/Hour	0			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 60.0 Sec — Lost Time Per Cycle: 11.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP								
WB	LTP								
NB		LTP							
SB		LTP							
Green	35.0	14.0							0
Yellow / All Red	4.0 / 2.0	3.5 / 1.5							

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	601	0.006	0.583	L	0.010	5.3	A	6.5	A
	TR	2032	0.156	0.583	TR	0.268	6.5	A		
WB										
	* L	488	0.200	0.583	L	0.342	8.4	A	6.8	A
	TR	2039	0.097	0.583	TR	0.166	5.9	A		
NB										
	LT	344	0.026	0.233	LT	0.113	18.2	B	19.0	B
	* R	366	0.078	0.233	R	0.333	19.3	B		
SB										
	LTR	391	0.011	0.233	LTR	0.046	17.8	B	17.8	B

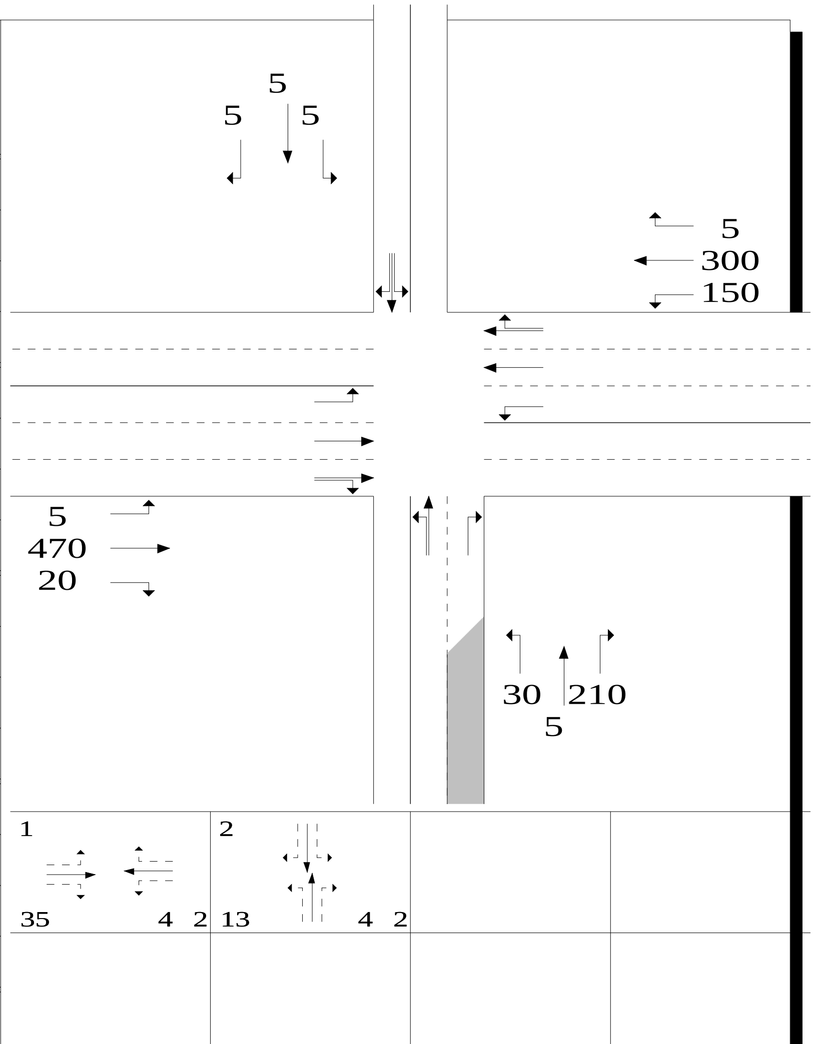
Intersection: Delay = 8.4 sec/veh — Int. LOS=A — X_c= 0.34 — * Critical Lane Group — Σ(v/s)Crit= 0.28

NETSIM Summary Results

5 Mile & HWY 312 Secondary Imps
R Marvin
PM Design Hour

Highway 312/Five Mile Align
12/01/2011
Case: MARYAL~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	31.5	0.0
	TR	2 / 4	19.4	0.0
	All		19.4	0.0
WB	L	1 / 3	17.0	0.0
	TR	2 / 2	20.4	0.0
	All		19.3	0.0
NB	LT	0 / 1	21.3	0.0
	R	1 / 3	16.3	0.0
	All		18.7	0.0
SB	LTR	0 / 1	11.8	0.0
	All		11.8	0.0
Intersect.			19.1	



APPENDIX K

Mary Street Alignment/Bitteroot Drive

Design Options

Figures & Capacity Calculations

APPENDIX K

Mary Street Alignment/Bitteroot Drive

Design Option Figures

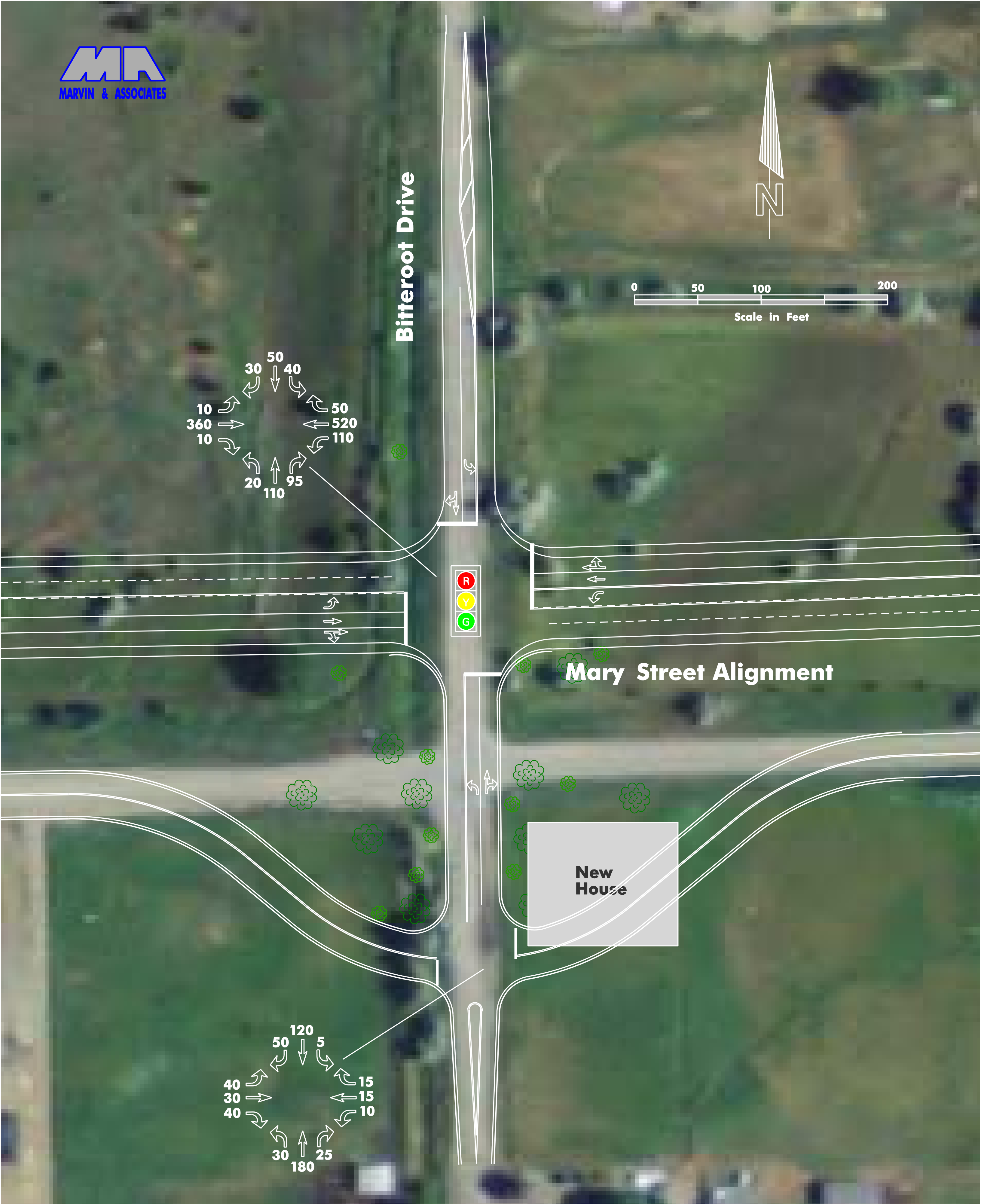


Figure K1. Mary Street Alignments Design Option A

Figure K2. Mary Street Alignments Design Option B

Figure K3. Mary Street Alignment Design Option C

Figure K4. Mary Street Alignments Design Option D

Figure K5. Mary Street Alignments Design Option E

Figure K6. Mary Street Alignment Design Option F

Figure K7. Mary Street Alignments Design Option G

APPENDIX K

Mary Street Alignment/Bitteroot Drive

Design Options

Capacity Calculations

HCM Analysis Summary

Mary Alignment Bitteroot Alt A | Mary Alignment/Bitteroot | Area Type: Non CBD
R Marvin | 11/29/2011 | Analysis Duration: 15 mins.
Design Hour PM | Case: Mary Align & Bitteroot Alt A 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	10	360	10	110	520	50	20	110	95	40	50	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			10			25			5		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		32.0		18.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

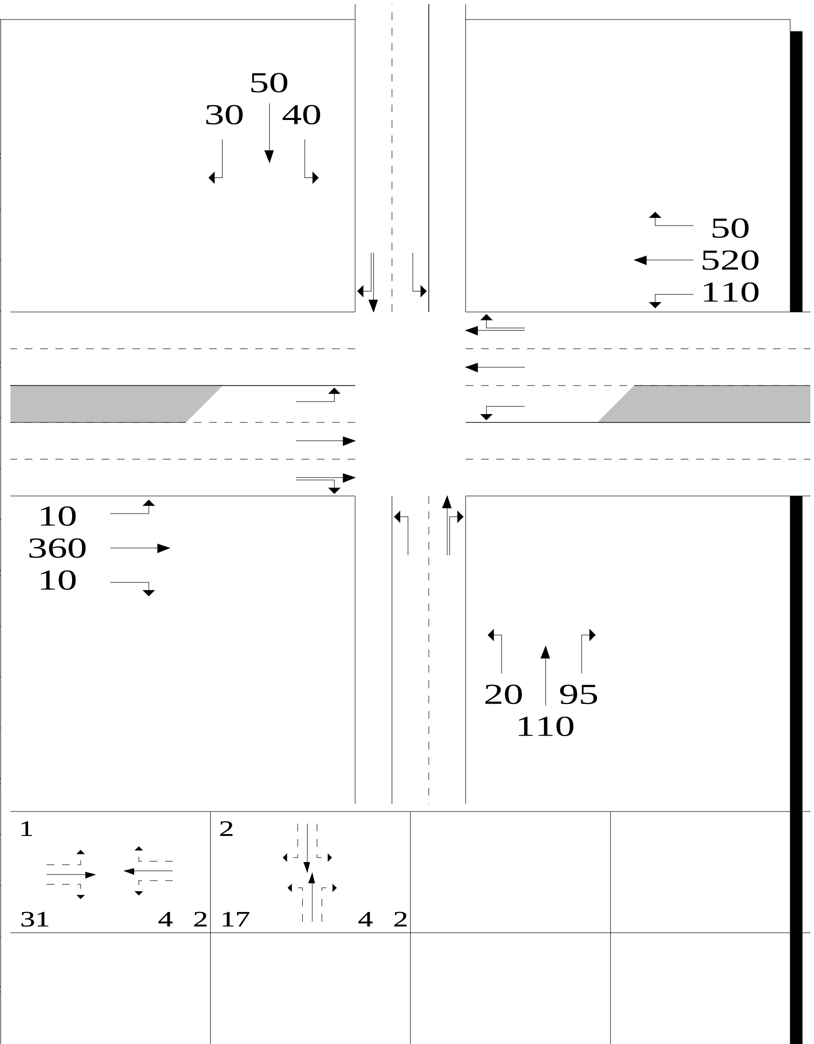
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	401	0.015	0.533	L	0.027	6.8	A	7.7	A
	TR	1844	0.119	0.533	TR	0.223	7.7	A		
WB										
	L	516	0.126	0.533	L	0.236	8.6	A	8.5	A
	* TR	1831	0.181	0.533	TR	0.340	8.5	A		
NB										
	L	399	0.017	0.300	L	0.055	15.0	B	16.6	B
	* TR	530	0.113	0.300	TR	0.377	16.7	B		
SB										
	L	354	0.037	0.300	L	0.124	15.3	B	15.4	B
	TR	535	0.047	0.300	TR	0.157	15.5	B		

Intersection: Delay = 10.0 sec/veh | Int. LOS=B | X_c= 0.35 | * Critical Lane Group | Σ(v/s)Crit= 0.29

NETSIM Summary Results

Mary Alignment Bitteroot Alt A	Mary Alignment/Bitteroot
R Marvin	11/29/2011
Design Hour PM	Case: Mary Align & Bitteroot Alt A 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	28.9	0.0
	TR	2 / 3	18.1	0.0
	All		18.2	0.0
WB	L	1 / 2	14.4	0.0
	TR	3 / 4	17.6	0.0
	All		17.4	0.0
NB	L	0 / 1	12.5	0.0
	TR	2 / 3	17.7	0.0
	All		17.1	0.0
SB	L	1 / 2	12.5	0.0
	TR	1 / 2	17.3	0.0
	All		15.1	0.0
Intersect.			17.3	



LANE SUMMARY

Site: Mary Alignment Bitteroot Alt B 2035 PM

Mary Street Alignment Bitteroot Alternative B
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Bitteroot NB																
Lane 1	22	120	103	245	0.0	778	0.314	100	4.7	LOS A	1.4	35.5	200	–	0.0	0.0
Approach	22	120	103	245	0.0		0.314		4.7	LOS A	1.4	35.5				
East: Mary Alignment WB																
Lane 1	120	234	0	353	2.6	1201	0.294	100	7.9	LOS A	1.9	48.5	1600	–	0.0	0.0
Lane 2	0	331	54	386	3.4	1311	0.294	100	5.3	LOS A	1.9	49.6	1600	–	0.0	0.0
Approach	120	565	54	739	3.1		0.294		6.6	LOS A	1.9	49.6				
North: Bitteroot SB																
Lane 1	43	54	33	130	0.3	661	0.197	100	6.9	LOS A	0.8	19.8	1600	–	0.0	0.0
Approach	43	54	33	130	0.3		0.197		6.9	LOS A	0.8	19.8				
West: Mary Alignment EB																
Lane 1	11	184	0	195	3.8	1125	0.174	100	5.9	LOS A	0.9	24.5	1600	–	0.0	0.0
Lane 2	0	207	11	218	3.8	1255	0.174	100	5.4	LOS A	1.0	24.9	1600	–	0.0	0.0
Approach	11	391	11	413	3.8		0.174		5.7	LOS A	1.0	24.9				
Intersection				1527	2.5		0.314		6.0	LOS A	1.9	49.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

HCM Analysis Summary

Mary Alignment Bitteroot Alt C	Mary Alignment/Bitteroot	Area Type: Non CBD
R Marvin	11/29/2011	Analysis Duration: 15 mins.
Design Hour PM	Case: Mary Align & Bitteroot Alt C 2035 PM	

	Lanes		Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	1	1	LTR	12.0										
SB	1	1	LTR	12.0										

Data	East L	East T	East R	West L	West T	West R	North L	North T	North R	South L	South T	South R
Movement Volume (vph)	10	360	10	110	520	50	20	110	95	40	50	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR			LTR			LTR	
Arrival Type	3	3		3	3			3			3	
RTOR Vol (vph)		0			10			25			5	
Peds/Hour		5			5			5			5	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 60.0 Sec — Lost Time Per Cycle: 10.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP																
WB	LTP																
NB			LTP														
SB			LTP														
Green	32.0		18.0														0
Yellow / All Red	3.5	1.5	3.5	1.5													

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	L	401	0.015	0.533	L	0.027	6.8	A	7.7	A
	TR	1844	0.119	0.533	TR	0.223	7.7	A		
WB										
	L	516	0.126	0.533	L	0.236	8.6	A	8.5	A
	* TR	1831	0.181	0.533	TR	0.340	8.5	A		
NB										
	* LTR	523	0.127	0.300	LTR	0.424	17.0	B	17.0	B
SB										
	LTR	466	0.082	0.300	LTR	0.275	16.1	B	16.1	B

Capacity Analysis Results

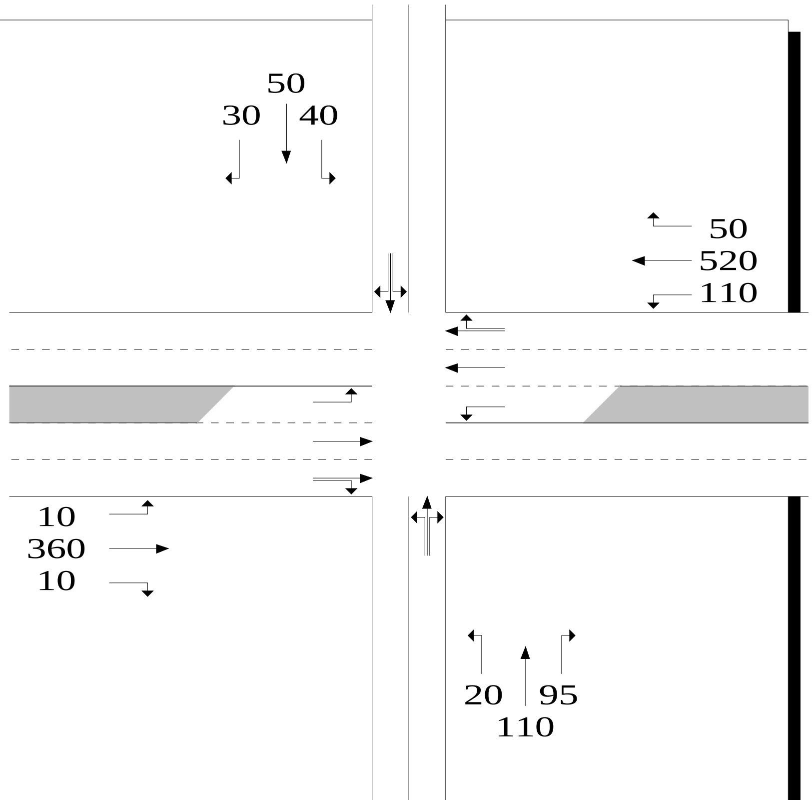
Intersection: Delay = 10.2 sec/veh — Int. LOS=B — X_c = 0.37 — * Critical Lane Group — Σ(v/s)Crit= 0.31

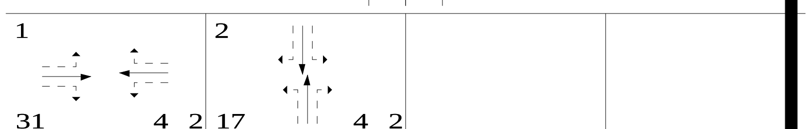
NETSIM Summary Results

Mary Alignment Bitteroot Alt C
R Marvin
Design Hour PM

Mary Alignment/Bitteroot
11/29/2011
Case: Mary Align & Bitteroot Alt C 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	28.9	0.0
	TR	2 / 3	18.2	0.0
	All		18.2	0.0
WB	L	1 / 2	14.5	0.0
	TR	3 / 4	17.7	0.0
	All		17.4	0.0
NB	LTR	2 / 3	16.5	0.0
	All		16.5	0.0
SB	LTR	2 / 2	14.6	0.0
	All		14.6	0.0
Intersect.			17.2	





TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary & Bitteroot All Options*
Jurisdiction	*MDT*
Analysis Year	*Year 2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* North/South Street: *Bitteroot*

Intersection Orientation: *North-South* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*30*	*180*	*35*	*5*	*120*	*50*
Peak-Hour Factor, PHF	*0.80*	*0.80*	*0.80*	*0.75*	*0.75*	*0.75*
Hourly Flow Rate, HFR (veh/h)	*37*	*224*	*43*	*6*	*160*	*66*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration	*LTR*			*LTR*		
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*40*	*30*	*40*	*10*	*15*	*5*
Peak-Hour Factor, PHF	*0.70*	*0.70*	*0.70*	*0.60*	*0.60*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*57*	*42*	*57*	*16*	*24*	*8*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*LTR*	*LTR*		*LTR*			*LTR*	
v (veh/h)	*37*	*6*		*48*			*156*	
C (m) (veh/h)	*1354*	*1308*		*434*			*520*	
v/c	*0.03*	*0.00*		*0.11*			*0.30*	
95% queue length	*0.08*	*0.01*		*0.37*			*1.25*	
Control Delay (s/veh)	*7.7*	*7.8*		*14.3*			*14.9*	
LOS	*A*	*A*		*B*			*B*	
Approach Delay (s/veh)	--	--	*14.3*			*14.9*		
Approach LOS	--	--	*B*			*B*		

 *HCS+*TM Version 5.6 Generated: 12/22/2011 2:47 PM

HCM Analysis Summary

Mary Alignment Bitterroot Alt D | Mary Alignment/Bitteroot | Area Type: Non CBD
R Marvin | 4/6/12 | Analysis Duration: 15 mins.
Design Hour PM | Case: MARY ALIGN & BITTEROOT ALT D 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	10	410	10	120	535	50	20	100	75	45	50	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			10			25			5		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		32.0		18.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	392	0.015	0.533	L	0.028	6.8	A	7.9	A
	TR	1845	0.135	0.533	TR	0.253	7.9	A		
WB										
	L	489	0.145	0.533	L	0.272	9.0	A	8.6	A
	* TR	1831	0.186	0.533	TR	0.348	8.5	A		
NB										
	L	399	0.017	0.300	L	0.055	15.0	B	16.2	B
	* TR	535	0.094	0.300	TR	0.312	16.3	B		
SB										
	L	370	0.041	0.300	L	0.135	15.4	B	15.4	B
	TR	535	0.047	0.300	TR	0.157	15.5	B		

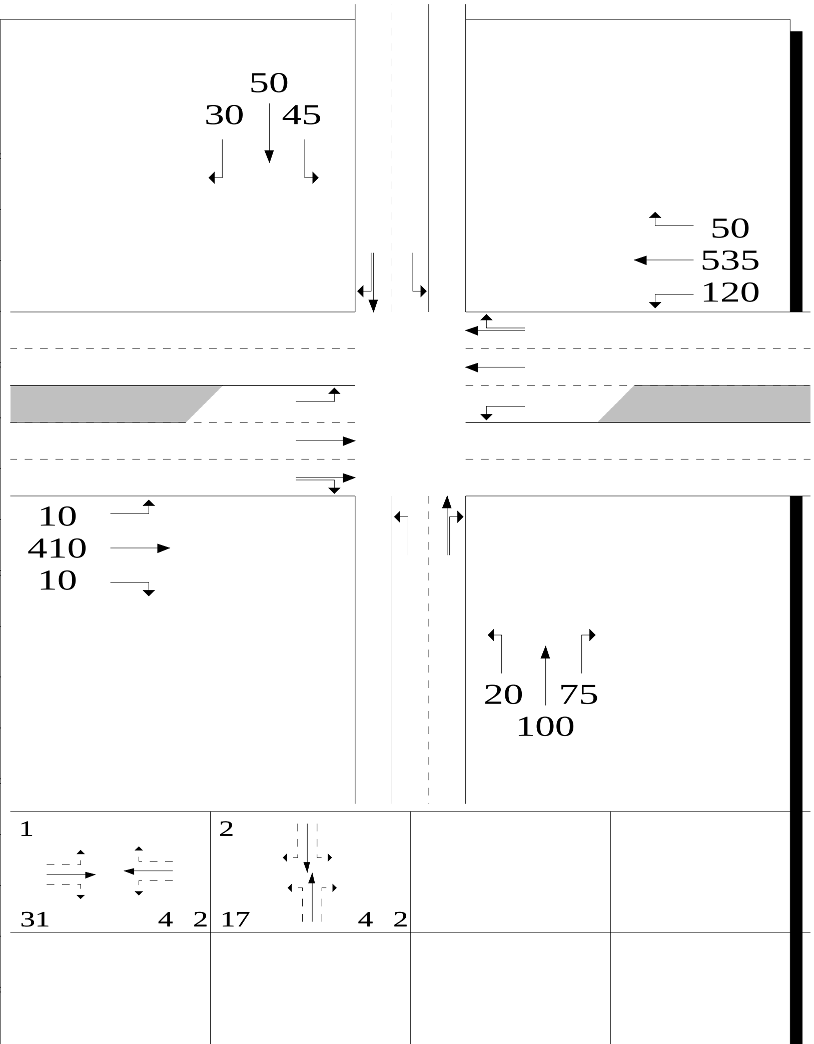
Intersection: Delay = 9.9 sec/veh | Int. LOS=A | X_c= 0.34 | * Critical Lane Group | Σ(v/s)Crit= 0.28

NETSIM Summary Results

Mary Alignment Bitterroot Alt D
R Marvin
Design Hour PM

Mary Alignment/Bitteroot
4/6/12
Case: MARY ALIGN & BITTEROOT ALT D 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	27.4	0.0
	TR	2 / 4	18.7	0.0
	All		18.8	0.0
WB	L	2 / 3	8.4	0.0
	TR	3 / 6	18.6	0.0
	All		17.2	0.0
NB	L	0 / 1	14.8	0.0
	TR	2 / 3	15.9	0.0
	All		15.8	0.0
SB	L	0 / 2	14.4	0.0
	TR	1 / 2	14.9	0.0
	All		14.7	0.0
Intersect.			17.2	



HCM Analysis Summary

Mary Alignment Bitterroot Alt E | Mary Alignment/Bitteroot | Area Type: Non CBD
R Marvin | 4/6/12 | Analysis Duration: 15 mins.
Design Hour PM | Case: MARY ALIGN & BITTEROOT ALT E Cap

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	25	375	50	90	550	65	50	80	105	45	25	50
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			15			35			10		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		32.0		18.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

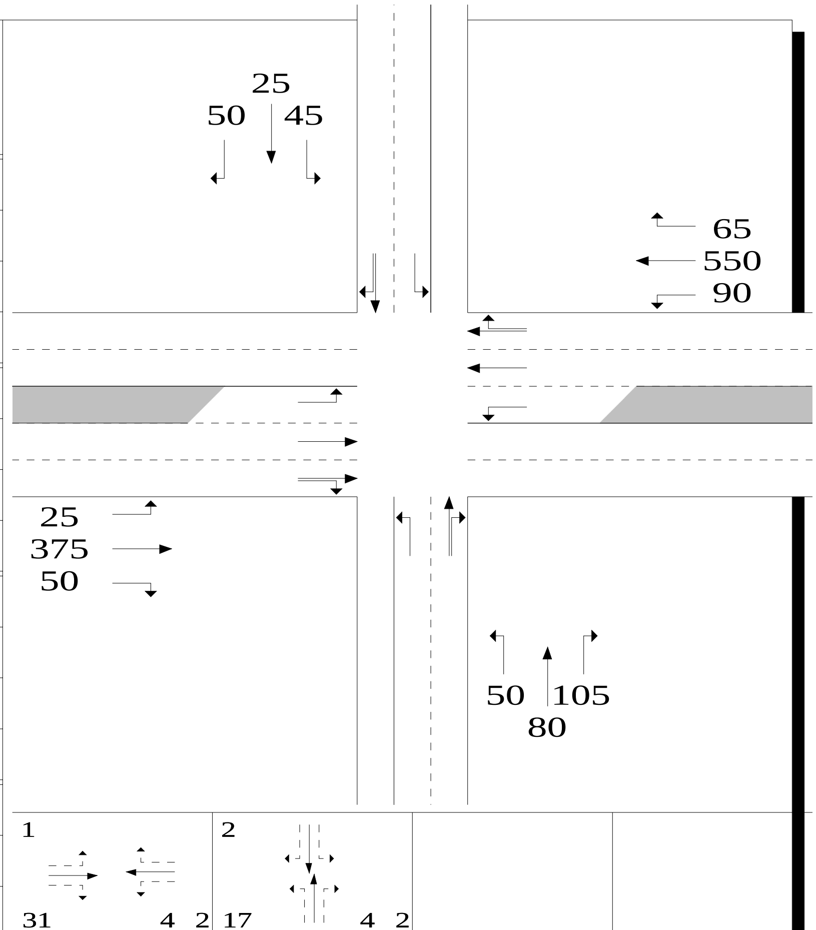
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	377	0.040	0.533	L	0.074	7.2	A	7.9	A
	TR	1818	0.139	0.533	TR	0.260	7.9	A		
WB										
	L	486	0.110	0.533	L	0.206	8.3	A	8.6	A
	* TR	1827	0.195	0.533	TR	0.365	8.7	A		
NB										
	L	403	0.042	0.300	L	0.139	15.4	B	16.1	B
	* TR	529	0.095	0.300	TR	0.316	16.4	B		
SB										
	L	370	0.041	0.300	L	0.135	15.4	B	15.4	B
	TR	516	0.042	0.300	TR	0.140	15.4	B		

Intersection: Delay = 9.9 sec/veh | Int. LOS=A | X_c= 0.35 | * Critical Lane Group | Σ(v/s)Crit= 0.29

NETSIM Summary Results

Mary Alignment Bitterroot Alt E	Mary Alignment/Bitteroot
R Marvin	4/6/12
Design Hour PM	Case: MARY ALIGN & BITTEROOT ALT E Cap

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 1	11.6	0.0
	TR	3 / 3	18.4	0.0
	All		18.1	0.0
WB	L	1 / 2	8.9	0.0
	TR	3 / 4	18.4	0.0
	All		17.6	0.0
NB	L	1 / 2	12.7	0.0
	TR	2 / 3	15.9	0.0
	All		15.1	0.0
SB	L	0 / 2	16.0	0.0
	TR	1 / 1	20.4	0.0
	All		18.3	0.0
Intersect.			17.3	



HCM Analysis Summary

Mary Alignment Bitterroot Alt F — Mary Alignment/Bitteroot — Area Type: Non CBD
R Marvin — 4/6/12 — Analysis Duration: 15 mins.
Design Hour PM — Case: MARY ALIGN & BITTEROOT ALT F Cap

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	10	360	10	110	520	110	20	110	95	40	50	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			15			35			10		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 60.0 Sec — Lost Time Per Cycle: 10.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP								
WB	LTP								
NB		LTP							
SB		LTP							
Green	32.0	18.0							0
Yellow / All Red	3.5 / 1.5	3.5 / 1.5							

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	L	367	0.016	0.533	L	0.030	6.8	A	7.7	A
	TR	1844	0.119	0.533	TR	0.223	7.7	A		
WB										
	L	516	0.126	0.533	L	0.236	8.6	A	8.7	A
	* TR	1825	0.200	0.533	TR	0.375	8.8	A		
NB										
	L	401	0.016	0.300	L	0.055	15.0	B	16.4	B
	* TR	533	0.106	0.300	TR	0.355	16.6	B		
SB										
	L	363	0.036	0.300	L	0.121	15.3	B	15.4	B
	TR	540	0.043	0.300	TR	0.144	15.4	B		

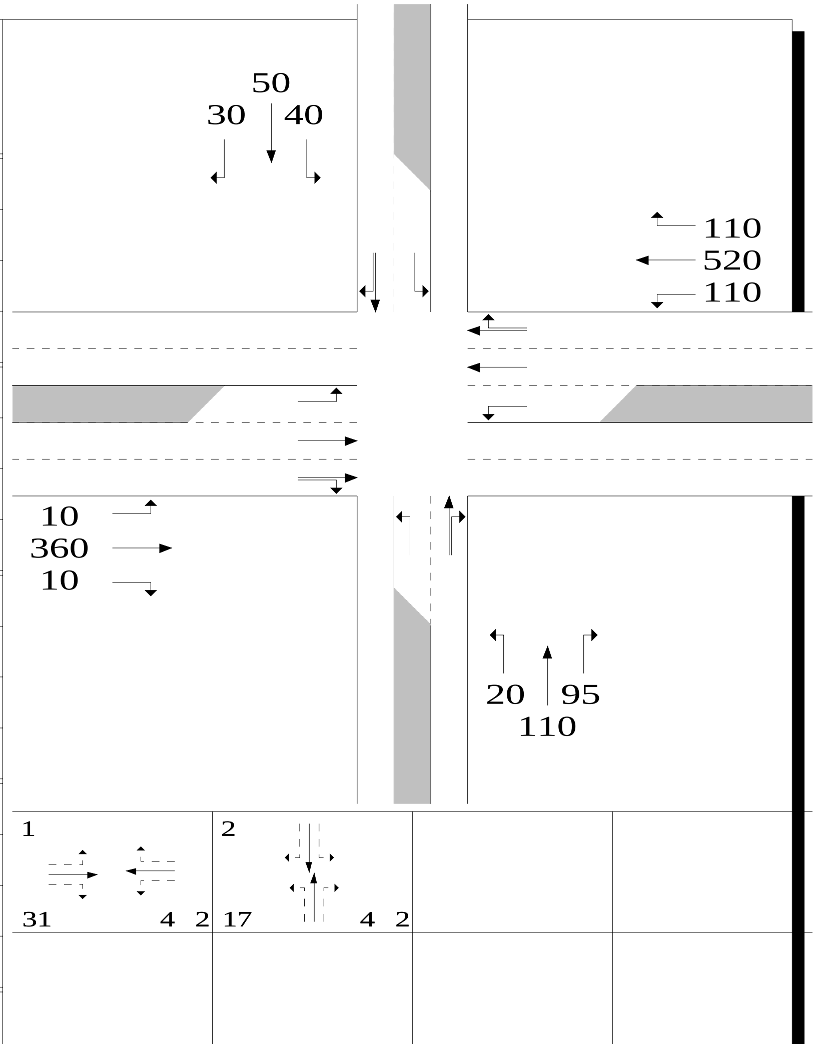
Intersection: Delay = 10.0 sec/veh — Int. LOS=A — X_c= 0.37 — * Critical Lane Group — Σ(v/s)Crit= 0.31

NETSIM Summary Results

Mary Alignment Bitterroot Alt F
R Marvin
Design Hour PM

Mary Alignment/Bitteroot
4/6/12
Case: MARY ALIGN & BITTEROOT ALT F Cap

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	28.9	0.0
	TR	2 / 3	18.0	0.0
	All		18.1	0.0
WB	L	1 / 2	15.3	0.0
	TR	4 / 5	17.5	0.0
	All		17.4	0.0
NB	L	0 / 1	6.4	0.0
	TR	2 / 4	16.9	0.0
	All		16.1	0.0
SB	L	1 / 2	9.6	0.0
	TR	1 / 2	18.8	0.0
	All		15.5	0.0
Intersect.			17.2	



HCM Analysis Summary

Mary Alignment Bitterroot Alt G	Mary Alignment/Bitteroot	Area Type: Non CBD
R Marvin	4/6/12	Analysis Duration: 15 mins.
Design Hour PM	Case: MARY ALIGN & BITTEROOT ALT G Cap	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	10	360	10	135	520	65	20	105	150	45	50	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			15			50			10		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 60.0 Sec Lost Time Per Cycle: 10.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP																
WB	LTP																
NB			LTP														
SB			LTP														
Green	32.0		18.0														0
Yellow / All Red	3.5	1.5	3.5	1.5													

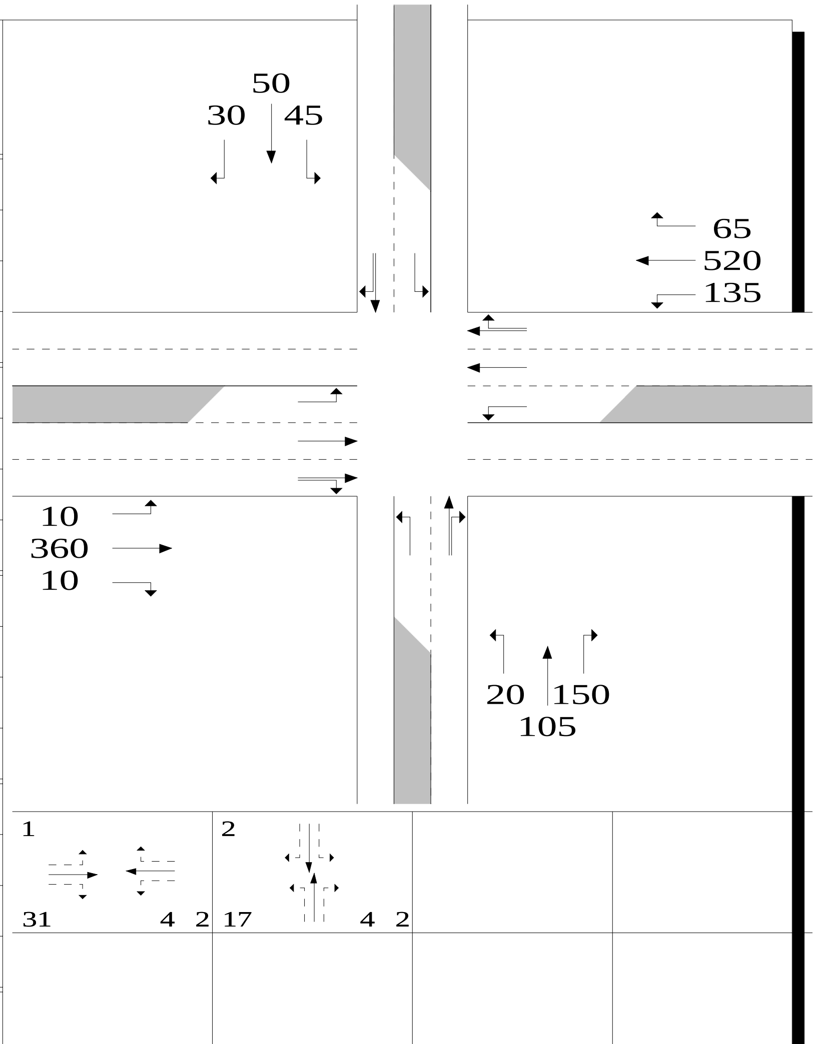
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	394	0.015	0.533	L	0.028	6.8	A	7.7	A
	TR	1844	0.119	0.533	TR	0.223	7.7	A		
WB										
	L	516	0.155	0.533	L	0.291	9.2	A	8.7	A
	* TR	1826	0.185	0.533	TR	0.347	8.5	A		
NB										
	L	401	0.016	0.300	L	0.055	15.0	B	16.9	B
	* TR	527	0.130	0.300	TR	0.433	17.1	B		
SB										
	L	329	0.046	0.300	L	0.152	15.5	B	15.4	B
	TR	540	0.043	0.300	TR	0.144	15.4	B		

Intersection: Delay = 10.2 sec/veh Int. LOS=B X_c= 0.38 * Critical Lane Group Σ(v/s)Crit= 0.31

NETSIM Summary Results

Mary Alignment Bitterroot Alt G	Mary Alignment/Bitteroot
R Marvin	4/6/12
Design Hour PM	Case: MARY ALIGN & BITTEROOT ALT G Cap

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	28.9	0.0
	TR	2 / 3	18.1	0.0
	All		18.1	0.0
WB	L	1 / 2	10.3	0.0
	TR	3 / 4	18.9	0.0
	All		17.8	0.0
NB	L	0 / 1	9.6	0.0
	TR	2 / 4	16.2	0.0
	All		15.7	0.0
SB	L	0 / 2	11.9	0.0
	TR	1 / 2	16.7	0.0
	All		15.5	0.0
Intersect.			17.2	



TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*MArvin Associates*
Date Performed	*4/6/2012*
Analysis Time Period	*PM Design*

Site Information

Intersection	*Mary Street & Bitterroot Opt D*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* | North/South Street: *Bitterroot Drive*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*180*	*25*		*130*	*50*
Peak-Hour Factor, PHF	*1.00*	*0.90*	*0.90*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*0*	*200*	*27*	*0*	*144*	*55*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Raised curb*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration			*TR*			*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)			*40*			*15*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*0.90*	*1.00*	*1.00*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*44*	*0*	*0*	*16*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*1*	*0*	*0*	*1*
Configuration			*R*			*R*

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration					*R*			*R*
v (veh/h)					*16*			*44*
C (m) (veh/h)					*831*			*877*
v/c					*0.02*			*0.05*
95% queue length					*0.06*			*0.16*
Control Delay (s/veh)					*9.4*			*9.3*
LOS					*A*			*A*
Approach Delay (s/veh)	--	--	*9.4*			*9.3*		
Approach LOS	--	--	*A*			*A*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*4/6/2012*
Analysis Time Period	*PM Design*

Site Information

Intersection	*Mary Street & Bitterroot Opt G*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* | North/South Street: *Bitterroot Drive*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*30*	*205*			*130*	*65*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*1.00*	*1.00*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*33*	*227*	*0*	*0*	*144*	*72*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*0*	*1*	*0*
Configuration	*L*	*T*				*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*40*		*70*			
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*40*	*0*	*70*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*						*LR*	
v (veh/h)	*33*						*110*	
C (m) (veh/h)	*1366*						*711*	
v/c	*0.02*						*0.15*	
95% queue length	*0.07*						*0.55*	
Control Delay (s/veh)	*7.7*						*11.0*	
LOS	*A*						*B*	
Approach Delay (s/veh)	--	--				*11.0*		
Approach LOS	--	--				*B*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*4/9/2012*
Analysis Time Period	*Pm Design Hour*

Site Information

Intersection	*Mary Align & Minor Connection*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street Alignments* North/South Street: *Minor Connection Road*

Intersection Orientation: *East-West* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*1*	*495*	*60*	*5*	*695*	*2*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*1*	*550*	*66*	*5*	*772*	*2*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*1*	*2*	*0*
Configuration	*L*	*T*	*TR*	*L*	*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*25*	*0*	*10*	*0*	*0*	*1*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*27*	*0*	*11*	*0*	*0*	*1*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*		*LTR*			*LTR*	
v (veh/h)	*1*	*5*		*38*			*1*	
C (m) (veh/h)	*851*	*974*		*260*			*665*	
v/c	*0.00*	*0.01*		*0.15*			*0.00*	
95% queue length	*0.00*	*0.02*		*0.50*			*0.00*	
Control Delay (s/veh)	*9.2*	*8.7*		*21.2*			*10.4*	
LOS	*A*	*A*		*C*			*B*	
Approach Delay (s/veh)	--	--	*21.2*			*10.4*		
Approach LOS	--	--	*C*			*B*		

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BILLINGS BYPASS EIS
NCPD 56(55)CN 4199

SECTION 2:
Geometric Design Report

Billings Bypass

April, 2012

MONTANA MDT DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

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GEOMETRIC DESIGN

DOWL HKM completed research on applicable design standards, and developed geometric design criteria for roadways as a part of this project. Summaries of their efforts are contained within the following memorandums and typical section drawings.

There are two memorandums included herein. The first memorandum is dated February 11, 2012 and it addresses the design standards applicable to the proposed alternative alignments associated with this project. It includes all of the alignments that were evaluated in the Draft Environmental Impact Statement (EIS). Each alignment is discussed and specific details relative to alignment length, surrounding land use, boundary conditions, functional classification, and speed limits are presented. Design standards applicable to each roadway classification under various jurisdictional controls are also detailed.

The second memorandum is dated February 22, 2012 and it deals with design criteria relative to each of the alignment alternatives. Design criteria are categorized by both Urban or Rural NHS Principal Arterial standards and the design speed is noted for each alternative alignment. Specific design elements are discussed and typical section drawings are provided for the corridor alignments.

The addition of Secondary Improvements to either Mary Street or Five Mile Road required investigations into City and County standard typical sections that would be required. Therefore, one additional drawing was added to the end of this report section that illustrates the required typical sections that would be associated with Secondary Corridor Improvements.

MEMORANDUM

TO: Laura Meyer, David Evans & Associates
Debra Perkins-Smith, David Evans & Associates

FROM: Doug Enderson, PE, PTOE DRE
DOWL HKM

DATE: February 11, 2011

RE: Design Standards Memorandum

COPIES: Todd Cormier, DOWL HKM
John Shoff, DOWL HKM
Bob Marvin, Marvin & Associates

The purpose of this memorandum is to evaluate the current alignments illustrated on the Design Analysis Map (January 2011) produced by David Evans & Associates and to determine if the MDT National Highway System (NHS) Rural Principal Arterial design criteria can be met. The MDT NHS Rural Principal Arterial design criteria has been chosen as the base design criteria for evaluation and any deviations necessary from that criteria are discussed in the following table.

The design speed for an MDT NHS Rural Principal Arterial for level terrain is 70 mph. Additional design criteria for an MDT NHS facility is detailed within the attached design criteria matrix. For comparison, the matrix also includes design criteria for local jurisdictions. Ultimately, design criteria will be established individually for each alignment. For example, the Johnson alignments connected to the Mary Street alignments would be designed with urban design criteria for the entire alignment instead of having a rural segment (M-1a or M-1b) between two urban segments.

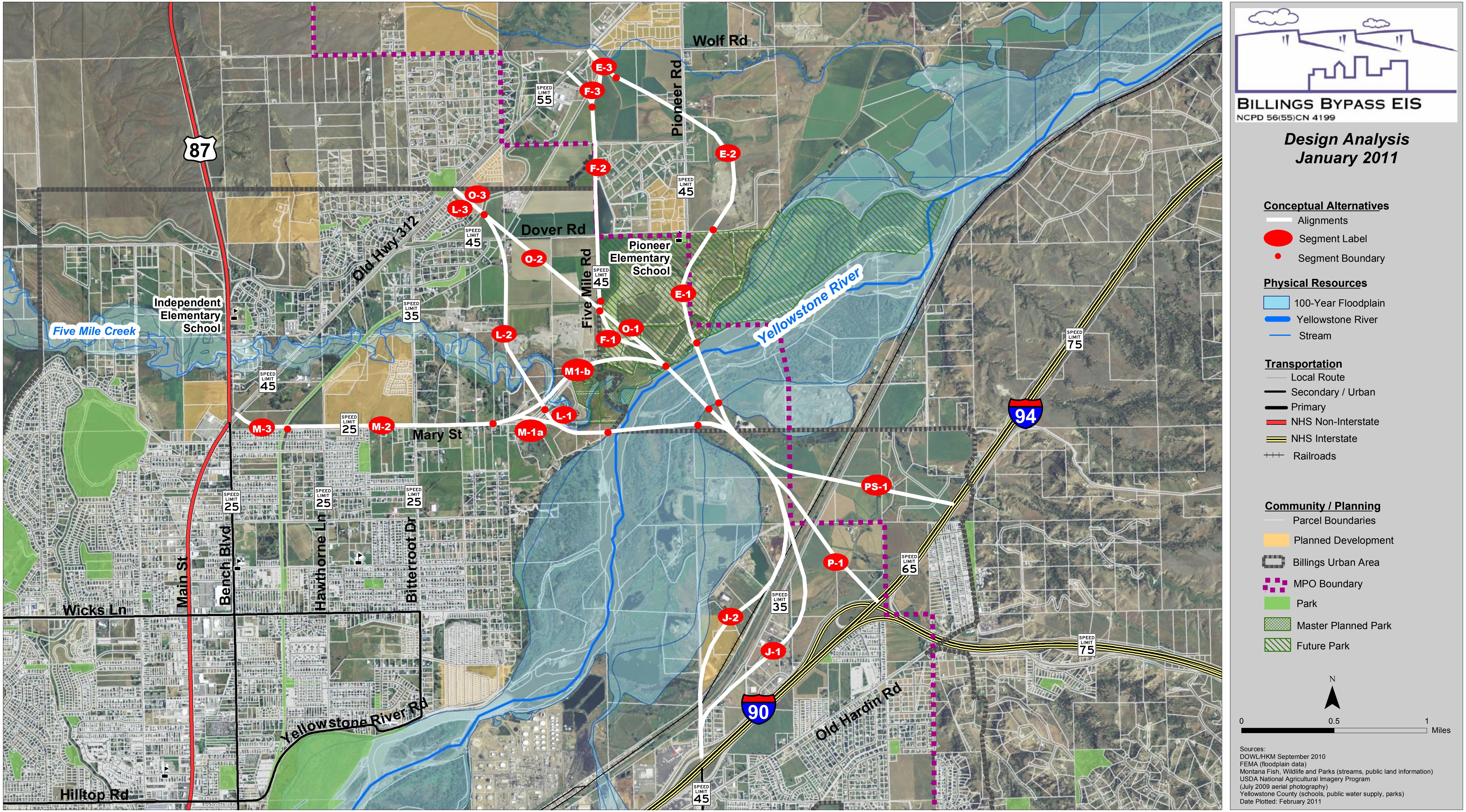
Information detailed in this memorandum will serve as the foundation for the development of the Design Criteria Memorandum, as well as the continued design and refinement of the alternatives for Activity 102.

Alignment	ID #	Design Standards Discussion
South of Yellowstone River		
Johnson Lane	J-1	The NHS Rural Principal Arterial design criteria for level terrain fit within this segment. However, the current and future commercial/industrial land use along this alignment warrants an Urban Principal Arterial design criteria to minimize right-of-way impacts and optimize access along the route. Also if the Urban Principal Arterial design criteria are considered, this alignment could be shifted to follow the existing Coulson Road alignment to further minimize right-of-way impacts and still provide access to local businesses.
	J-2	The NHS Rural Principal Arterial design criteria for level terrain fit within this segment. However, the current and future commercial/industrial land use along this alignment warrants an Urban Principal Arterial design criteria to minimize right-of-way impacts and optimize access along the route.
Pinehills Interchange	P-1	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this alignment.
Pinehills Split Interchange	PS-1	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this alignment.
Yellowstone River Crossing		
All Alignment Options		The bridge options can meet any NHS Principal Arterial design criteria. How the chosen alignment enters or departs the bridge location may dictate the exact design criteria for the bridge structure.
North of Yellowstone River		
Mary Street	M-1a	The NHS Rural Principal Arterial design criteria for level terrain (70 mph) *cannot* be met for this alignment without major impacts to Five Mile Creek and existing residential homes. The design criteria for rolling terrain (60 mph) are more desirable in this section to minimize right-of way impacts and to avoid the Five Mile Creek floodplain.
	M-1b	The NHS Rural Principal Arterial design criteria for level terrain (70 mph) *cannot* be met for this alignment without major impacts to Five Mile Creek and existing residential homes. The design criteria for rolling terrain (60 mph) are more desirable in this section to minimize right-of way impacts and to avoid the Five Mile Creek floodplain.

	M-2	The NHS Rural Principal Arterial design criteria for level terrain can be met in this section as the segment is generally straight. However, residential development currently exists south of the alignment and a subdivided residential development exists north of the alignment. Also along this segment, the current residents directly access Mary Street on the south side of the alignment. An Urban Principal Arterial design criteria is recommended for this segment because of the current and future land use and access requirements. A frontage road may be necessary for access control along this segment.
	M-3	The transition to connect to the existing Old Highway 312 is recommended as a NHS Urban Principal Arterial with a maximum design speed of 55 mph to minimize impacts (right-of-way), improve safety through controlled speed, and as the alignment will be ending at a controlled at-grade intersection at Old Highway 312.
Legacy Lane	L-1	The NHS Rural Principal Arterial design criteria for level terrain (70 mph) *cannot* be met for this segment without major impacts to Five Mile Creek. The design criteria for rolling terrain (60 mph) are more desirable in this section to minimize right-of way impacts and to avoid the Five Mile Creek floodplain.
	L-2	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this segment.
	L-3	The transition to connect to the existing Old Highway 312 is recommended as a NHS Urban Principal Arterial with a maximum design speed of 55 mph to minimize impacts (right-of-way), improve safety through controlled speed, and as the alignment will be ending at a controlled at-grade intersection at Old Highway 312.
Oxbow Park	O-1	These segments can be designed to the NHS Rural Principal Arterial design criteria for level terrain as the alignment is a relatively straight from the Yellowstone River crossing to the Old Highway 312 connection. If any horizontal curves need to be introduced, NHS Rural Principal Arterial design criteria can be accommodated.
	O-2	
	O-3	The transition to connect to the existing Old Highway 312 is recommended as a NHS Urban Principal Arterial with a maximum design speed of 55 mph to minimize impacts (right-of-way), improve safety through controlled speed, and as the alignment will be ending at a controlled at-grade intersection at Old Highway 312.
Five Mile Road	F-1	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this segment.

	F-2	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this segment.
	F-3	The transition to connect to the existing Old Highway 312 is recommended as a NHS Urban Principal Arterial with a maximum design speed of 55 mph to minimize impacts (right-of-way), improve safety through controlled speed, and as the alignment will be ending at a controlled at-grade intersection at Old Highway 312.
E1-E3	E-1	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this segment.
	E-2	The NHS Rural Principal Arterial design criteria for level terrain can be accommodated for this segment.
	E-3	The transition to connect to the existing Old Highway 312 is recommended as a NHS Urban Principal Arterial with a maximum design speed of 55 mph to minimize impacts (right-of-way), improve safety through controlled speed, and as the alignment will be ending at a controlled at-grade intersection at Old Highway 312.

Attachments: Design Analysis Map (January 2011) - Modified
Design Analysis Matrix
Design Criteria Matrix



BILLINGS BYPASS EIS
NCPD 56(55)CN 4199
Design Analysis
January 2011
Conceptual Alternatives
Alignments
Segment Label
Segment Boundary
Physical Resources
100-Year Floodplain
Yellowstone River
Stream
Transportation
Local Route
Secondary / Urban
Primary
NHS Non-Interstate
NHS Interstate
Railroads
Community / Planning
Parcel Boundaries
Planned Development
Billings Urban Area
MPO Boundary
Park
Master Planned Park
Future Park
N
0
0.5
1
Miles
Sources:
DOWL/HKM September 2010
FEMA (floodplain data)
Montana Fish, Wildlife and Parks (streams, public land information)
USDA National Agricultural Imagery Program
(July 2009 aerial photography)
Yellowstone County (schools, public water supply, parks)
Date Plotted: February 2011
Wolf Rd
Pioneer Rd
Dover Rd
Five Mile Rd
Old Hwy 312
Pioneer
Elementary
School
Independent
Elementary
School
Five Mile Creek
Yellowstone River
Mary St
Main St
Bench Blvd
Hawthorne Ln
Bitterroot Dr
Wicks Ln
Hilltop Rd
Yellowstone River Rd
Old Hardin Rd
87
94
90
E-3
F-3
E-2
F-2
O-3
L-3
O-2
E-1
L-2
O-1
F-1
M1-b
L-1
M-1a
M-3
M-2
PS-1
P-1
J-2
J-1
SPEED LIMIT 55
SPEED LIMIT 45
SPEED LIMIT 35
SPEED LIMIT 25
SPEED LIMIT 75
SPEED LIMIT 65

Alignment	Segment Information			Character of Surrounding Area				Connecting Streets		
	ID Number	Description	Length (in miles)	Within MPO	Within Urban Area Boundary	Current Land Use (Based on 2009 Aerial Mapping)	Zoning	City/County Functional Classification	MDT Functional Classification	Speed Limits
South of Yellowstone River										
Johnson Ln	J-1	Interstate to Yellowstone River floodplain (south option)	2.4	Yes	Yes	Agricultural / Industrial	Commercial/ Agricultural/ Industrial	Coulson Rd - Local Johnson Ln - Principal Arterial	Coulson Rd - Local Johnson Ln - Minor Arterial I-90 - Interstate Principal Arterial	Coulson Rd - 35 Johnson Ln - 45 I-90 - 65
	J-2	Interstate to Yellowstone River floodplain (north option)	2	Yes	Yes	Agricultural	Commercial/ Agricultural/ Industrial	Coulson Rd - Local Johnson Ln - Principal Arterial	Coulson Rd - Local Johnson Ln - Minor Arterial I-90 - Interstate Principal Arterial	Coulson Rd - 35 Johnson Ln - 45 I-90 - 65
Pinehills	P-1	Interstate to Yellowstone River floodplain	1.38	Yes	Yes	Agricultural	Agricultural	Coulson Rd - Local I-94 -Interstate	Coulson Rd - Local I-94 -Interstate Principal Arterial I-90 - Interstate Principal Arterial	Coulson Rd - 35 I-90 - 65 I-94 - 65
Pinehills Split	PS-1	Interstate to Yellowstone River floodplain	1.43	Yes	Yes	Agricultural	Agricultural	Coulson Rd - Local I-94 - Interstate I-90 - Interstate	Coulson Rd - Local I-94 - Interstate Principal Arterial I-90 - Interstate Principal Arterial	Coulson Rd - 35 I-90 - 65 I-94 - 65
Yellowstone River Crossing										
All Alignment Options	NA	Yellowstone River Floodplain	0.3 - 0.5	Yes	No	Floodplain	Agricultural	NA	NA	NA
North of Yellowstone River										
Mary Street	M-1a	Yellowstone River floodplain to residential area (south option)	1.1	Yes	Yes	Agricultural / Low Density Residential	Agricultural	Mary St - Principal Arterial Five Mile Rd - Minor Arterial Flaming Creek - Local	Mary St - Urban Collector Five Mile Rd - Local Flaming Creek - Local	Mary St - 45 Five Mile Rd - 35 Flaming Creek - 25
	M1-b	Yellowstone River floodplain to residential area (north option)	1.5	Yes	Yes	Agricultural / Low Density Residential	Agricultural	Mary St - Principal Arterial Five Mile Rd - Minor Arterial	Mary St - Urban Collector Five Mile Rd - Local	Mary St - 45 Five Mile Rd - 35
	M-2	Residential area to 312 transition	0.72	Yes	Yes	Residential / Agricultural	Residential / Agricultural	Mary St - Principal Arterial Bitterroot Dr - Principal Arterial Columbine Dr - Local Hawthorne Ln - Local	Mary St - Urban Collector Bitterroot Dr - Urban Collector (south) Bitterroot Dr - Local (north) Columbine Dr - Local Hawthorne Ln - Local	Mary St - 45 Bitterroot Dr - 25 Columbine Dr - 25 Hawthorne Ln - 25
	M-3	Transition to Old Hwy 312	0.25	Yes	Yes	Residential/ Agricultural	Agricultural/ Residential/ Commercial	Old Hwy 312 - US Hwy	Old Hwy 312 - Minor Arterial	Old Hwy 312 - 45
Legacy Lane	L-1	Yellowstone River floodplain to Mary Street	0.37	Yes	Yes	Agricultural	Agricultural	Five Mile Rd - Minor Arterial	Five Mile Rd - Local	Five Mile Rd - 35
	L-2	Mary Street to Old Hwy 312 transition	1.16	Yes	Yes	Agricultural / Low Density Residential	Agricultural/ Suburban Agricultural/ Residential	Five Mile Rd - Minor Arterial Dover Rd - Minor Arterial	Five Mile Rd - Local Dover Rd - Local	Five Mile Rd - 35 Dover Rd - 45
	L-3	Transition to Old Hwy 312	0.25	Yes	No	Residential	Residential	Old Hwy 312 - US Hwy	Old Hwy 312 - Minor Arterial	Old Hwy 312 - 55
Oxbow Park	O-1	Yellowstone River floodplain to Five Mile Road	0.47	Yes	No	Mining (Future Park)	Agricultural	NA	NA	NA
	O-2	Five Mile Road to 312 transition	0.78	Yes	Yes	Agricultural	Agricultural	Dover Rd - Minor Arterial Five Mile Rd - Minor Arterial	Dover Rd - Local Five Mile Rd - Local	Dover Rd - 45 Five Mile Rd - 45
	O-3	Transition to Old Hwy 312	0.25	Yes	Yes	Residential	Residential	Old Hwy 312 - US Hwy	Old Hwy 312 - Minor Arterial	Old Hwy 312 - 55
Five Mile Road	F-1	Yellowstone River floodplain to Five Mile Road	0.54	Yes	No	Mining (Future Park)	Agricultural	Five Mile Rd - Minor Arterial	Five Mile Rd - Local	Five Mile Rd - 45
	F-2	Five Mile Road to 312 transition	1.57	Partial	On border	Agricultural	Agricultural/ Beyond Zoning Limits	Dover Rd - Minor Arterial	Dover Rd - Local	Dover Rd - 45
	F-3	Transition to Old Hwy 312	0.25	No	No	Agricultural / Low Density Residential	Beyond Zoning Limits	Old Hwy 312 - US Hwy	Old Hwy 312 - Minor Arterial	Old Hwy 312 - 55
E1-E3	E-1	Yellowstone River floodplain to Dover Road	0.65	Partial	No	Mining (Future Park)	Agricultural/ Beyond Zoning Limits	Dover Rd - Minor Arterial	Dover Rd - Local	Dover Rd - 45
	E-2	Dover Road to 312 transition	1.2	No	No	Agricultural	Beyond Zoning Limits	Pioneer Rd - Minor Arterial Dover Rd - Minor Arterial	Pioneer Rd - Local Dover Rd - Local	Pioneer Rd - 45 Dover Rd - 45
	E-3	Transition to Old Hwy 312	0.25	No	No	Agricultural / Low Density Residential	Beyond Zoning Limits	Old Hwy 312 - US Hwy	Old Hwy 312 - Minor Arterial	Old Hwy 312 - 55

Design Elements	MDT			City of Billings	Yellowstone County
	Bypass Mainline - Rural	Bypass Mainline - Urban	Bypass Mainline - Urban		
Design Standards	NHS - Rural Principal Arterial (MDT Traffic Engr. Manual)	NHS - Urban Principal Arterial (MDT Traffic Engr. Manual)	Non-NHS Urban Principal Arterial[2]	Subdivision Regulations, AASHTO	Subdivision Regulations, AASHTO
Lanes	2 - 4 lanes	4 lanes plus center turn lane	4 lanes plus center turn lane	4 lanes plus center turn lane	4 lanes plus center turn lane
Design Speed	Level = 70mph Rolling = 60 mph Mountainous = 50 mph	40 - 55 mph (Uncurbed, Multi-lane)	40 mph	–	–
Vertical Grade (max)	Level = 3% Rolling = 4% Mountainous = 7%	Level = 6% (40-50mph), 5% (55mph) Rolling = 7% (40-50mph), 6% (55mph) Mountainous = 9% (40-50mph), 8% (55mph)	7% max grade (desirable) 10% max grade (with approval)	Per AASHTO	Per AASHTO
Superelevation	e_{max} = 8%	40-45 mph: e_{max} = 4% 50-55 mph: e_{max} = 8%	e_{max} = 4%	Per AASHTO	Per AASHTO
Vertical Curve (Sag)	Level: K = 96 Rolling: K = 136 Mountainous: K = 181	40 mph: K = 64 45 mph: K = 79 50 mph: K = 96 55 mph: K = 115	K = 64 (desirable)	Per AASHTO	Per AASHTO
Vertical Curve (Crest)	Level: K = 84 Rolling: K = 151 Mountainous: K = 247	40 mph: K = 44 45 mph: K = 61 50 mph: K = 84 55 mph: K = 114	K = 44 (desirable)	Per AASHTO	Per AASHTO
Horizontal Curve (min)	Level = 1810 ft at e_{max} Rolling = 1200 ft at e_{max} Mountainous = 758 ft at e_{max}	40 mph = 533' 45 mph = 711' 50 mph = 760' 55 mph = 960'	533 ft. (40 mph @ e_{max})	Per AASHTO	Per AASHTO
Access Control	Limited Control of Access at discretion of MDT	Limited Control of Access at discretion of MDT	Limited Control of Access at discretion of MDT	–	–
Right of Way Requirements					
R/W Width	160 ft. (min.)[3] (80 ft. from C.L. each side)	160 ft. (min.)[3] (80 ft. from C.L. each side)	140 ft. (approx.)[3] (70 ft. from C.L. each side)	130 ft. Desired	120 ft. Desired
Typical Section Elements					
Driving Lane	12 ft.	4 at 12-ft; Turn Lane at 16 ft.	12' Outside, 11' Inside, 12' Turn Lane	14 ft. TWLTL; 11 ft. inside; 12 ft. outside	14 ft. TWLTL; 12 ft. inside; 14 ft. outside
Shoulder	8 ft.	8 ft.	6 ft.	Shoulder project specific 10 ft. boulevard	
Stormwater	Roadside ditches	Project Specific	Project Specific	Project Specific	Roadside ditches or project specific
Roadway Width	40 ft., Two Lane (min.) or project specific	80 ft.	70 ft.	64 - 86 ft.	92 ft.
Bicycles	Provided on shoulder (no striped bike lane)	Project Specific	4 ft. (minimum) 5 ft. (desirable)	Bike lanes (case-by-case) [1]	Bike lanes (case-by-case) [1]
Sidewalk	NA	5 - 10 ft.	5 ft.	5 ft. & 10 ft. (Min.) 10 ft. & 10 ft. (Desired)	5 ft.
Median	As Required 14 ft. (min); 50 ft. (desireable)	TWLTL or project specific	4 ft. (raised) (min.)	–	–
Cross Slope	2% Crown (typical)	2% Crown (typical)	1.5% (minimum) 2% (desirable)	2% Crown (typical)	2% Crown (typical)
Frontage Road	–	–	–	–	–

[1] Based on current update to Billings Area Bikeway and Trail Master Plan Draft Report (Jan 2011)
[2] From the *Montana Department of Transportation Geometric Design Standards for Urban and Developed Areas*
[3] Final rightof-way width will contain all design elements plus 10 feet.

M E M O R A N D U M

TO: Laura Meyer, David Evans & Associates
Debra Perkins-Smith, David Evans & Associates

FROM: Doug Enderson, PE, PTOE DRE
DOWL HKM

DATE: February 22, 2011

RE: Design Criteria Technical Memorandum

COPIES: Todd Cormier, DOWL HKM
John Shoff, DOWL HKM
Bob Marvin, Marvin & Associates

INTRODUCTION

The Billings North Bypass Feasibility Study, NCPD 56(42) CN 4199, was completed in 2001. Initially, the bypass route was planned to connect the I-90/94 interchange area east of Billings with N-53 (MT 3) northwest of Billings. This route would also serve local traffic by providing an alternative route for local traffic traversing eastern and northeastern portions of the city. This study concluded that a bypass was feasible from an economic and engineering perspective and should be advanced for environmental analysis and refinement. In 2010, the scope of the project was amended to study a bypass connecting the I-90/94 interchange area east of Billings with Old Highway 312.

An environmental impact statement (EIS) is now being prepared toward the continued development of the bypass. For design purposes associated with the EIS, this Design Criteria Technical Memorandum is being prepared to identify the appropriate geometric design criteria applicable to each classification of roadway and corresponding alignment segment to be included within the project boundary. On February 11, 2011 a design standards memorandum was completed and submitted to the Montana Department of Transportation (MDT) as an initial screening of the design criteria used for each bypass alternative. MDT and FHWA approved the design standards memorandum in a teleconference discussion on February 17, 2011. The design criteria identified in that memorandum will be reiterated and expanded upon in this document and ultimately serve as the basis for preliminary design throughout the EIS process.

EXISTING CONDITIONS

Currently, no portion of a bypass exists as a functional roadway or as undeveloped right-of-way for the purpose of future development of a bypass, although some elements or portions of existing roadways and right-of-way within the study area may be utilized for the development of the final alignment.

EVALUATION GUIDELINES

Design criteria are based on current MDT design guidelines as detailed within the MDT Road Design Manual, and corresponding design manuals. A design criteria matrix was created for initial evaluation purposes for the design standards memorandum. That matrix included MDT design standards and for purposes of comparison, also included Yellowstone County and City of Billings design standards. The matrix is attached to this memorandum for information purposes.

The following table summarizes the design criteria identified in the design standards memorandum and was approved by MDT. The attached figure identifies the locations of the alignment segments corresponding to the ID# in the table below:

Alignment	ID #	MDT Design Criteria	Proposed Design Speed
South of Yellowstone River			
Johnson Lane	J-1	NHS Urban Principal Arterial	55 mph
	J-2	NHS Urban Principal Arterial	55 mph
Pinehills Interchange	P-1	NHS Rural Principal Arterial	70 mph
Pinehills Split Interchange	PS-1	NHS Rural Principal Arterial	70 mph
Yellowstone River Crossing			
All Alignment Options		The bridge options can meet any NHS Principal Arterial design criteria. How the chosen alignment enters or departs the bridge location may dictate the exact design criteria for the bridge structure.	
North of Yellowstone River			
Mary Street	M-1a	NHS Rural Principal Arterial	60 mph
	M-1b	NHS Rural Principal Arterial	60 mph
	M-2	NHS Urban Principal Arterial	55 mph

	M-3	NHS Urban Principal Arterial	55 mph
Legacy Lane	L-1	NHS Rural Principal Arterial	60 mph
	L-2	NHS Rural Principal Arterial	70 mph
	L-3	NHS Urban Principal Arterial	55 mph
Oxbow Park	O-1	NHS Rural Principal Arterial	70 mph
	O-2		
	O-3	NHS Urban Principal Arterial	55 mph
Five Mile Road	F-1	NHS Rural Principal Arterial	70 mph
	F-2	NHS Rural Principal Arterial	70 mph
	F-3	NHS Urban Principal Arterial	55 mph
E1-E3	E-1	NHS Rural Principal Arterial	70 mph
	E-2	NHS Rural Principal Arterial	70 mph
	E-3	NHS Urban Principal Arterial	55 mph

The design criteria identified in the table above are the maximum criteria to be used for each segment. Ultimately, design criteria will be established individually for each alignment once the preferred alignment is chosen for final evaluation. For example, the Johnson Lane alignments connected to the Mary Street alignments would be designed with urban design criteria for the entire alignment instead of having a rural segment (M-1a or M-1b) between two urban segments (M-2 and J-1 or J-2).

DESIGN ELEMENTS

Vertical/Horizontal Geometry: Vertical profiles and horizontal alignments will be developed based on the design criteria presented herein, and will be evaluated based on standard design guidelines and project constraints including basic design parameters (design speed, minimum radii, K-values, etc.), utility locations, environmental and social considerations, right-of-way, and minimizing impacts overall. Two-foot contour mapping of the corridor will be used to determine the vertical and horizontal elements of each alignment identified on the alternatives map.

Typical Sections: Typical sections for each of the design criteria alternatives discussed above are provided as attachments to this report. These typical sections are not intended to comprise all instances within the project corridor, but rather are intended to depict the typical sections on which the various roadway segments will be evaluated. Additional typical sections may be necessary as the project progresses.

Cut/Fill Slopes: Cut and fill slopes will follow standard MDT cut and fill slope criteria. Standard slopes are provided on the typical section sheet and the design criteria matrix attached to this memorandum.

Right-of-Way: Standard MDT policy regarding right-of-way is to acquire “sufficient, but not excessive, width to accommodate construction and maintenance operations” including all travel lanes, shoulders, slopes, median, and clear zones. Standard MDT practice is to acquire the minimum amount of right-of-way necessary to contain the roadway construction limits plus a 10-foot buffer. Minimum right-of-way requirements are identified on the design criteria matrix and the typical sections exhibit. Additional right-of-way beyond these minimum widths will be considered as necessary for bridge structures, slopes, ramps, or intersections as determined through the planning and design process.

Bicycle/Pedestrian Facilities: The State of Montana allows bicycle travel on state highways and freeways through Montana Code Annotated (MCA) Title 61 Chapter 8 Part 6, which states:

> *Every person operating a bicycle shall be granted all of the rights and shall be subject to all of the duties applicable to the driver of any other vehicle by chapter 7, this chapter, and chapter 9 except as to special regulations in this part and except as to those provisions of chapter 7, this chapter, and chapter 9 which by their very nature can have no application.*

Because bicycle travel on Montana highways and freeways is allowed, the Montana Department of Transportation (MDT) does not have a comprehensive program to design and install recreational facilities (shared-use detached bike paths). As such, the current highway standard of an 8-foot shoulder is considered adequate to accommodate bicycle travel.

The 2010 Administrative Draft of the Billings Area Bikeway and Trail Master Plan identifies a number of routes within the study corridor as bike routes. Mary Street, Dover Road, and Five Mile Road are classified as primary bike routes; Old Highway 312, Bitterroot Drive and Johnson Lane are classified as arterial bike routes; Coulson Road is classified as a secondary bike route; and a multi-use trail currently terminates at Mary Street between Bench Boulevard and Hawthorne Lane with future plans to cross Mary Street. Due to the existing and planned locations of bicycle and pedestrian facilities within the study corridor, consideration should be given to underpass or overpass facilities along the bypass. The inclusion of overpass or underpass facilities is also supported by MDT as a means of maintaining the safe movement of pedestrians and bicyclists across MDT facilities.

The inclusion of bicycle facilities along each alignment is not included in the base typical sections at this time. However, bicycle facilities will be considered during the next phase of the planning process.

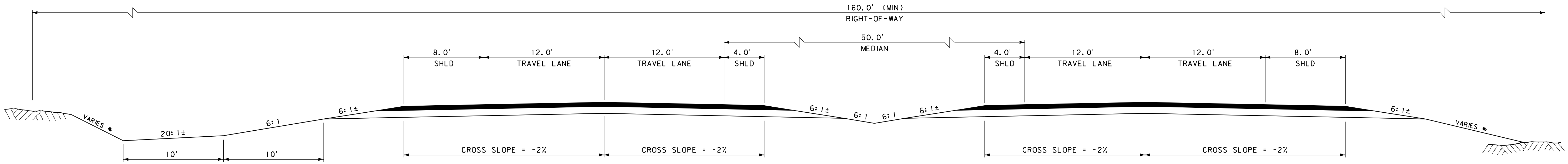
SUMMARY

This document is intended to identify a set of typical design standards to be incorporated within the planning and design throughout the EIS process. It should be noted, however, that modifications to the standard design criteria may occur through the design process as required or as necessary to develop a viable design based on obstacles encountered in within the study area. Furthermore, actual right-of-way widths necessary to develop the facility will vary from the typical widths identified in this memorandum.

Attachments: Typical Section Exhibit
Design Criteria Matrix
Design Analysis Map (January 2011)

NHS RURAL PRINCIPAL ARTERIAL

DESIGN SPEED: 70 MPH (FLAT TERRAIN), 60 MPH (ROLLING TERRAIN)

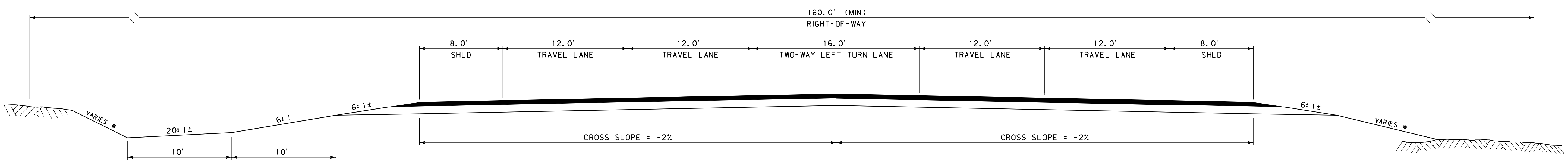


* FILL SLOPES	
0' - 10'	6:1
10' - 20'	4:1
20' - 30'	3:1
OVER 30'	2:1

* BACK SLOPES	
0' - 5'	5:1
5' - 10'	4:1
10' - 15'	3:1
15' - 20'	2:1
OVER 20'	1.5:1

NHS URBAN PRINCIPAL ARTERIAL

DESIGN SPEED: 55 MPH

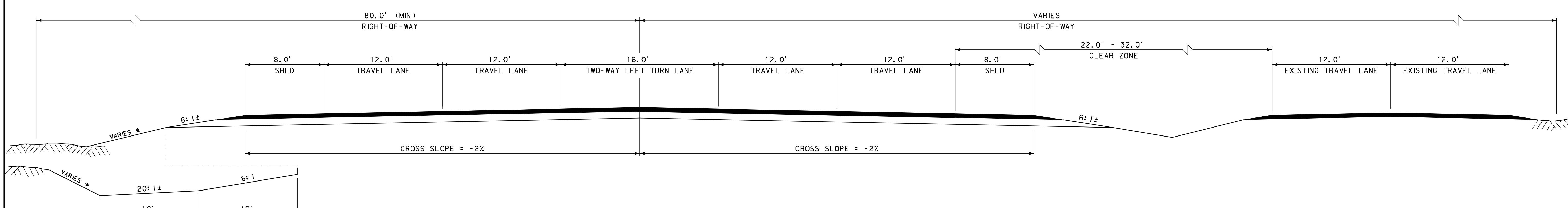


* FILL SLOPES	
0' - 10'	6:1
10' - 20'	4:1
20' - 30'	3:1
OVER 30'	2:1

* BACK SLOPES	
0' - 5'	5:1
5' - 10'	4:1
10' - 15'	3:1
15' - 20'	2:1
OVER 20'	1.5:1

NHS URBAN PRINCIPAL ARTERIAL WITH FRONTAGE ROAD

DESIGN SPEED: 55 MPH



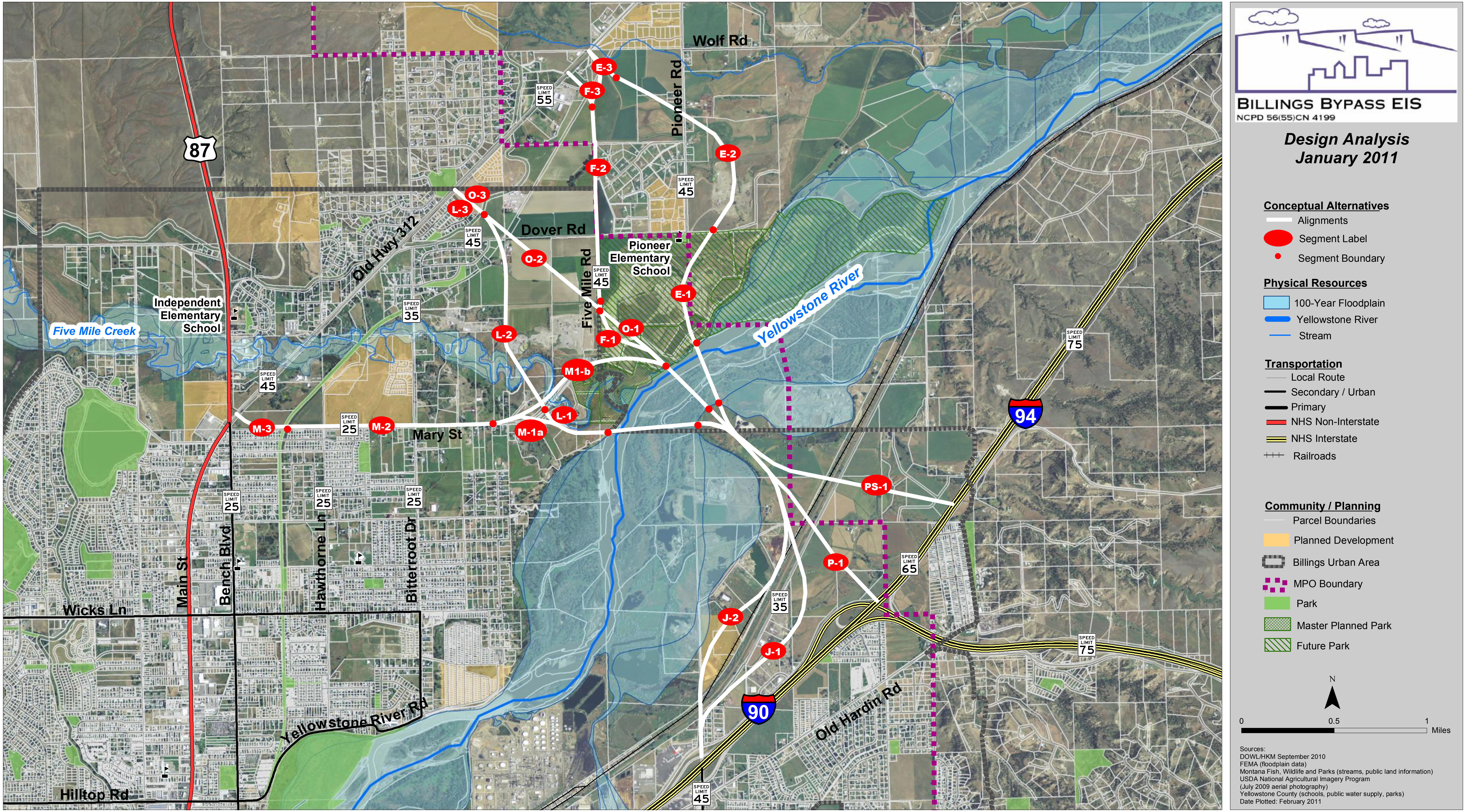
DOWL HKM

3	MDT MONTANA DEPARTMENT OF TRANSPORTATION	...\03\4199\rd\4199rdtypz01.dgn	DESIGNED BY		
2		2/21/2011	REVIEWED BY		
1		11:59:00 AM Doug.Enderson	CHECKED BY		

Billings Bypass Design Criteria

Design Elements	MDT			City of Billings	Yellowstone County
	Bypass Mainline - Rural	Bypass Mainline - Urban	Bypass Mainline - Urban		
Design Standards	NHS - Rural Principal Arterial (MDT Traffic Engr. Manual)	NHS - Urban Principal Arterial (MDT Traffic Engr. Manual)	Non-NHS Urban Principal Arterial[2]	Subdivision Regulations, AASHTO	Subdivision Regulations, AASHTO
Lanes	2 - 4 lanes	4 lanes plus center turn lane	4 lanes plus center turn lane	4 lanes plus center turn lane	4 lanes plus center turn lane
Design Speed	Level = 70mph Rolling = 60 mph Mountainous = 50 mph	40 - 55 mph (Uncurbed, Multi-lane)	40 mph	–	–
Vertical Grade (max)	Level = 3% Rolling = 4% Mountainous = 7%	Level = 6% (40-50mph), 5% (55mph) Rolling = 7% (40-50mph), 6% (55mph) Mountainous = 9% (40-50mph), 8% (55mph)	7% max grade (desirable) 10% max grade (with approval)	Per AASHTO	Per AASHTO
Superelevation	e_{max} = 8%	40-45 mph: e_{max} = 4% 50-55 mph: e_{max} = 8%	e_{max} = 4%	Per AASHTO	Per AASHTO
Vertical Curve (Sag)	Level: K = 96 Rolling: K = 136 Mountainous: K = 181	40 mph: K = 64 45 mph: K = 79 50 mph: K = 96 55 mph: K = 115	K = 64 (desirable)	Per AASHTO	Per AASHTO
Vertical Curve (Crest)	Level: K = 84 Rolling: K = 151 Mountainous: K = 247	40 mph: K = 44 45 mph: K = 61 50 mph: K = 84 55 mph: K = 114	K = 44 (desirable)	Per AASHTO	Per AASHTO
Horizontal Curve (min)	Level = 1810 ft at e_{max} Rolling = 1200 ft at e_{max} Mountainous = 758 ft at e_{max}	40 mph = 533' 45 mph = 711' 50 mph = 760' 55 mph = 960'	533 ft. (40 mph @ e_{max})	Per AASHTO	Per AASHTO
Access Control	Limited Control of Access at discretion of MDT	Limited Control of Access at discretion of MDT	Limited Control of Access at discretion of MDT	–	–
Right of Way Requirements					
R/W Width	160 ft. (min.)[3] (80 ft. from C.L. each side)	160 ft. (min.)[3] (80 ft. from C.L. each side)	140 ft. (approx.)[3] (70 ft. from C.L. each side)	130 ft. Desired	120 ft. Desired
Typical Section Elements					
Driving Lane	12 ft.	4 at 12-ft; Turn Lane at 16 ft.	12' Outside, 11' Inside, 12' Turn Lane	14 ft. TWLTL; 11 ft. inside; 12 ft. outside	14 ft. TWLTL; 12 ft. inside; 14 ft. outside
Shoulder	Outside = 8 ft. Inside = 4 ft.	Outside = 8 ft.	Outside = 6 ft.	Shoulder project specific 10 ft. boulevard	
Stormwater	Roadside ditches	Project Specific	Project Specific	Project Specific	Roadside ditches or project specific
Roadway Width	40 ft., Two Lane (min.) or project specific	80 ft.	70 ft.	64 - 86 ft.	92 ft.
Bicycles	Provided on shoulder (no striped bike lane)	Project Specific	4 ft. (minimum) 5 ft. (desirable)	Bike lanes (case-by-case) [1]	Bike lanes (case-by-case) [1]
Sidewalk	NA	5 - 10 ft.	5 ft.	5 ft. & 10 ft. (Min.) 10 ft. & 10 ft. (Desired)	5 ft.
Median	As Required 14 ft. (min); 50 ft. (desireable)	TWLTL or project specific	4 ft. (raised) (min.)	–	–
Cross Slope	2% Crown (typical)	2% Crown (typical)	1.5% (minimum) 2% (desirable)	2% Crown (typical)	2% Crown (typical)
Frontage Road	–	–	–	–	–

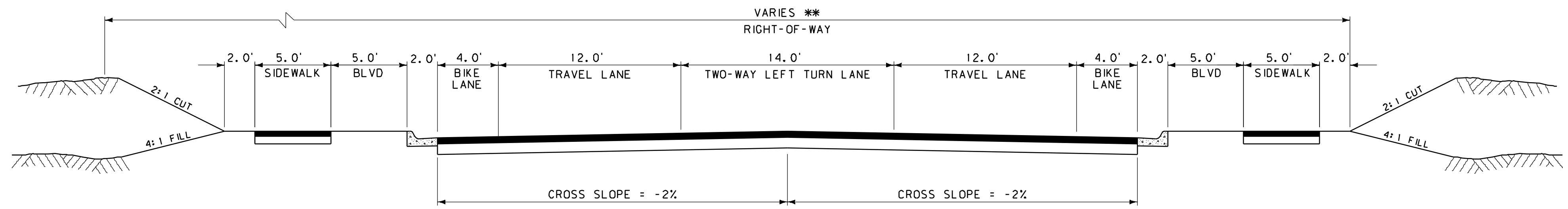
[1] Based on current update to Billings Area Bikeway and Trail Master Plan Draft Report (Jan 2011)
[2] From the *Montana Department of Transportation Geometric Design Standards for Urban and Developed Areas*
[3] Final rightof-way width will contain all design elements plus 10 feet.


BILLINGS BYPASS EIS
NCPD 56(55)CN 4199
Design Analysis
January 2011
Conceptual Alternatives
Alignments
Segment Label
Segment Boundary
Physical Resources
100-Year Floodplain
Yellowstone River
Stream
Transportation
Local Route
Secondary / Urban
Primary
NHS Non-Interstate
NHS Interstate
Railroads
Community / Planning
Parcel Boundaries
Planned Development
Billings Urban Area
MPO Boundary
Park
Master Planned Park
Future Park
N
0
0.5
1
Miles
Sources:
DOWL/HKM September 2010
FEMA (floodplain data)
Montana Fish, Wildlife and Parks (streams, public land information)
USDA National Agricultural Imagery Program
(July 2009 aerial photography)
Yellowstone County (schools, public water supply, parks)
Date Plotted: February 2011
Wolf Rd
Pioneer Rd
Dover Rd
Five Mile Rd
Old Hwy 312
Pioneer Elementary School
Independent Elementary School
Five Mile Creek
Yellowstone River
Mary St
Main St
Bench Blvd
Hawthorne Ln
Bitterroot Dr
Wicks Ln
Yellowstone River Rd
Hilltop Rd
Old Hardin Rd
87
94
90
E-3
F-3
E-2
F-2
O-3
L-3
O-2
E-1
O-1
F-1
L-2
M1-b
L-1
M-1a
M-3
M-2
PS-1
P-1
J-2
J-1
SPEED LIMIT 55
SPEED LIMIT 45
SPEED LIMIT 35
SPEED LIMIT 25
SPEED LIMIT 75
SPEED LIMIT 65

SECONDARY CORRIDOR IMPROVEMENTS

MARY STREET

CITY OF BILLINGS – PRINCIPAL ARTERIAL
PROJECTED 2035 ADT = 9500 VPD



** PER CURRENT CITY OF BILLINGS SUBDIVISION REGULATIONS:
PRINCIPAL ARTERIAL = 130'
MINOR ARTERIAL = 100'

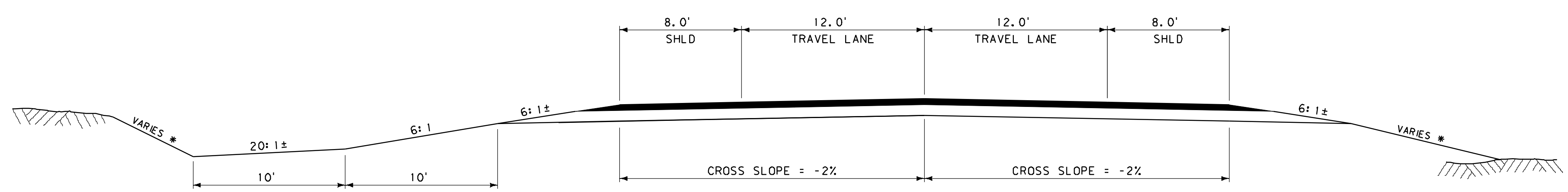
* FILL SLOPES	
0' - 10'	6:1
10' - 20'	4:1
20' - 30'	3:1
OVER 30'	2:1

* BACK SLOPES	
0' - 5'	5:1
5' - 10'	4:1
10' - 15'	3:1
15' - 20'	2:1
OVER 20'	1.5:1

DOWL HKM

FIVE MILE ROAD

RURAL COLLECTOR ROAD
DESIGN SPEED: 60 MPH (FLAT TERRAIN)
PROJECTED 2035 ADT = 5100 VPD



BILLINGS BYPASS EIS
NCPD 56(55)CN 4199

SECTION 3:
Traffic Signal Warrant Study Report

Billings Bypass

April, 2012

MONTANA MDT DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

Table of Contents

List of Tables

INTRODUCTION

This report summarizes traffic signal warrant analysis for intersections associated with the three preliminary alignment alternatives contained within the Draft Environment Impact Statement (EIS). Intersections investigated for traffic signal warrants include those intersections along the alternative alignment and those along the secondary improvement roadways. The alternative alignments and secondary improvement roadways listed below have been described within the Preliminary Traffic Study:

Mary Street Alignment Option 1 with Secondary Improvements to Five Mile Road
Mary Street Alignment Option 2 with Secondary Improvements to Five Mile Road
Five Mile Road Alignment with Secondary Improvements to Mary Street

Since there is less than 3% difference in year 2035 traffic projections between the Mary Street Alignment Options 1 and 2, traffic signal warrant analysis was based on Mary Street Alignment Option1 traffic projections and the intersections contained within this report refer to the Mary Street Option 1 & 2 Alignment. The signal warrant results can be applied to either of the Mary Street Alignments.

The intersections detailed within this report are limited to existing intersections that are not currently signalized and future intersections that would not operate at acceptable levels of service under year 2035 traffic loadings with stop control. Specific intersections that were excluded from the warrant analysis are discussed in the next section of this report.

The signal warrant calculations were based upon applicable warrants contained within the Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, 2009 Edition. Those warrants not considered to be applicable to most of the intersections included herein are: Warrant #4 - Pedestrian Volumes, Warrant #5 – School Crossing, Warrant #6 – Coordinated Signal System, Warrant # 7 – Crash Experience, Warrant # 8 – Roadway Network, and Warrant # 9 – Railroad Crossing Proximity. Warrants #1 – Eight-hour Vehicular Volume, Warrant #2 – Four-hour Vehicular Volume, and Warrant #3 – Peak Hour Traffic are applicable to all of the intersections.

Comparisons between non-signalized and signalized capacity are made for all of intersections contained within this report. Justification of traffic signal installation is discussed and alternative traffic control measures, such as 4-way stop control and roundabouts, are evaluated for safety, efficiency, and overall practicality. General design recommendations for each intersection conclude this report.

ALTERNATIVE ALIGNMENT INTERSECTIONS

Table 1 lists all of the alternative alignment intersections and their traffic control status associated with year 2035 traffic volume projections. Two of the intersections are currently signalized and at one intersection (US 87/Old Hwy 312/Bench/Main) a signal is currently being designed as part of the Bench Boulevard reconstruction project.

Table 1. Year 2035 Traffic Control Status - Alignment Intersections

Intersections	Currently Signalized	Two-way Stop LOS > C	Signal Warrant Analysis Req'd
MARY ST. ALIGNMENT OPTIONS 1 & 2:			
US 87/Old Hwy 312/Bench/Main Street	In Design		
Mary St. Alignment & Hawthorne		Stop Hawthorne	
Mary Street & Hawthorne		Stop Hawthorne	
Mary St. Alignment & Bitterroot Dr.			This Study
Mary Street & Bitterroot Drive		Stop Mary	
Old Hwy 312 & Five Mile Road Ext.			This Study
Five Mile Road & Dover Road		Stop Dover	
Mary St. Alignment & Five Mile Road			This Study
Mary St. Alignment & Coulson Road		Stop Coulson	
Mary St. Alignment & Johnson Lane		Stop Johnson	
Johnson Lane & N. Frontage Rd.			This Study
Johnson Ln. & I-90 WB Ramps			This Study
Johnson Ln. & I-90 EB Ramps	Existing		
Johnson Lane & Old Hardin Road	Existing		
FIVE MILE ROAD ALIGNMENT:			
US 87/Old Hwy 312/Bench/Main Street	In Design		
Mary Street & Hawthorne		Stop Hawthorne	
Mary Street & Bitterroot Drive			This Study
Old Hwy 312 & Five Mile Road Align.			This Study
Five Mile Road Align. & Dover Road		Stop Dover	
Five Mile Road Align. & Mary Street			This Study
Five Mile Road Align. & Coulson Rd.		Stop Coulson	
Five Mile Road Align. & Johnson Lane		Stop Johnson	
Johnson Lane & N. Frontage Rd.			This Study
Johnson Ln. & I-90 WB Ramps			This Study
Johnson Ln. & I-90 EB Ramps	Existing		
Johnson Lane & Old Hardin Road	Existing		

Intersections along the alignment alternatives that would operate at acceptable levels of service with stop control on the minor intersection legs are:

Hawthorne Lane & Mary Street	Stop on Hawthorne
Hawthorne Lane & Mary Alignments	Stop on Hawthorne
Bitterroot Drive & Mary Street - Mary Alignments	Stop on Mary Street
Five Mile Road & Dover Road	Stop on Dover Road
Coulson Road & New Project Alignment	Stop on Coulson Road
Johnson Lane & New Project Alignment	Stop on Johnson Lane

The ten intersections that are included in the signal warrant analysis and summarized within this report are:

Mary Street Alignment Options 1 and 2 Intersections:

Old Hwy 312 & Five Mile Road Secondary Improvements
Bitterroot Drive & Mary Street Options 1 & 2 Alignment
Five Mile Road & Mary Street - Options 1 & 2 Alignment
Johnson Lane & North Frontage Road - Mary Street Options 1 & 2 Alignment
Johnson Lane & WB I-90 Ramps - Mary Street Options 1 & 2 Alignment

Five Mile Road Alignment Intersections:

Old Hwy 312 & Five Mile Road Alignment
Bitterroot Drive & Mary Street - Secondary Improvements
Five Mile Road (Mary Street) & Five Mile Road Alignment
Johnson Lane & North Frontage Road - Five Mile Road Alignment
Johnson Lane & WB I-90 Ramps - Five Mile Road Alignment

NON-SIGNALIZED INTERSECTION OPERATIONS

Year 2035 design hour traffic projections for the warrant study intersections were used to determine measures of effectiveness (MOEs) that would result if the intersections were to operate with stop control. Table 1 present a summary of level-of-service (LOS) and delay, in terms of seconds per vehicle, for each approach leg of the intersection. Capacity calculations for non-signalized conditions can be found in Appendix 1 of this report. For purposes of design, any LOS less than "C" would be considered unacceptable. Table 2 indicates that all of the study intersection would have at least one approach leg that would operate at a LOS less than "C". Eight of the intersections would have at least two approach legs operating at LOS "F".

Table 2. Year 2035 Non-Signalized Intersection Capacity Summary

Intersection	NB LOS	NB Delay (s/v)	SB LOS	SB Delay (s/v)	EB LOS	EB Delay (s/v)	WB LOS	WB Delay (s/v)
MARY ST. ALIGNMENT OPTIONS 1 & 2:								
Old Hwy 312 & Five Mile Road Ext.	C	21	E	40	A	8	A	9
Mary St. Align. & Five Mile Road	F	70	F	1159	B	10	A	9
Mary St. Alignment & Bitterroot Dr.	F	125	F	459	A	9	A	9
Johnson Lane & N. Frontage Rd.	B	12	B	11	F	333	F	547
Johnson Ln. & I-90 WB Ramps	B	14					F	4345
FIVE MILE ROAD ALIGNMENT:								
Old Hwy 312 & Five Mile Rd. Align.	C	20	E	40	A	8	A	9
Five Mile Rd. Align. & Mary Street	A	10			F	119		
Mary Street & Bitterroot Drive	F	54	F	79	A	8	A	8
Johnson Lane & N. Frontage Rd.	B	11	A	10	F	2194	F	988
Johnson Ln. & I-90 WB Ramps	B	13					F	3484

= LOS D & E (green shading)   = LOS F (pink shading)

SIGNAL WARRANT ANALYSIS

Signal warrants, as contained in the Manual on Uniform Traffic Control Devices (MUTCD), 2009 Edition were evaluated using year 2035 traffic volume projections at the ten intersections noted in Table 2. It was determined that only three of the nine traffic signal warrants would be applicable to these intersections: Warrant 1. Eight-Hour Vehicular Volumes, Warrant 2. Four-Hour Vehicular Volumes, and Warrant 3. Peak Hour.

The pedestrian volume warrant was not investigated since none of the intersections are located in areas with potential for high pedestrian activities such as the central business district. School crossing warrants were not investigated because none of the alignments are on or cross existing school routes. The crash experience warrant was not analyzed since it requires a history of crash experience. Coordinated signals and roadway network warrants are commonly invoked when quantitative measures are below warrant values or when additional justification is needed for signal installation. In this case, it was felt that quantitative measures would be more appropriate due to the inherent uncertainties associated with long terms projections. Warrant 9 involves intersections near at-grade railroad crossings and would not apply to any of the study intersections.

Vehicular traffic data used in the traffic signal warrant analysis requires hourly volumes for at least a 12 hour period of the average day. For this study, existing electronic traffic counts on existing streets were used to approximate hourly traffic variation percentages and those percentages were applied to the 2035 average daily traffic (ADT) projections on each intersection approach. Existing counts used in this analysis were on Johnson Lane, US 87, Main Street, Bench Boulevard, and Old Hwy 312. Summaries of the warrant calculations for each intersection can be found in Appendix 2 of this report.

Old Hwy 312 Intersections

There are two intersection conditions associated with the Five Mile Road connection to Old Hwy 312: 1 - Five Mile Road as a Secondary Improvement associated with the Mary Street Alignment Options 1 and 2 - Five Mile Road Alignment connection to Old Hwy 312. The Five Mile Road Alignment intersection would have slightly higher traffic volumes (3%) which would not result a distinct difference in the warrant analysis values. The main difference between the two conditions would be the number of approach and departure lanes. Five Mile Road, as a secondary improvement, would have a single approach lane with an auxiliary right-turn lane and a single departure lane. The Five Mile Road Alignment intersection would have two approach lanes with an auxiliary right-turn lane and two departure lanes.

Signal warrant analysis for the Mary Street Alignment Secondary Improvements and the Five Mile Road Alignment alternative intersection conditions indicate that all three vehicular volume warrants would be met for both alternative alignment intersections. Warrant 1 - Eight-Hour Volumes Condition A would range from 141% to 151% of the minimum and Condition B would range from 109% to 112% of the minimum warrant volume. Warrant 2 – Four-Hour Volumes would range from 180% to 205% of the minimum warrant value, while Warrant 3 – Peak Hour Condition B would range from 164% to 185% of the minimum warrant value.

Since capacity calculations indicate that almost all of the approach movements would operate at an acceptable LOS, except the northbound left-turn lane (LOS “D”), justification for a signal would be questionable. If a significant portion or all of the northbound right-turn lane traffic volumes were eliminated from the warrant calculations, then none of the signal warrants would be met and a signal would not be justified for either alternative alignment at this location. Since there would be one movement at the intersection that would operate below the acceptable design LOS “D”, alternative intersection traffic control would weigh more heavily, as discussed further within this report.

Bitterroot Drive Intersections

There are two intersections with Bitterroot Drive investigated within this study. The first intersection is the Mary Street Alignment Options 1 & 2 intersection with Bitterroot Drive. That intersection involves issues with adjacent structure impacts and multiple alternatives involving both signals and roundabouts being carried through the EIS process. Therefore, signal warrant analysis contained within this report provides warranting information, but does not fully address alternative traffic control measures. Alternative control measures are addressed as alternative intersection design options within the Preliminary Traffic Study.

Signal warrant analysis indicates that all three vehicular volume warrants would be met for the Mary Street Alignment intersection with Bitterroot Drive. Warrant 1 - Eight-Hour Volumes Condition A would be at 145% of the minimum warrant value. Warrant 2 – Four-Hour Volumes would be at 152% of the minimum warrant value while Warrant 3 – Peak Hour Condition A would be met at 148% of the minimum warrant value and Condition B would be at 151% of the minimum warrant value.

The intersection of Mary Street and Bitterroot Drive with Secondary Improvements to Mary Street would involve an improved typical section along Mary Street with a single through travel lane in each direction and a two-way left-turn lane (TWLTL) in the middle. The Bitterroot Drive approaches would be widened to accommodate auxiliary left-turn lanes for northbound and southbound traffic.

Traffic signal warrant analysis indicates that two of the three vehicular warrants calculated in this study would be met for the Five Mile Road Alignment alternative involving secondary improvements to Mary Street and Bitterroot Drive. Warrant 1 Condition A would be met at only 101% of the minimum warrant value and Warrant 3 Condition A and B would be met with 108% and 171% of the minimum warrant values respectively. Warrant 2 – Four-Hour Volumes would be close to being met at 95% of the minimum warrant value.

Five Mile Road Intersections

There are three alternative alignments that would intersect Five Mile Road at different locations. Two of the intersections, involving Mary Street Alignment Option 1 and Mary Street Alignment Option 2 are at different locations, but both would have very similar traffic projections, and the number of approach and departure lanes would be identical for both intersections. Thus, signal warrant analysis was performed to encompass both Mary Street Alignment Options 1 and 2, even though alternative traffic control measures are addressed separately to account for topographical differences at each respective location.

Warrant analysis for the Mary Street Alignment options indicate that the three vehicular warrants calculated within this study would be met. Warrant 1 – Eight-Hour Vehicular Volumes would be met at 130% of minimum warrant values for condition A and 136% of minimum warrant values for Condition B. Warrant 2 – Four-Hour Vehicular Volumes would be met at 384% of the minimum warrant value and Warrant 3 – Peak Hour would have both Conditions A and B met at 158% and 198% of minimum warrant values, respectively.

The Five Mile Road Alignment intersection with Mary Street would be a “T” type intersection involving a realignment of Mary Street and connection to the Five Mile Road Alignment Alternative. It should be noted that Mary Street is actually Five Mile Road since secondary Improvements to Mary Street would extend northeast of the location where Mary Street veers from its east-west alignment and becomes Five Mile Road on a north-south bearing. At this intersection, Five Mile Road would be a four lane facility, incorporating an auxiliary left-turn lane for northbound traffic, and Mary Street would have one through lane in each direction with an auxiliary left-turn lane on its approach to the Five Mile Road Alignment intersection.

The Five Mile Alignment and Mary Street intersection would also meet the three vehicular warrants evaluated within this study. Warrant 1 – Eight-Hour Vehicular Volumes would be met at 130% of minimum warrant values for condition A, but would not meet warrant values for Condition B. Warrant 2 – Four-Hour Vehicular Volumes would be met at 220% of the minimum warrant value and Warrant 3 – Peak Hour would have Conditions B met at 238% of the minimum warrant value. Warrant 3, Condition A would not meet the minimum warrant values.

Johnson Lane Intersections

There are two intersections on Johnson Lane that are not currently signalized which are included in this study. The first intersection is Johnson Lane and the I-90 North Frontage Road intersection and the second is the Johnson Lane and I-90 Westbound ramp intersection. Warrant analysis was completed for each of the two intersections using Mary Street Alignment Options 1 and 2 year 2035 traffic projections and Five Mile Road alignment traffic projections.

All three of the signal warrants for the Johnson Lane and North Frontage Road intersection were met for both the Mary Street Alignment traffic volumes and the Five Mile Road Alignment volumes. For both alternative alignments, Warrant 1 – Eight-Hour Vehicular Volumes would meet at least 141% of minimum warrant values for Condition B, but Condition A would not be met. Warrant 2 – Four-Hour Vehicular Volumes would meet at least 278% of the minimum warrant values. Warrant 3 – Peak Hour would meet Conditions A by at least 208% of minimum warrant values and Condition B would be met by at least 324% of the minimum warrant values for each alternative alignment.

At the Johnson Lane and I-90 Westbound Ramp intersection, similar warrant values were met for each of the alternative alignments traffic conditions in the year 2035 with all three vehicular warrants being met. The only exception would be Warrant 1 – Eight-Hour Vehicular Volumes, where Condition A would meet at least 165% of the minimum warrant values, unlike the North Frontage Road and Johnson Lane intersection, where Condition A warrants were not met.

SIGNALIZED INTERSECTION OPERATIONS

Capacity calculations using SigCinema software and year 2035 PM design hour traffic projections were completed for all of the intersections meeting signal warrants and summaries of those calculations can be found in Appendix 3 of this report. The only exception is the intersections of I-90 Westbound Ramps for both the Mary Street Alignments and the Five Mile Road Alignment alternatives. In that case, design options for the Johnson Lane Interchange, as detailed in the Preliminary Traffic Study, do not include a single signalized intersection for the I-90 Westbound Ramp on Johnson Lane. Therefore, that intersection was excluded from further consideration as a signalized intersection.

Approach lane geometry, indicated by the typical sections for each alternative alignment, contained in Section 2 of this document, was used for the major intersection legs and auxiliary turn lanes were added to enhance operations, as necessary. Capacity calculations were made based on the assumption that none of the signals within this report would be part of a future coordinated signal system.

Table 3 presents a summary of level-of-service (LOS) and delay, in terms of seconds per vehicle, for each approach leg of the intersection. Capacity calculations for signalized conditions can be found in Appendix 3 of this report. For purposes of design, any LOS worse than "C" would be considered unacceptable. Table 3 indicates that all of the study intersections would have all approach legs operating at a LOS "C" or better. In comparing Table 3 to Table 2, it can be seen that the extreme delay (300 s/v and greater) associated with stop control would experience a vast improvement with traffic signal operations. The greatest delay shown in Table 3 would be approximately 30 seconds on the Mary Street approach to the Five Mile Road Alignment. It should also be noted that the signalized intersections would actually increase delay on the principal alignment approaches. However, the highest increase would only amount to an increase of three seconds per vehicle. This would result in a net decrease in overall intersection delay at all of the intersections with the exception of the Old Hwy 312 intersections, where the non-signalized delay would only impact a minor volume of traffic.

Table 3. Year 2035 Signalized Intersection Capacity Summary

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
MARY ST. ALIGNMENT OPTIONS 1 & 2:								
Old Hwy 312 & Five Mile Road Ext.	B	19	B	18	A	7	A	7
Mary St. Align. & Five Mile Road	B	13	B	14	A	9	B	12
Mary St. Alignment & Bitterroot Dr.	B	17	B	15	A	8	A	9
Johnson Lane & N. Frontage Rd.	A	9	B	17	C	23	C	20
FIVE MILE ROAD ALIGNMENT:								
Old Hwy 312 & Five Mile Rd. Align.	B	19	B	18	A	7	A	7
Five Mile Rd. Align. & Mary Street	B	13	C	28	C	30		
Mary Street & Bitterroot Drive	B	18	B	17	A	9	A	10
Johnson Lane & N. Frontage Rd.	A	8	B	16	C	23	C	20

ALTERNATIVE INTERSECTION TRAFFIC CONTROL

According to the MDT Traffic Manual, alternative traffic control measures other than traffic signals must be considered and evaluated in the warrant study. In this study, alternatives are limited to roundabouts because 4-way stop control would not be an acceptable alternative since all of the intersections would involve principal arterial roadways with mobility being the prime consideration and interruption of traffic flow could not be justified.

Capacity

Capacity calculations, using Sidra software, were completed for the same intersections included in Table 3 and summaries of those calculations can be found in Appendix 4 of this report. Approach lane geometry, derived from alternative alignment typical sections contained in Section 2 of this document, was used for the major intersection approach legs. Specific approach and circulating lane usage for each intersection are illustrated in the Preliminary Traffic Study, Section 1 of this document.

Table 4 presents a summary of level-of-service (LOS) and delay, in terms of seconds per vehicle, for each approach leg of the intersection. Capacity calculations for roundabout conditions can be found in Appendix 4 of this report. In Table 4, it can be seen that roundabout operations would result in LOS "A" on all approaches except for the Westbound approach on North Frontage Road at Johnson Lane, which would operate at LOS "B" with 12 seconds delay per vehicle. That same approach with signal operations would operate at LOS "C" and have 20 seconds per vehicle delay.

Each intersection would experience a net savings in total delay with roundabout operations. The savings would range from 13 seconds per vehicle, at the Mary Street Alignment and Five Mile Road intersection, to 47 seconds per vehicle, at the Five Mile Road Alignment and Mary Street intersection. Thus, the result would be a net decrease in overall intersection delay at all of the intersections and from an efficiency perspective, roundabouts would appear to be the preferred alternative.

Table 4. Year 2035 Roundabout Intersection Capacity Summary

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	**LOS**	**Delay (s/v)**	**LOS**	**Delay (s/v)**	**LOS**	**Delay (s/v)**	**LOS**	**Delay (s/v)**
MARY ST. ALIGNMENT OPTIONS 1 & 2:								
Old Hwy 312 & Five Mile Road Ext.	A	9	A	8	A	5	A	7
Mary St. Align. & Five Mile Road	A	8	B	16	A	6	A	5
Mary St. Alignment & Bitterroot Dr.	A	5	A	7	A	6	A	7
Johnson Lane & N. Frontage Rd.	A	5	A	4	A	7	B	12
FIVE MILE ROAD ALIGNMENT:								
Old Hwy 312 & Five Mile Rd. Align.*	A	9	A	8	A	5	A	7
Five Mile Rd. Align. & Mary Street	A	10	A	7	A	7		
Mary Street & Bitterroot Drive	A	6	A	8	A	6	A	5
Johnson Lane & N. Frontage Rd.*	A	5	A	4	A	7	B	12

* Lane Control Same as Mary Alignment with Less Traffic Capacity Analysis Not Performed

Safety

Within the past 10 years it has been documented in a variety of publications that roundabouts typically produce crash rates that are substantially less than signalized intersections. Reduced crash rates range between 20% and 70% of those associated with traffic signals. Since roundabouts also experience much lower crash severity rates than signalized intersections, due to slower entry speeds, safety benefits would be especially important due to the relatively higher speed of the new roadway facilities that would exist at the study intersections. Thus, from a safety perspective, it would appear that roundabouts would be the preferred alternative for all of the study intersections.

Geometry
All of the roundabouts on the new alternative alignments would have two entry and two departure lanes that would carry the 4 lane typical sections associated with the alternative alignments. The intersecting roadways would have single entry and departure lanes except for situations where an auxiliary right-turn lane would enhance operations. Minor streets would have a single circulation lane within the roundabouts. The inscribed diameter of these roundabouts would range between 170 feet and 200 feet.

Adjacent Land Use Impacts
Existing structures would not be impacted by construction at all but one of the study intersections. The intersection of Mary Street and Bitterroot Drive, constructed as secondary improvements to the Five Mile Road Alignment, could impact a new residence located in the southeast corner of the intersection depending on the alternative intersection improvement.

With the exception of the North Frontage Road and Johnson Lane intersection, adjacent land uses at the remaining intersections are agricultural. Some additional commercial property right-of-way would be required at the North Frontage Road and Johnson Lane intersection.

Access to adjacent properties would be better served by roundabouts at all of the intersections with the exception of the Highway 312 and Five Mile Road intersections. Traffic signals at the Highway 312 intersections would allow the existing adjacent accesses to operate with about the same degree of safety as the roundabout alternatives because existing approaches would be located a sufficient distance beyond the intersections' operational area of influence.

RECOMMENDATIONS

All of the study intersections would meet traffic signal warrants in the design year 2035 and signals would be justified at all intersections except for the ***Old Hwy 312 and Five Mile Road intersection***. A traffic signal at that intersection would be less efficient than stop control on Five Mile Road. A roundabout would be the most desirable alternative in terms of safety. However, the ultimate intersection control will be determined in the final design stage of this project.

The intersections of both the ***Mary Street Alignment and the Five Mile Road Alignment with the North Frontage Road and the I-90 Westbound Ramp at Johnson Lane*** are included in the overall interchange design options. Johnson Lane Interchange design options are described and evaluated in the Preliminary Traffic Study. These intersections were only analyzed within this warrant study to document that traffic signal warrants would be met.

Design options at the intersection of ***Mary Street Alignment and Bitterroot Drive*** are also detailed in the Preliminary Traffic Study and final design will determine the ultimate configuration and traffic control features. Similar to the Johnson Lane intersections, the Mary Street Alignment and Bitterroot Drive intersection was only included in this study to document traffic signal warrants.

At the ***Mary Street and Bitterroot Drive intersection associated with the Five Mile Road Alignment***, traffic signal warrants would be met and traffic signals would provide a safe and efficient operating environment. While a roundabout would provide measurably better operation in terms of delay and safety, it would require additional right-of-way that would severely impact a structure in the southeast corner. If Mary Street were realigned to the north in order minimize impacts to that structure, there would be additional impacts to residential properties in the northeast corner. Therefore, it is recommended that a traffic signal be designed as the ultimate traffic control device at this intersection.

At the ***Mary Street Option 1 and Option 2 Alignments' intersections with Five Mile Road***, traffic signal warrants are met and traffic signals would provide a desirable level of safety and efficiency. However, roundabouts at these intersections would provide a greater degree of safety and efficiency. Roundabouts would have minimal impacts on adjacent land uses and access to adjacent properties would be accommodated to a greater extent than with signals. At the Mary Street Option 1 Alignment and Five Mile Road intersection a roundabout would easily accommodate access to a number of existing driveway and street approaches, while a traffic signal would require numerous road approach realignments and directional access restrictions. For these reasons it is recommended that roundabouts be considered as the preferred alternatives in final design.

The ***Five Mile Road Alignment intersection with Mary Street*** would be a three-legged "T" intersection for which minimum traffic signal warrants would be met. As with the other intersections, traffic signals would provide a safe and efficient operating environment. However, a high level of turning movements at this intersection would only provide LOS "C" operations on the eastbound and southbound approaches and there would be very little capacity remaining beyond the design year 2035. Since roundabout operation would provide LOS "A" on all approaches, the operational benefits of the roundabout are clearly superior. Because this intersection could be constructed with minimal land use or access impacts, it is recommended that a roundabout be considered as the preferred alternative in final design

APPENDIX 1

Non-Signalized Intersection

Capacity Calculations

TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*HWY 312 & 5 Mile Mary Opt 1*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*10/3/2011*	Analysis Year	*2035*
Analysis Time Period	*Design Hour PM*		
Project Description *Billings Bypass*			
East/West Street: *HWY 312*		North/South Street:	
Intersection Orientation: *East-West*		Study Period (hrs): *0.25*	

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	5	470	20	150	300	5
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	5	522	22	166	333	5
Percent Heavy Vehicles	0	--	--	3	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	0	1	0	1	1	0
Configuration	LTR			L		TR
Upstream Signal		0			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	30	5	210	5	5	5
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.60	0.60	0.60
Hourly Flow Rate, HFR (veh/h)	33	5	233	8	8	8
Percent Heavy Vehicles	3	0	3	0	0	0
Percent Grade (%)		0			0	
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	1	0	1	0
Configuration	LT		R		LTR	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	LTR	L	LT		R		LTR	
v (veh/h)	5	166	38		233		24	
C (m) (veh/h)	1232	1020	132		545		128	
v/c	0.00	0.16	0.29		0.43		0.19	
95% queue length	0.01	0.58	1.11		2.12		0.66	
Control Delay (s/veh)	7.9	9.2	42.9		16.4		39.5	
LOS	A	A	E		C		E	
Approach Delay (s/veh)	--	--	20.2			39.5		
Approach LOS	--	--	C			E		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Associates*
Date Performed	*1/25/2012*
Analysis Time Period	*PM Design Hour*

Site Information

Intersection	*Mary Align & Five Mile Road*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Align Opt 1 & 2* — North/South Street: *Five Mile Road*

Intersection Orientation: *East-West* — Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	5	450	5	20	700	230
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.92	0.92	0.92
Hourly Flow Rate, HFR (veh/h)	5	500	5	21	760	249
Percent Heavy Vehicles	1	--	--	1	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	2	0	1	2	0
Configuration	L	T	TR	L	T	TR
Upstream Signal		0			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	5	50	20	170	10	5
Peak-Hour Factor, PHF	0.70	0.70	0.70	0.80	0.80	0.80
Hourly Flow Rate, HFR (veh/h)	7	71	28	212	12	6
Percent Heavy Vehicles	0	2	1	2	1	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	1	1	0	1	1	0
Configuration	L		TR	L		TR

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L	L	L		TR	L		TR
v (veh/h)	5	21	7		99	212		18
C (m) (veh/h)	689	1063	199		143	61		174
v/c	0.01	0.02	0.04		0.69	3.48		0.10
95% queue length	0.02	0.06	0.11		3.93	22.42		0.34
Control Delay (s/veh)	10.3	8.5	23.7		73.4	1255		28.1
LOS	B	A	C		F	F		D
Approach Delay (s/veh)	--	--	70.1			1159		
Approach LOS	--	--	F			F		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary Align & Bitteroot Opt 1*
Jurisdiction	*MDT*
Analysis Year	*Year 2035*

Project Description *Billings Bypass*

East/West Street: *Mary Street* | North/South Street: *Bitteroot*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*10*	*360*	*10*	*110*	*520*	*50*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*11*	*400*	*11*	*122*	*577*	*55*
Percent Heavy Vehicles	*1*	--	--	*1*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*1*	*2*	*0*
Configuration	*L*	*T*	*TR*	*L*	*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*20*	*110*	*95*	*40*	*50*	*30*
Peak-Hour Factor, PHF	*0.80*	*0.80*	*0.80*	*0.80*	*0.80*	*0.80*
Hourly Flow Rate, HFR (veh/h)	*24*	*137*	*118*	*49*	*62*	*37*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*	*L*		*TR*	*L*		*TR*
v (veh/h)	*11*	*122*	*24*		*255*	*49*		*99*
C (m) (veh/h)	*953*	*1152*	*119*		*232*	*17*		*211*
v/c	*0.01*	*0.11*	*0.20*		*1.10*	*2.88*		*0.47*
95% queue length	*0.04*	*0.35*	*0.71*		*11.32*	*6.73*		*2.28*
Control Delay (s/veh)	*8.8*	*8.5*	*42.7*		*133.2*	*1314*		*36.3*
LOS	*A*	*A*	*E*		*F*	*F*		*E*
Approach Delay (s/veh)	--	--	*125.4*			*459.4*		
Approach LOS	--	--	*F*			*F*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*N Frntg & Johnson Mary Opt 1&2*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *N Frontage Road*

North/South Street: *Johnson Lane*

Intersection Orientation: *North-South*

Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*190*	*930*	*30*	*5*	*700*	*100*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*211*	*1033*	*33*	*5*	*777*	*111*
Percent Heavy Vehicles	*8*	--	--	*4*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*1*	*2*	*0*
Configuration	*L*	*T*	*TR*	*L*	*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*155*	*25*	*210*	*25*	*20*	*5*
Peak-Hour Factor, PHF	*0.85*	*0.85*	*0.85*	*0.60*	*0.60*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*182*	*29*	*247*	*41*	*33*	*8*
Percent Heavy Vehicles	*4*	*4*	*8*	*4*	*4*	*4*
Percent Grade (%)		*0*			*0*	
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*	*L*		*TR*	*L*		*TR*
v (veh/h)	*211*	*5*	*41*		*41*	*182*		*276*
C (m) (veh/h)	*722*	*638*	*0*		*28*	*0*		*175*
v/c	*0.29*	*0.01*			*1.46*			*1.58*
95% queue length	*1.22*	*0.02*			*4.82*			*18.29*
Control Delay (s/veh)	*12.0*	*10.7*			*547.3*			*332.8*
LOS	*B*	*B*	*F*		*F*	*F*		*F*
Approach Delay (s/veh)	--	--						
Approach LOS	--	--						

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Johnson & WB Ramps*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*1/25/2012*	Analysis Year	*2035 Mary Opt 1&2 Align*
Analysis Time Period	*PM Design Hour*		

Project Description *Billings Bypass*	
East/West Street: *Westbound I90 Ramps*	North/South Street: *Johnson Lane*
Intersection Orientation: *North-South*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*230*	*950*			*675*	*260*
Peak-Hour Factor, PHF	*0.92*	*0.92*	*1.00*	*1.00*	*0.92*	*0.92*
Hourly Flow Rate, HFR (veh/h)	*249*	*1032*	*0*	*0*	*733*	*282*
Percent Heavy Vehicles	*5*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*0*	*1*	*0*
Configuration	*L*	*T*				*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*175*	*1*	*200*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.85*	*0.85*	*0.85*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*205*	*1*	*235*
Percent Heavy Vehicles	*0*	*0*	*0*	*8*	*8*	*10*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*1*	*0*
Configuration					*LTR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*			*LTR*				
v (veh/h)	*249*			*441*				
C (m) (veh/h)	*672*			*43*				
v/c	*0.37*			*10.26*				
95% queue length	*1.71*			*52.88*				
Control Delay (s/veh)	*13.5*			*4345*				
LOS	*B*			*F*				
Approach Delay (s/veh)	--	--	*4345*					
Approach LOS	--	--	*F*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/3/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*HWY 312 & 5 Mile Five Mile Alt*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *HWY 312* | North/South Street: *Five Mile Roa*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	5	470	20	150	310	5
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	5	522	22	166	344	5
Percent Heavy Vehicles	0	--	--	3	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	1	0	1	1	0
Configuration	L		TR	L		TR
Upstream Signal		0			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	30	5	230	5	5	5
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	33	5	255	5	5	5
Percent Heavy Vehicles	3	0	3	0	0	0
Percent Grade (%)		0			0	
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	1	0	1	0
Configuration	LT		R		LTR	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L	L	LT		R		LTR	
v (veh/h)	5	166	38		255		15	
C (m) (veh/h)	1221	1020	132		545		118	
v/c	0.00	0.16	0.29		0.47		0.13	
95% queue length	0.01	0.58	1.11		2.47		0.42	
Control Delay (s/veh)	8.0	9.2	42.9		17.3		39.9	
LOS	A	A	E		C		E	
Approach Delay (s/veh)	--	--	20.6			39.9		
Approach LOS	--	--	C			E		

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Five Mile Alignment & Mary*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*1/25/2012*	Analysis Year	*2035*
Analysis Time Period	*PM Design Hour*		

Project Description *Billings Bypass*	
East/West Street: *Mary Street*	North/South Street: *Five Mile Road Alignment*
Intersection Orientation: *North-South*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	500	280			30	190
Peak-Hour Factor, PHF	0.92	0.92	1.00	1.00	0.80	0.80
Hourly Flow Rate, HFR (veh/h)	543	304	0	0	37	237
Percent Heavy Vehicles	2	--	--	0	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	1	0	0	2	0
Configuration	L	T			T	TR
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	30		330			
Peak-Hour Factor, PHF	0.90	1.00	0.90	1.00	1.00	1.00
Hourly Flow Rate, HFR (veh/h)	33	0	366	0	0	0
Percent Heavy Vehicles	1	0	2	0	0	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	1	0	1	0	0	0
Configuration	L		R			

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L					L		R
v (veh/h)	543					33		366
C (m) (veh/h)	1286					61		910
v/c	0.42					0.54		0.40
95% queue length	2.14					2.18		1.96
Control Delay (s/veh)	9.8					119.0		11.6
LOS	A					F		B
Approach Delay (s/veh)	--	--				20.5		
Approach LOS	--	--				C		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*1/24/2012*
Analysis Time Period	*Design PM*

Site Information

Intersection	*Mary & Bitterroot*
Jurisdiction	*MDT*
Analysis Year	*2035 Five Mile Align Sec Imps*

Project Description *Billings Bypass*

East/West Street: *Mary Street* | North/South Street: *Bitterroot*

Intersection Orientation: *East-West* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	20	310	50	80	390	60
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	22	344	55	88	433	66
Percent Heavy Vehicles	1	--	--	1	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	1	0	1	1	0
Configuration	L		TR	L		TR
Upstream Signal		0			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	50	100	80	40	60	10
Peak-Hour Factor, PHF	0.80	0.80	0.80	0.75	0.75	0.75
Hourly Flow Rate, HFR (veh/h)	62	124	99	53	80	13
Percent Heavy Vehicles	0	0	1	1	0	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	1	1	0	1	1	0
Configuration	L		TR	L		TR

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L	L	L		TR	L		TR
v (veh/h)	22	88	62		223	53		93
C (m) (veh/h)	1070	1165	119		286	67		217
v/c	0.02	0.08	0.52		0.78	0.79		0.43
95% queue length	0.06	0.24	2.43		6.02	3.67		1.99
Control Delay (s/veh)	8.4	8.3	64.3		50.9	157.8		33.5
LOS	A	A	F		F	F		D
Approach Delay (s/veh)	--	--	53.8			78.6		
Approach LOS	--	--	F			F		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/8/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*N Frntg & Johnson 5 Mile Align*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *N Frontage Road* | North/South Street: *Johnson Lane*

Intersection Orientation: *North-South* | Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	195	785	30	5	600	90
Peak-Hour Factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Hourly Flow Rate, HFR (veh/h)	216	872	33	5	666	100
Percent Heavy Vehicles	8	--	--	4	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	2	0	1	2	0
Configuration	L	T	TR	L	T	TR
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	135	25	215	25	20	5
Peak-Hour Factor, PHF	0.85	0.85	0.85	0.60	0.60	0.60
Hourly Flow Rate, HFR (veh/h)	158	29	252	41	33	8
Percent Heavy Vehicles	4	4	8	4	4	4
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	1	1	0	1	1	0
Configuration	L		TR	L		TR

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L	L	L		TR	L		TR
v (veh/h)	216	5	41		41	158		281
C (m) (veh/h)	805	735	12		44	11		248
v/c	0.27	0.01	3.42		0.93	14.36		1.13
95% queue length	1.08	0.02	6.13		3.74	21.17		12.53
Control Delay (s/veh)	11.1	9.9	1719		257.3	6679		140.5
LOS	B	A	F		F	F		F
Approach Delay (s/veh)	--	--	988.0			2494		
Approach LOS	--	--	F			F		

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TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	*R Marvin*	Intersection	*Johnson & WB Ramps*
Agency/Co.	*Marvin Associates*	Jurisdiction	*MDT*
Date Performed	*1/25/2012*	Analysis Year	*2035 Five Mile Road Align*
Analysis Time Period	*PM Design Hour*		

Project Description *Billings Bypass*

East/West Street: *Westbound I90 Ramps*	North/South Street: *Johnson Lane*
Intersection Orientation: *North-South*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*270*	*860*			*640*	*200*
Peak-Hour Factor, PHF	*0.92*	*0.92*	*1.00*	*1.00*	*0.92*	*0.92*
Hourly Flow Rate, HFR (veh/h)	*293*	*934*	*0*	*0*	*695*	*217*
Percent Heavy Vehicles	*5*	--	--	*0*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*0*	*1*	*0*
Configuration	*L*	*T*				*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				*150*	*1*	*170*
Peak-Hour Factor, PHF	*1.00*	*1.00*	*1.00*	*0.85*	*0.85*	*0.85*
Hourly Flow Rate, HFR (veh/h)	*0*	*0*	*0*	*176*	*1*	*199*
Percent Heavy Vehicles	*0*	*0*	*0*	*8*	*8*	*10*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*1*	*0*
Configuration					*LTR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*			*LTR*				
v (veh/h)	*293*			*376*				
C (m) (veh/h)	*735*			*45*				
v/c	*0.40*			*8.36*				
95% queue length	*1.92*			*44.54*				
Control Delay (s/veh)	*13.1*			*3484*				
LOS	*B*			*F*				
Approach Delay (s/veh)	--	--	*3484*					
Approach LOS	--	--	*F*					

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APPENDIX 2

Traffic Signal Warrant Summaries

Intersection:	Highway 312	and	Five Mile Road
Case:	**Mary Street Alternative Options 1 & 2 Year 2035**		
Date:	January 24, 2012		

Major Street:	Highway 312	**Minor Street 1:**	Five Mile Road	**Minor Street 2:**	Private Road
Major Street Dir. (N-S or E-W):	E-W	**Minor Street 1 Dir. (N-S or E-W):**	N-S	**Minor Street 2 Dir. (N-S or E-W):**	N-S
		Approach Dir. (NB or SB)	NB	**Approach Dir. (NB or SB)**	SB

Major Street Speed Limit: 50 **mph** ***Major Street 85th % Speed:*** 55 **mph** ***Total Intersection Approaches:*** 4

Beginning Hour	**Highway 312 EB**	**WB**	**Five Mile Road NB**	**SB**	**Total Major**	**High Minor**	**Total Entering**	
7:00 AM	213	611	79	2	824	79	905	
8:00 AM	238	510	147	2	748	147	897	
9:00 AM	219	350	82	1	569	82	652	
10:00 AM	232	323	90	1	555	90	646	
11:00 AM	281	339	98	1	620	98	719	
12:00 AM	321	332	124	1	653	124	778	
1:00 PM	361	327	148	1	688	148	837	**< 8th Highest**
2:00 PM	408	337	167	1	745	167	913	**< 4th Highest**
3:00 PM	454	352	170	1	806	170	977	
4:00 PM	508	391	190	1	899	190	1090	
5:00 PM	557	364	211	1	921	211	1133	**< Peak Hour**
6:00 PM	412	314	147	1	726	147	874	
7:00 PM	353	226	106	1	579	106	686	
Ave. Weekday Volumes =	5500	5700	2050	20	11200	2050	13270	

Volume Warrants	**Condition A**				**Condition B**			
	Values		**Minimums**		**Values**		**Minimums**	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrai	688	148	***420***	***105***	688	148	***630***	***53***
4th Hour Vehicular Volume Warrai	745	167	***745***	***93***				
Peak Hour Vehicular Volume Warrai	1133	211	***800***	***100***	921	211	***921***	***129***
Crash Experience Warran	688	148	***480***	***120***	688	148	***720***	***60***
Roadway Network Warran	1133		***(1000)***					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	141.0%
Warrant 1 Condition B Met	YES	109.2%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	179.6%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	NO	31.3%
Warrant 3 Condition A.2 Met	YES	211.0%
Warrant 3 Condition A.3 Met	YES	141.6%
Warrant 3 Condition B Met	YES	163.6%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		***Met***	***Percent Met***
1	**Eight-hour Vehicular Volume**	YES	141.0%
2	**Four-hour Vehicular Volume**	YES	179.6%
3	**Peak Hour**	YES	163.6%
4	**Pedestrian Volumes**	N/A	N/A
5	**School Crossing**	N/A	N/A
6	**Coordinated Signal System**	N/A	N/A
7	**Crash Experience**	N/A	N/A
8	**Roadway Network**	N/A	N/A

Total Number of Warrants Met	**3**

Intersection:	Five Mile Road	and	Mary Align. Opt 1&2
Case:	Mary Street Alternative Options 1 & 2 Year 2035		
Date:	January 25, 2012		

Major Street:	Mary Alignment Opt 1&2	**Minor Street 1:**	Five Mile Road	**Minor Street 2:**	Five Mile Road
Major Street Dir. (N-S or E-W):	E-W	**Minor Street 1 Dir. (N-S or E-W):**	N-S	**Minor Street 2 Dir. (N-S or E-W):**	N-S
		Approach Dir. (NB or SB)	NB	**Approach Dir. (NB or SB)**	SB

Major Street Speed Limit: 45 **mph** ***Major Street 85th % Speed:*** 50 **mph** ***Total Intersection Approaches:*** 4

Beginning Hour	**Mary Alignment EB**	**Mary Alignment WB**	**Five Mile Road NB**	**Five Mile Road SB**	**Total Major**	**High Minor**	**Total Entering**	
7:00 AM	622	385	19	230	1007	230	1256	< 4th Highest
8:00 AM	518	344	36	222	862	222	1120	
9:00 AM	356	317	20	169	673	169	862	
10:00 AM	328	335	22	161	663	161	846	
11:00 AM	345	406	24	163	751	163	938	
12:00 AM	338	465	30	142	803	142	975	
1:00 PM	333	521	36	136	854	136	1026	< 8th Highest
2:00 PM	343	590	41	172	933	172	1146	
3:00 PM	358	656	42	169	1014	169	1225	
4:00 PM	398	735	46	162	1133	162	1341	
5:00 PM	408	804	52	158	1212	158	1422	< Peak Hour
6:00 PM	319	595	36	135	914	135	1085	
7:00 PM	230	511	26	92	741	92	859	
Ave. Weekday Volumes =	5800	7950	500	2500	13750	2500	16750	

Volume Warrants	**Condition A**				**Condition B**			
	Values		**Minimums**		**Values**		**Minimums**	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrant	854	136	***420***	***105***	854	136	***630***	***53***
4th Hour Vehicular Volume Warrant	1007	230	***1007***	***60***				
Peak Hour Vehicular Volume Warrant	1422	158	***800***	***100***	1212	158	***1212***	***80***
Crash Experience Warrant	854	136	***480***	***120***	854	136	***720***	***60***
Roadway Network Warrant	1422		***(1000)***					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	129.5%
Warrant 1 Condition B Met	YES	135.6%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	383.3%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	1490.0%
Warrant 3 Condition A.2 Met	YES	158.0%
Warrant 3 Condition A.3 Met	YES	177.8%
Warrant 3 Condition B Met	YES	197.5%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		*Met*	*Percent Met*
1	**Eight-hour Vehicular Volume**	YES	129.5%
2	**Four-hour Vehicular Volume**	YES	383.3%
3	**Peak Hour**	YES	197.5%
4	**Pedestrian Volumes**	N/A	N/A
5	**School Crossing**	N/A	N/A
6	**Coordinated Signal System**	N/A	N/A
7	**Crash Experience**	N/A	N/A
8	**Roadway Network**	N/A	N/A
Total Number of Warrants Met			**3**

Intersection:	Bitterroot Drive	and	Mary Align. Opt 1&2
Case:	Mary Street Alternative Options 1 & 2 Year 2035		
Date:	January 24, 2012		

Major Street:	Mary Alignment Opt 1&2	**Minor Street 1:**	Bitterroot Drive	**Minor Street 2:**	Bitterroot Drive
Major Street Dir. (N-S or E-W):	E-W	**Minor Street 1 Dir. (N-S or E-W):**	N-S	**Minor Street 2 Dir. (N-S or E-W):**	N-S
		Approach Dir. (NB or SB)	NB	**Approach Dir. (NB or SB)**	SB

Major Street Speed Limit: 45 **mph** ***Major Street 85th % Speed:*** 50 **mph** ***Total Intersection Approaches:*** 4

Beginning Hour	**Mary Alignment EB**	**Mary Alignment WB**	**Bitterroot Drive NB**	**Bitterroot Drive SB**	**Total Major**	**High Minor**	**Total Entering**	
7:00 AM	472	266	81	143	738	143	962	**< 4th Highest**
8:00 AM	393	238	151	137	631	151	919	
9:00 AM	270	219	84	105	489	105	678	
10:00 AM	249	232	92	100	481	100	673	
11:00 AM	262	281	100	101	543	101	744	
12:00 AM	256	321	127	88	577	127	792	
1:00 PM	252	361	152	85	613	152	850	**< 8th Highest**
2:00 PM	260	408	172	107	668	172	947	
3:00 PM	272	454	174	105	726	174	1005	
4:00 PM	302	508	195	100	810	195	1105	
5:00 PM	309	557	217	98	866	217	1181	**< Peak Hour**
6:00 PM	242	412	151	83	654	151	888	
7:00 PM	175	353	109	57	528	109	694	
Ave. Weekday Volumes =	4400	5500	2100	1550	9900	2100	13550	

Volume Warrants	**Condition A**				**Condition B**			
	Values		**Minimums**		**Values**		**Minimums**	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrant	613	152	***420***	***105***	613	152	***630***	***53***
4th Hour Vehicular Volume Warrant	738	143	***738***	***94***				
Peak Hour Vehicular Volume Warrant	1181	217	***800***	***100***	866	217	***866***	***144***
Crash Experience Warrant	613	152	***480***	***120***	613	152	***720***	***60***
Roadway Network Warrant	1181		***(1000)***					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	144.8%
Warrant 1 Condition B Met	NO	97.3%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	152.1%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	382.5%
Warrant 3 Condition A.2 Met	YES	217.0%
Warrant 3 Condition A.3 Met	YES	147.6%
Warrant 3 Condition B Met	YES	150.7%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		***Met***	***Percent Met***
1	**Eight-hour Vehicular Volume**	YES	144.8%
2	**Four-hour Vehicular Volume**	YES	152.1%
3	**Peak Hour**	YES	147.6%
4	**Pedestrian Volumes**	N/A	N/A
5	**School Crossing**	N/A	N/A
6	**Coordinated Signal System**	N/A	N/A
7	**Crash Experience**	N/A	N/A
8	**Roadway Network**	N/A	N/A
Total Number of Warrants Met			**3**

Intersection:	North Frontage Road	and	Johnson Lane
Case:	**Mary Alignment Opt 1&2 Year 2035**		
Date:	January 25, 2012		

Major Street:	Johnson Lane	**Minor Street 1:**	North Frontage Road	**Minor Street 2:**	North Frontage Road
Major Street Dir. (N-S or E-W):	N-S	**Minor Street 1 Dir. (N-S or E-W):**	E-W	**Minor Street 2 Dir. (N-S or E-W):**	E-W
		Approach Dir. (EB or WB)	WB	**Approach Dir. (EB or WB)**	EB

Major Street Speed Limit: 35 **mph** ***Major Street 85th % Speed:*** 40 **mph** ***Total Intersection Approaches:*** 4

Beginning Hour	**Johnson Lane NB**	**Johnson Lane SB**	**North Frontage WB**	**North Frontage EB**	**Total Major**	**High Minor**	**Total Entering**	
7:00 AM	346	911	31	126	1257	126	1414	**< 8th Highest**
8:00 AM	646	877	28	141	1523	141	1692	
9:00 AM	361	668	24	168	1029	168	1221	
10:00 AM	395	638	38	165	1033	165	1236	
11:00 AM	429	644	27	181	1073	181	1281	
12:00 AM	542	563	30	197	1105	197	1332	
1:00 PM	649	540	27	206	1189	206	1422	
2:00 PM	735	682	30	210	1417	210	1657	
3:00 PM	747	668	30	233	1415	233	1678	**< 4th Highest**
4:00 PM	836	641	30	292	1477	292	1799	
5:00 PM	928	628	31	339	1556	339	1926	**< Peak Hour**
6:00 PM	646	533	27	244	1179	244	1450	
7:00 PM	466	364	20	168	830	168	1018	
Ave. Weekday Volumes =	9000	9900	500	3400	18900	3400	22800	

Volume Warrants	**Condition A**				**Condition B**			
	Values		**Minimums**		**Values**		**Minimums**	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrai	1257	126	***500***	***150***	1257	126	***750***	***75***
4th Hour Vehicular Volume Warrai	1415	233	***1415***	***80***				
Peak Hour Vehicular Volume Warrai	1926	339	***800***	***100***	1556	339	***1556***	***100***
Crash Experience Warran	1257	126	***400***	***120***	1257	126	***600***	***60***
Roadway Network Warran	1926		***(1000)***					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	NO	84.0%
Warrant 1 Condition B Met	YES	167.6%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	291.3%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	1040.0%
Warrant 3 Condition A.2 Met	YES	339.0%
Warrant 3 Condition A.3 Met	YES	240.8%
Warrant 3 Condition B Met	YES	339.0%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		***Met***	***Percent Met***
1	**Eight-hour Vehicular Volume**	YES	167.6%
2	**Four-hour Vehicular Volume**	YES	291.3%
3	**Peak Hour**	YES	339.0%
4	**Pedestrian Volumes**	N/A	N/A
5	**School Crossing**	N/A	N/A
6	**Coordinated Signal System**	N/A	N/A
7	**Crash Experience**	N/A	N/A
8	**Roadway Network**	N/A	N/A

Total Number of Warrants Met	3

Intersection: WB Off -Ramp and Johnson Lane

Case: Mary Alignment Opt 1&2 Year 2035

Date: January 25, 2012

Major Street:	Johnson Lane	Minor Street 1:	WB Off Ramp	Minor Street 2:	
Major Street Dir. (N-S or E-W):	N-S	Minor Street 1 Dir. (N-S or E-W):	E-W	Minor Street 2 Dir. (N-S or E-W):	
		Approach Dir. (EB or WB)	WB	Approach Dir. (EB or WB)	

Major Street Speed Limit: 35 mph *Major Street 85th % Speed:* 35 mph *Total Intersection Approaches:* 3

Beginning Hour	Johnson Lane NB	Johnson Lane SB	WB Off Ramp WB	Total Major	High Minor	Total Entering	
7:00 AM	381	888	276	1269	276	1545	
8:00 AM	711	855	246	1566	246	1812	
9:00 AM	398	651	212	1049	212	1261	
10:00 AM	435	622	336	1057	336	1393	
11:00 AM	472	628	234	1100	234	1334	
12:00 AM	596	549	262	1145	262	1407	< 8th Highest
1:00 PM	714	526	238	1240	238	1478	
2:00 PM	809	664	260	1473	260	1733	
3:00 PM	822	651	264	1473	264	1737	< 4th Highest
4:00 PM	920	625	264	1545	264	1809	
5:00 PM	1021	612	270	1633	270	1903	< Peak Hour
6:00 PM	711	520	236	1231	236	1467	
7:00 PM	512	355	174	867	174	1041	
Ave. Weekday Volumes =	9900	9650	4400	19550	4400	23950	

Volume Warrants	Condition A				Condition B			
	Values		Minimums		Values		Minimums	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrai	1145	262	500	150	1145	262	750	75
4th Hour Vehicular Volume Warrai	1473	276	1473	80				
Peak Hour Vehicular Volume Warrai	1903	270	650	100	1633	270	1633	100
Crash Experience Warran	1145	262	400	120	1145	262	600	60
Roadway Network Warran	1903		(1000)					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	174.7%
Warrant 1 Condition B Met	YES	152.7%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	345.0%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	13300.0%
Warrant 3 Condition A.2 Met	YES	270.0%
Warrant 3 Condition A.3 Met	YES	292.8%
Warrant 3 Condition B Met	YES	270.0%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		*Met*	*Percent Met*
1	Eight-hour Vehicular Volume	YES	152.7%
2	Four-hour Vehicular Volume	YES	345.0%
3	Peak Hour	YES	270.0%
4	Pedestrian Volumes	N/A	N/A
5	School Crossing	N/A	N/A
6	Coordinated Signal System	N/A	N/A
7	Crash Experience	N/A	N/A
8	Roadway Network	N/A	N/A
Total Number of Warrants Met			3

Intersection:	Highway 312	and	Five Mile Road
Case:	**Five Mile Road Alignment & Old Hwy 312**		
Date:	January 24, 2012		

Major Street:	Highway 312	**Minor Street 1:**	Five Mile Road	**Minor Street 2:**	Private Road
Major Street Dir. (N-S or E-W):	E-W	**Minor Street 1 Dir. (N-S or E-W):**	N-S	**Minor Street 2 Dir. (N-S or E-W):**	N-S
		Approach Dir. (NB or SB)	NB	**Approach Dir. (NB or SB)**	SB

Major Street Speed Limit: 50 **mph** ***Major Street 85th % Speed:*** 55 **mph** ***Total Intersection Approaches:*** 4

Beginning Hour	**Highway 312 EB**	**WB**	**Five Mile Road NB**	**SB**	**Total Major**	**High Minor**	**Total Entering**	
7:00 AM	219	627	85	2	846	85	933	
8:00 AM	244	523	158	2	767	158	927	
9:00 AM	225	359	88	1	584	88	673	
10:00 AM	238	331	97	1	569	97	667	
11:00 AM	288	348	105	1	636	105	742	
12:00 AM	330	341	133	1	671	133	805	
1:00 PM	370	335	159	1	705	159	865	**< 8th Highest**
2:00 PM	419	346	180	1	765	180	946	**< 4th Highest**
3:00 PM	466	361	183	1	827	183	1011	
4:00 PM	522	401	204	1	923	204	1128	
5:00 PM	572	374	227	1	946	227	1174	**< Peak Hour**
6:00 PM	423	322	158	1	745	158	904	
7:00 PM	363	232	114	1	595	114	710	
Ave. Weekday Volumes =	5650	5850	2200	20	11500	2200	13720	

Volume Warrants	**Condition A**				**Condition B**			
	Values		**Minimums**		**Values**		**Minimums**	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrai	705	159	***420***	***105***	705	159	***630***	***53***
4th Hour Vehicular Volume Warrai	765	180	***765***	***88***				
Peak Hour Vehicular Volume Warrai	1174	227	***800***	***100***	946	227	***946***	***123***
Crash Experience Warran	705	159	***480***	***120***	705	159	***720***	***60***
Roadway Network Warran	1174		***(1000)***					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	151.4%
Warrant 1 Condition B Met	YES	111.9%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	204.5%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	NO	33.8%
Warrant 3 Condition A.2 Met	YES	227.0%
Warrant 3 Condition A.3 Met	YES	146.8%
Warrant 3 Condition B Met	YES	184.6%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		***Met***	***Percent Met***
1	**Eight-hour Vehicular Volume**	YES	111.9%
2	**Four-hour Vehicular Volume**	YES	204.5%
3	**Peak Hour**	YES	184.6%
4	**Pedestrian Volumes**	N/A	N/A
5	**School Crossing**	N/A	N/A
6	**Coordinated Signal System**	N/A	N/A
7	**Crash Experience**	N/A	N/A
8	**Roadway Network**	N/A	N/A

Total Number of Warrants Met	**3**

Intersection: Five Mile Road and Five Mile Rd Align

Case: Five Mile Road Alignment Year 2035

Date: January 25, 2012

Major Street:	Mary Sreet Secondary Imp.	**Minor Street 1:**	Five Mile Road Align	**Minor Street 2:**	
Major Street Dir. (N-S or E-W):	E-W	**Minor Street 1 Dir. (N-S or E-W):**	N-S	**Minor Street 2 Dir. (N-S or E-W):**	
		Approach Dir. (NB or SB)	NB	**Approach Dir. (EB or WB)**	

Major Street Speed Limit: 45 mph *Major Street 85th % Speed:* 50 mph *Total Intersection Approaches:* 3

Beginning Hour	Five Mile Road NB	Five Mile Road SB	Mary Street EB	Mary Street WB	Total Major	High Minor	Total Entering	
7:00 AM	697	126	169		823	169	992	< 4th Highest
8:00 AM	581	112	316		693	316	1009	
9:00 AM	399	104	177		503	177	680	
10:00 AM	368	110	193		478	193	671	
11:00 AM	387	133	210		520	210	730	
12:00 AM	378	152	265		530	265	795	
1:00 PM	373	170	317		543	317	860	< 8th Highest
2:00 PM	384	193	359		577	359	936	
3:00 PM	402	215	365		617	365	982	
4:00 PM	446	240	409		686	409	1095	
5:00 PM	457	263	454		720	454	1174	< Peak Hour
6:00 PM	358	195	316		553	316	869	
7:00 PM	258	167	228		425	228	653	
Ave. Weekday Volumes =	6500	2600	4400		9100	4400	13500	

Volume Warrants	Condition A				Condition B			
	Values		Minimums		Values		Minimums	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrant	543	317	*420*	*105*	543	317	*630*	*53*
4th Hour Vehicular Volume Warrant	823	169	*823*	*77*				
Peak Hour Vehicular Volume Warrant	1174	454	*650*	*100*	720	454	*720*	*191*
Crash Experience Warrant	543	317	*480*	*120*	543	317	*720*	*60*
Roadway Network Warrant	1174		*(1000)*					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	129.3%
Warrant 1 Condition B Met	NO	86.2%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	219.5%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	NO	41.0%
Warrant 3 Condition A.2 Met	YES	454.0%
Warrant 3 Condition A.3 Met	YES	180.6%
Warrant 3 Condition B Met	YES	237.7%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		*Met*	*Percent Met*
1	Eight-hour Vehicular Volume	YES	129.3%
2	Four-hour Vehicular Volume	YES	219.5%
3	Peak Hour	YES	237.7%
4	Pedestrian Volumes	N/A	N/A
5	School Crossing	N/A	N/A
6	Coordinated Signal System	N/A	N/A
7	Crash Experience	N/A	N/A
8	Roadway Network	N/A	N/A
Total Number of Warrants Met			3

Intersection: Bitterroot Drive and Mary Street

Case: Five Mile Road Alignment Secondary Improvements Year 2035

Date: January 24, 2012

Major Street:	Mary Street	**Minor Street 1:**	Bitterroot Drive	**Minor Street 2:**	Bitterroot Drive
Major Street Dir. (N-S or E-W):	E-W	**Minor Street 1 Dir. (N-S or E-W):**	N-S	**Minor Street 2 Dir. (N-S or E-W):**	N-S
		Approach Dir. (NB or SB)	NB	**Approach Dir. (NB or SB)**	SB

Major Street Speed Limit: 35 **mph** ***Major Street 85th % Speed:*** 40 **mph** ***Total Intersection Approaches:*** 4

Beginning Hour	**Mary Street EB**	**Mary Street WB**	**Bitterroot Drive NB**	**Bitterroot Drive SB**	**Total Major**	**High Minor**	**Total Entering**	
7:00 AM	472	213	81	175	685	175	941	**< 4th Highest**
8:00 AM	393	190	151	168	583	168	902	
9:00 AM	270	176	84	128	446	128	658	
10:00 AM	249	186	92	122	435	122	649	
11:00 AM	262	225	100	124	487	124	711	
12:00 AM	256	257	127	108	513	127	748	
1:00 PM	252	289	152	104	541	152	797	**< 8th Highest**
2:00 PM	260	326	172	131	586	172	889	
3:00 PM	272	363	174	128	635	174	937	
4:00 PM	302	407	195	123	709	195	1027	
5:00 PM	309	445	217	120	754	217	1091	**< Peak Hour**
6:00 PM	242	329	151	102	571	151	824	
7:00 PM	175	283	109	70	458	109	637	
Ave. Weekday Volumes =	4400	4400	2100	1900	8800	2100	12800	

Volume Warrants	**Condition A**				**Condition B**			
	Values		**Minimums**		**Values**		**Minimums**	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrant	541	152	***500***	***150***	541	152	***750***	***75***
4th Hour Vehicular Volume Warrant	685	175	***685***	***185***				
Peak Hour Vehicular Volume Warrant	1091	217	***800***	***100***	754	217	***754***	***127***
Crash Experience Warrant	541	152	***400***	***120***	541	152	***600***	***60***
Roadway Network Warrant	1091		***(1000)***					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	101.3%
Warrant 1 Condition B Met	NO	72.1%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	NO	94.6%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	107.5%
Warrant 3 Condition A.2 Met	YES	217.0%
Warrant 3 Condition A.3 Met	YES	136.4%
Warrant 3 Condition B Met	YES	170.9%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

	Warrant Number and Title	***Met***	***Percent Met***
1	**Eight-hour Vehicular Volume**	YES	101.3%
2	**Four-hour Vehicular Volume**	NO	94.6%
3	**Peak Hour**	YES	107.5%
4	**Pedestrian Volumes**	N/A	N/A
5	**School Crossing**	N/A	N/A
6	**Coordinated Signal System**	N/A	N/A
7	**Crash Experience**	N/A	N/A
8	**Roadway Network**	N/A	N/A

Total Number of Warrants Met	**3**

Intersection: North Frontage Road and Johnson Lane

Case: Five Mile Road Alignment Year 2035

Date: January 25, 2012

Major Street:	Johnson Lane	Minor Street 1:	North Frontage Road	Minor Street 2:	North Frontage Road
Major Street Dir. (N-S or E-W):	N-S	Minor Street 1 Dir. (N-S or E-W):	E-W	Minor Street 2 Dir. (N-S or E-W):	E-W
		Approach Dir. (EB or WB)	WB	Approach Dir. (EB or WB)	EB

Major Street Speed Limit: 35 mph *Major Street 85th % Speed:* 40 mph *Total Intersection Approaches:* 4

Beginning Hour	Johnson Lane NB	Johnson Lane SB	North Frontage WB	North Frontage EB	Total Major	High Minor	Total Entering	
7:00 AM	292	764	31	121	1056	121	1208	< 8th Highest
8:00 AM	546	736	28	135	1282	135	1445	
9:00 AM	305	560	24	161	865	161	1050	
10:00 AM	334	535	38	158	869	158	1065	
11:00 AM	362	540	27	173	902	173	1102	
12:00 AM	458	472	30	188	930	188	1148	
1:00 PM	548	453	27	197	1001	197	1225	
2:00 PM	621	571	30	201	1192	201	1423	
3:00 PM	631	560	30	222	1191	222	1443	< 4th Highest
4:00 PM	706	537	30	279	1243	279	1552	
5:00 PM	784	526	31	324	1310	324	1665	< Peak Hour
6:00 PM	546	447	27	233	993	233	1253	
7:00 PM	393	306	20	160	699	160	879	
Ave. Weekday Volumes =	7600	8300	500	3250	15900	3250	19650	

Volume Warrants	Condition A Values		Condition A Minimums		Condition B Values		Condition B Minimums	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrai	1056	121	500	150	1056	121	750	75
4th Hour Vehicular Volume Warrai	1191	222	1191	80				
Peak Hour Vehicular Volume Warrai	1665	324	800	100	1310	324	1310	100
Crash Experience Warran	1056	121	400	120	1056	121	600	60
Roadway Network Warran	1665		(1000)					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	NO	80.7%
Warrant 1 Condition B Met	YES	140.8%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	277.5%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	647.5%
Warrant 3 Condition A.2 Met	YES	324.0%
Warrant 3 Condition A.3 Met	YES	208.1%
Warrant 3 Condition B Met	YES	324.0%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		*Met*	*Percent Met*
1	Eight-hour Vehicular Volume	YES	140.8%
2	Four-hour Vehicular Volume	YES	277.5%
3	Peak Hour	YES	208.1%
4	Pedestrian Volumes	N/A	N/A
5	School Crossing	N/A	N/A
6	Coordinated Signal System	N/A	N/A
7	Crash Experience	N/A	N/A
8	Roadway Network	N/A	N/A

Total Number of Warrants Met	3

Intersection: WB Off -Ramp and Johnson Lane

Case: Five Mile Road Alignment Year 2035

Date: January 25, 2012

Major Street:	Johnson Lane	Minor Street 1:	WB Off Ramp	Minor Street 2:	
Major Street Dir. (N-S or E-W):	N-S	Minor Street 1 Dir. (N-S or E-W):	E-W	Minor Street 2 Dir. (N-S or E-W):	
		Approach Dir. (EB or WB)	WB	Approach Dir. (EB or WB)	

Major Street Speed Limit: 35 mph — *Major Street 85th % Speed:* 35 mph — *Total Intersection Approaches:* 3

Beginning Hour	Johnson Lane NB	Johnson Lane SB	WB Off Ramp WB	Total Major	High Minor	Total Entering	
7:00 AM	319	745	260	1064	260	1324	
8:00 AM	596	718	232	1314	232	1546	
9:00 AM	333	547	200	880	200	1080	
10:00 AM	364	522	317	886	317	1203	
11:00 AM	396	527	221	923	221	1144	
12:00 AM	500	461	247	961	247	1208	< 8th Highest
1:00 PM	599	442	225	1041	225	1266	
2:00 PM	678	558	245	1236	245	1481	
3:00 PM	689	547	249	1236	249	1485	< 4th Highest
4:00 PM	771	525	249	1296	249	1545	
5:00 PM	856	513	255	1369	255	1624	< Peak Hour
6:00 PM	596	436	223	1032	223	1255	
7:00 PM	429	298	164	727	164	891	
Ave. Weekday Volumes =	8300	8100	4150	16400	4150	20550	

Volume Warrants	Condition A				Condition B			
	Values		Minimums		Values		Minimums	
	Major (Total Entering)	*Minor*	*Major (Total Entering)*	*Minor*	*Major*	*Minor*	*Major*	*Minor*
8th Hour Vehicular Volume Warrant	961	247	500	150	961	247	750	75
4th Hour Vehicular Volume Warrant	1236	260	1236	80				
Peak Hour Vehicular Volume Warrant	1624	255	650	100	1369	255	1369	117
Crash Experience Warrant	961	247	400	120	961	247	600	60
Roadway Network Warrant	1624		(1000)					

Warrant # 1 - Eight-hour Vehicular Volume

Warrant 1 Condition A Met	YES	164.7%
Warrant 1 Condition B Met	YES	128.1%

Warrant # 2 - Four-hour Vehicular Volume

Warrant 2 Conditions Met	YES	325.0%

Warrant # 3 - Peak Hour

Warrant 3 Condition A.1 Met	YES	7765.0%
Warrant 3 Condition A.2 Met	YES	255.0%
Warrant 3 Condition A.3 Met	YES	249.8%
Warrant 3 Condition B Met	YES	160.2%

Warrant # 4 - Pedestrian Volumes

Warrant 4 Condition A Met	N/A	N/A
Warrant 4 Condition B Met	N/A	N/A

Warrant # 5 - School Crossing

Warrant 5 Conditions Met	NA	NA

Warrant # 6 - Coordinated Signal System

Warrant 6 Conditions Met	NO	N/A

Warrant # 7 - Crash Experience

Warrant 7 Condition A Met	NO	N/A
Warrant 7 Condition B Met	NO	N/A
Warrant 7 Condition C Met	NO	N/A

Warrant # 8 - Roadway Network

Warrant 8 Conditions Met	NO	N/A

Warrant Number and Title		*Met*	*Percent Met*
1	Eight-hour Vehicular Volume	YES	128.1%
2	Four-hour Vehicular Volume	YES	325.0%
3	Peak Hour	YES	160.2%
4	Pedestrian Volumes	N/A	N/A
5	School Crossing	N/A	N/A
6	Coordinated Signal System	N/A	N/A
7	Crash Experience	N/A	N/A
8	Roadway Network	N/A	N/A
Total Number of Warrants Met			3

APPENDIX 3

Intersection Capacity with Traffic Signals

HCM Analysis Summary

5 Mile & HWY 312 Secondary Imps	Highway 312/Five Mile Align	Area Type: Non CBD
R Marvin	12/01/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: MARYAL~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	LT	12.0	R	12.0								
SB	1	1	LTR	12.0										

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	5	470	20	150	300	5	30	5	210	5	5	5
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	3	1	2	3	1	3	1	3	1	1	1
Lane Groups	L	TR		L	TR			LT	R		LTR	
Arrival Type	3	3		3	3			3	3		3	
RTOR Vol (vph)	0			0			100			0		
Peds/Hour	0			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 60.0 Sec Lost Time Per Cycle: 11.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		35.0		14.0														0
Yellow	All Red	4.0	2.0	3.5	1.5													

	Capacity Analysis Results								Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	601	0.006	0.583	L	0.010	5.3	A	6.5	A
	TR	2032	0.156	0.583	TR	0.268	6.5	A		
WB										
	* L	488	0.200	0.583	L	0.342	8.4	A	6.8	A
	TR	2039	0.097	0.583	TR	0.166	5.9	A		
NB										
	LT	344	0.026	0.233	LT	0.113	18.2	B	19.0	B
	* R	366	0.078	0.233	R	0.333	19.3	B		
SB										
	LTR	391	0.011	0.233	LTR	0.046	17.8	B	17.8	B

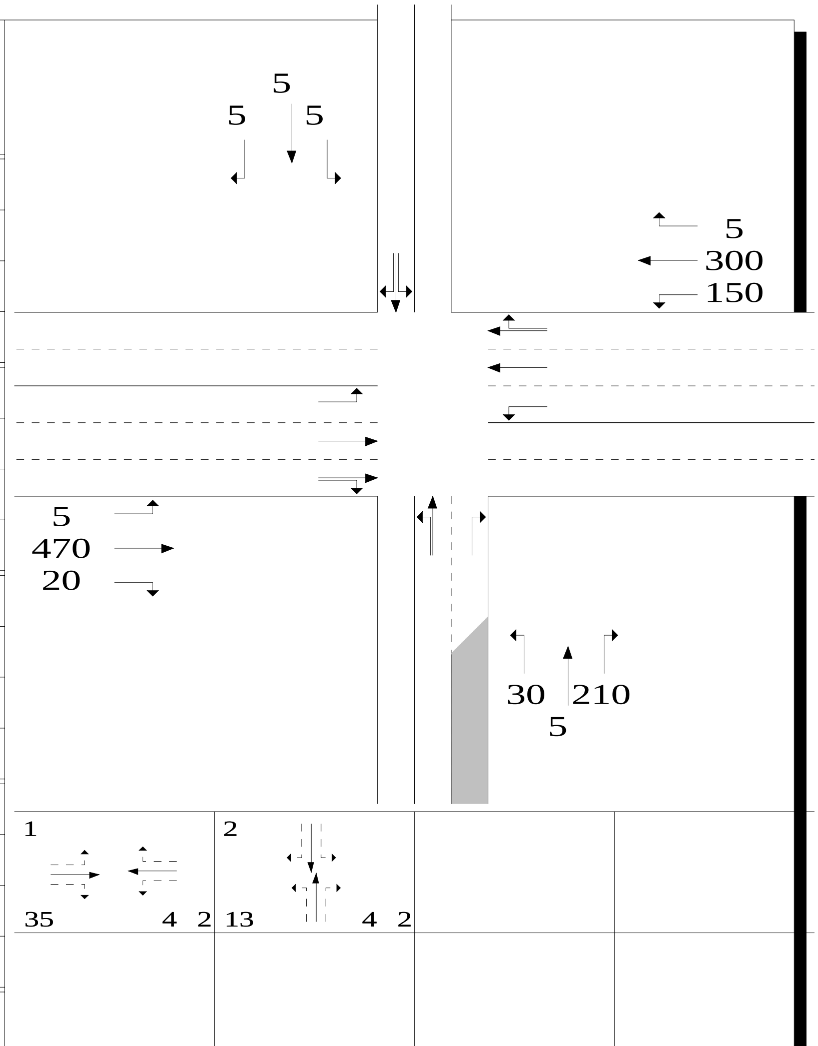
Intersection: Delay = 8.4 sec/veh Int. LOS=A X_c= 0.34 * Critical Lane Group Σ(v/s)Crit= 0.28

NETSIM Summary Results

5 Mile & HWY 312 Secondary Imps
R Marvin
PM Design Hour

Highway 312/Five Mile Align
12/01/2011
Case: MARYAL~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	31.5	0.0
	TR	2 / 4	19.4	0.0
	All		19.4	0.0
WB	L	1 / 3	17.0	0.0
	TR	2 / 2	20.4	0.0
	All		19.3	0.0
NB	LT	0 / 1	21.3	0.0
	R	1 / 3	16.3	0.0
	All		18.7	0.0
SB	LTR	0 / 1	11.8	0.0
	All		11.8	0.0
Intersect.			19.1	



HCM Analysis Summary

Marvin Associates
R Marvin
2035 PM Design Hour

Mary Alignment/Mary Street
02/24/2012
Case: Mary Opt 1_2 Five Mile Signal 2035

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	5	450	5	20	700	230	5	50	20	170	10	5
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	1	1	4	1	1	2	1	4	1	1
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			40			5			0		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 8.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP								
WB	LTP								
NB		LTP							
SB		LTP							
Green	30.0	22.0							0
Yellow / All Red	3.5 / 1.5	1.5 / 1.5							

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	207	0.014	0.500	L	0.029	7.9	A	9.2	A
	TR	1733	0.146	0.500	TR	0.292	9.2	A		
WB										
	L	434	0.025	0.500	L	0.051	7.9	A	12.0	B
	* TR	1695	0.292	0.500	TR	0.583	12.1	B		
NB										
	L	513	0.004	0.367	L	0.012	12.1	B	12.5	B
	TR	659	0.041	0.367	TR	0.111	12.6	B		
SB										
	* L	473	0.146	0.367	L	0.400	14.3	B	14.1	B
	TR	652	0.010	0.367	TR	0.026	12.2	B		

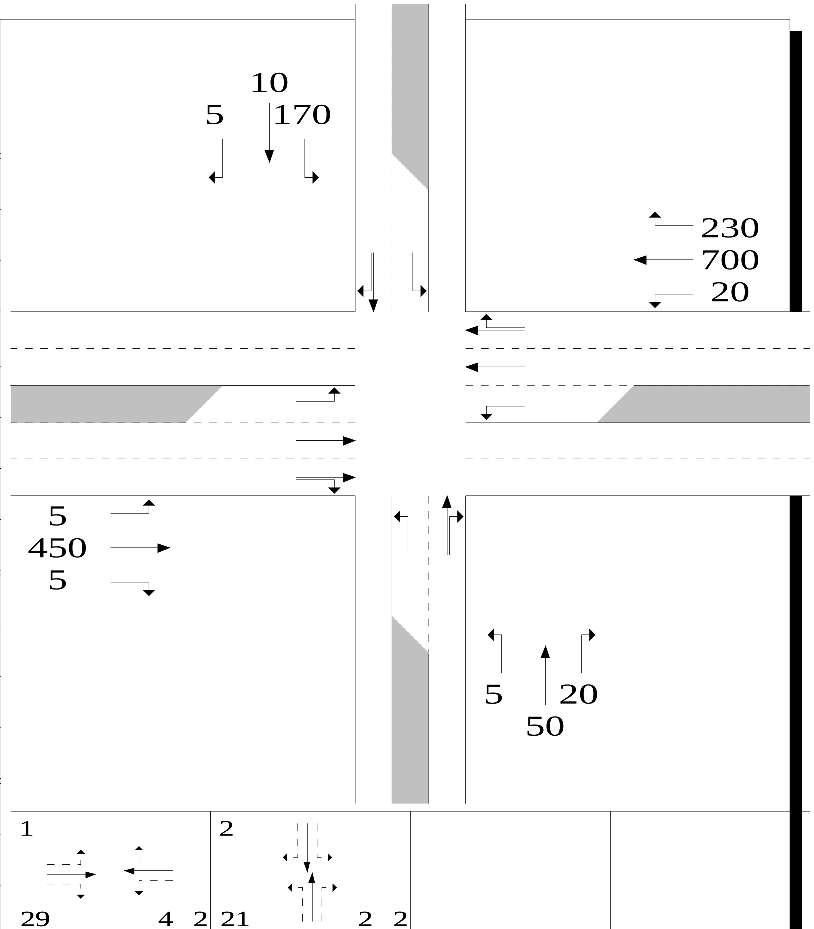
Intersection: Delay = 11.5 sec/veh   Int. LOS=B X_c = 0.51   * Critical Lane Group   Σ(v/s)Crit= 0.44

NETSIM Summary Results

Marvin Associates
R Marvin
2035 PM Design Hour

Mary Alignment/Mary Street
02/24/2012
Case: Mary Opt 1_2 Five Mile Signal 2035

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	27.4	0.0
	TR	3 / 4	17.8	0.0
	All		17.8	0.0
WB	L	0 / 1	12.5	0.0
	TR	5 / 6	15.2	0.0
	All		15.2	0.0
NB	L	0 / 1	6.5	0.0
	TR	1 / 1	18.1	0.0
	All		17.3	0.0
SB	L	2 / 3	9.2	0.0
	TR	0 / 1	24.3	0.0
	All		13.8	0.0
Intersect.			15.8	



HCM Analysis Summary

Mary Alignment Bitteroot Alt A
R Marvin
Design Hour PM

Mary Alignment/Bitteroot
11/29/2011
Case: Mary Align & Bitteroot Alt A 2035 PM

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	2	1	L	12.0	TR	12.0								
SB	2	1	L	12.0	TR	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	10	360	10	110	520	50	20	110	95	40	50	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	4	0	0	4	1	0	1	0	0	1	0
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	0			10			25			5		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 60.0 Sec Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		32.0		18.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	401	0.015	0.533	L	0.027	6.8	A	7.7	A
	TR	1844	0.119	0.533	TR	0.223	7.7	A		
WB										
	L	516	0.126	0.533	L	0.236	8.6	A	8.5	A
	* TR	1831	0.181	0.533	TR	0.340	8.5	A		
NB										
	L	399	0.017	0.300	L	0.055	15.0	B	16.6	B
	* TR	530	0.113	0.300	TR	0.377	16.7	B		
SB										
	L	354	0.037	0.300	L	0.124	15.3	B	15.4	B
	TR	535	0.047	0.300	TR	0.157	15.5	B		

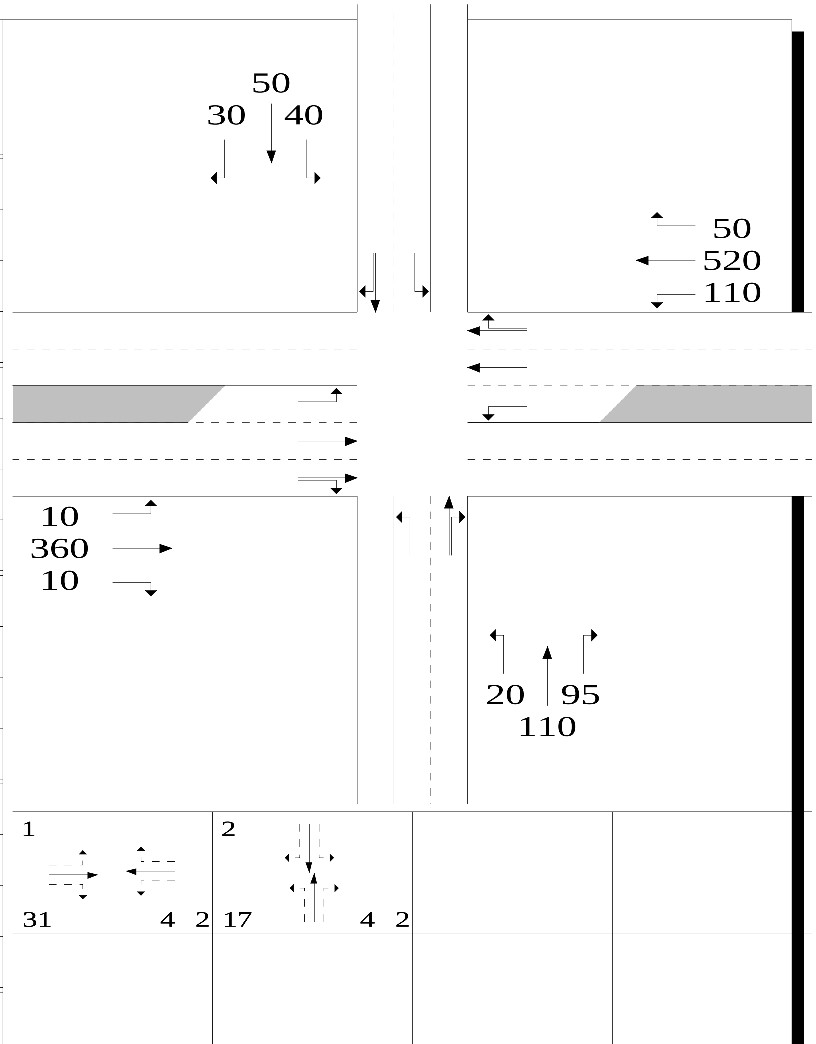
Intersection: Delay = 10.0 sec/veh Int. LOS=B X_c= 0.35 * Critical Lane Group Σ(v/s)Crit= 0.29

NETSIM Summary Results

Mary Alignment Bitteroot Alt A
R Marvin
Design Hour PM

Mary Alignment/Bitteroot
11/29/2011
Case: Mary Align & Bitteroot Alt A 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	28.9	0.0
	TR	2 / 3	18.1	0.0
	All		18.2	0.0
WB	L	1 / 2	14.4	0.0
	TR	3 / 4	17.6	0.0
	All		17.4	0.0
NB	L	0 / 1	12.5	0.0
	TR	2 / 3	17.7	0.0
	All		17.1	0.0
SB	L	1 / 2	12.5	0.0
	TR	1 / 2	17.3	0.0
	All		15.1	0.0
Intersect.			17.3	



HCM Analysis Summary

Year 2035 Mary Op1 Alt	N Frontage Rd/Johnson Lane	Area Type: Non CBD
R Marvin	10/20/11	Analysis Duration: 15 mins.
Peak PM	Case: N Frtg Johnson Mary Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	3	2	L	12.0	T	12.0	TR	12.0						
SB	3	2	L	12.0	T	12.0	TR	12.0						

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	155	25	210	25	20	5	190	930	30	5	700	100
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	4	2	8	2	2	2	8	4	2	2	4	2
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	40			0			5			30		
Peds/Hour	0			5			5			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 80.0 Sec Lost Time Per Cycle: 8.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTR		LTP												
SB						LTP												
Green		24.0		12.0		36.0												0
Yellow	All Red	0.0	0.0	3.0	0.0	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	389	0.130	0.300	L	0.432	22.8	C	22.9	C
	* TR	463	0.137	0.300	TR	0.458	23.0	C		
WB										
	L	241	0.034	0.300	L	0.112	20.4	C	20.1	C
	TR	543	0.015	0.300	TR	0.050	19.9	B		
NB	Lper	198	0.000	0.512					8.6	A
	* Lpro	251	0.124	0.150	L	0.461	10.5	B		
	TR	2204	0.300	0.637	TR	0.471	8.2	A		
SB										
	L	231	0.010	0.450	L	0.022	12.4	B	17.4	B
	* TR	1541	0.244	0.450	TR	0.543	17.4	B		

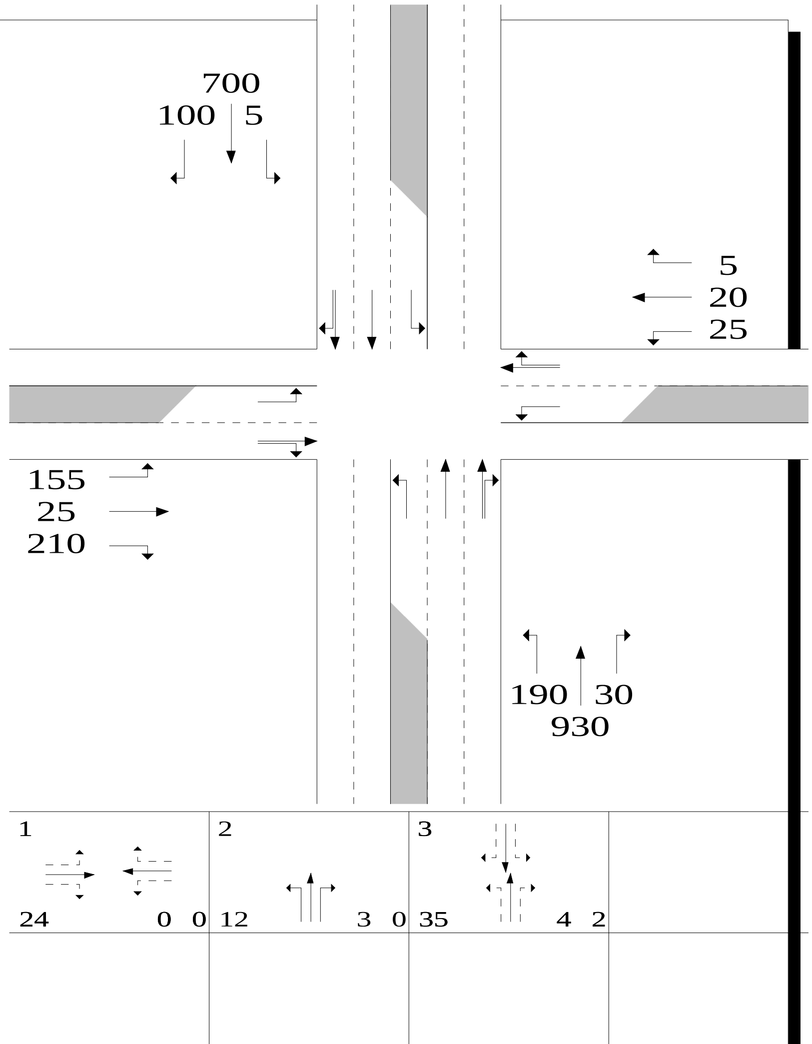
Intersection: Delay = 13.9 sec/veh Int. LOS=B X_c= 0.56 * Critical Lane Group Σ(v/s)Crit= 0.51

NETSIM Summary Results

Year 2035 Mary Op1 Alt
R Marvin
Peak PM

N Frontage Rd/Johnson Lane
10/20/11
Case: N Frtg Johnson Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	4 / 6	6.3	0.0
	TR	2 / 4	20.8	0.0
	All		13.2	0.0
WB	L	0 / 1	6.9	0.0
	TR	1 / 1	15.1	0.0
	All		12.2	0.0
NB	L	3 / 5	9.0	0.0
	TR	5 / 7	17.4	0.0
	All		15.6	0.0
SB	L	0 / 1	19.7	0.0
	TR	5 / 7	14.2	0.0
	All		14.3	0.0
Intersect.			14.6	



HCM Analysis Summary

Five Mile Align HWY 312 | Highway 312/Five Mile Align | Area Type: Non CBD
R Marvin | 12/01/2011 | Analysis Duration: 15 mins.
PM design Hour | Case: Five Mile Align 312 PM 2035

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	T	12.0	TR	12.0						
NB	3	1	L	12.0	T	12.0	R	12.0						
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	5	470	20	160	310	5	30	5	230	5	5	5
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	3	1	2	3	1	3	1	3	1	1	1
Lane Groups	L	TR		L	TR		L	T	R		LTR	
Arrival Type	3	3		3	3		3	3	3		3	
RTOR Vol (vph)	0			0			100			0		
Peds/Hour	0			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 60.0 Sec | Lost Time Per Cycle: 11.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		35.0		14.0														0
Yellow	All Red	4.0	2.0	3.5	1.5													

	Capacity Analysis Results								Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	595	0.006	0.583	L	0.010	5.3	A	6.5	A
	TR	2032	0.156	0.583	TR	0.268	6.5	A		
WB										
	* L	488	0.213	0.583	L	0.365	8.7	A	6.9	A
	TR	2039	0.100	0.583	TR	0.172	6.0	A		
NB										
	L	321	0.024	0.233	L	0.103	18.1	B	19.3	B
	T	439	0.003	0.233	T	0.014	17.7	B		
	* R	366	0.092	0.233	R	0.393	19.7	B		
SB										
	LTR	393	0.011	0.233	LTR	0.046	17.8	B	17.8	B

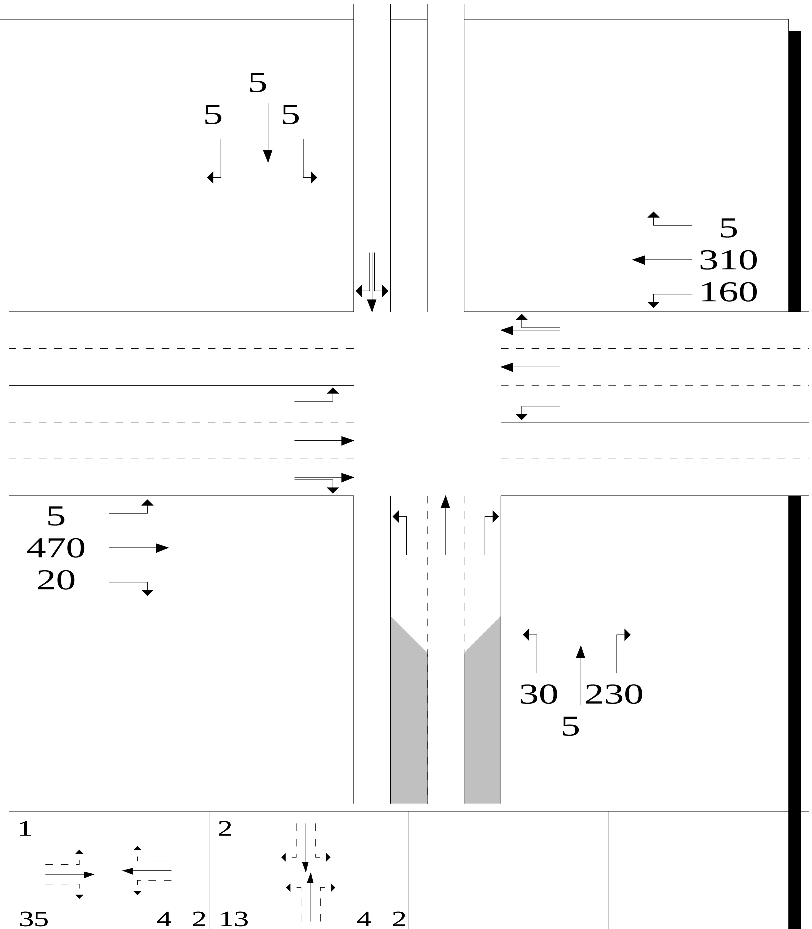
Intersection: Delay = 8.7 sec/veh   Int. LOS=A X_c= 0.37   * Critical Lane Group Σ(v/s)Crit= 0.30

NETSIM Summary Results

Five Mile Align HWY 312
R Marvin
PM design Hour

Highway 312/Five Mile Align
12/01/2011
Case: Five Mile Align 312 PM 2035

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 0	31.5	0.0
	TR	2 / 3	19.6	0.0
	All		19.6	0.0
WB	L	1 / 2	17.3	0.0
	TR	2 / 3	19.7	0.0
	All		19.0	0.0
NB	L	0 / 1	8.1	0.0
	T	0 / 1	24.6	0.0
	R	1 / 3	16.2	0.0
	All		18.2	0.0
SB	LTR	0 / 1	11.8	0.0
	All		11.8	0.0
Intersect.			19.0	



HCM Analysis Summary

Five Mile Align & Mary Signal | Mary Street/Five Mile Align | Area Type: Non CBD
R Marvin | 02/24/2012 | Analysis Duration: 15 mins.
2035 PM Design Hour | Case: Five Mile Align Mary Signal 2035

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	0	L	12.0	R	12.0								
WB	0	1												
NB	3	2	L	12.0	T	12.0	T	12.0						
SB	2	2	T	12.0	TR	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	30	0	330	0	0	0	500	280	0	0	190	30
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	2	2	4	2	2	2	4	2	2	2	2	4
Lane Groups	L		R				L	T			TR	
Arrival Type	3		3				3	3			3	
RTOR Vol (vph)	150			0			0			5		
Peds/Hour	0			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 65.0 Sec | Lost Time Per Cycle: 14.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	L P																
WB																	
NB			LT		T												
SB					TP												
Green	12.0		29.0		10.0												0
Yellow | All Red	3.5	1.5	4.0	0.0	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	327	0.019	0.185	L	0.101	22.1	C	29.6	C
	* R	287	0.129	0.185	R	0.697	30.9	C		
NB										
	* L	775	0.320	0.446	L	0.717	17.4	B	12.7	B
	T	2341	0.088	0.662	T	0.133	4.2	A		
SB										
	* TR	534	0.069	0.154	TR	0.448	27.7	C	27.7	C

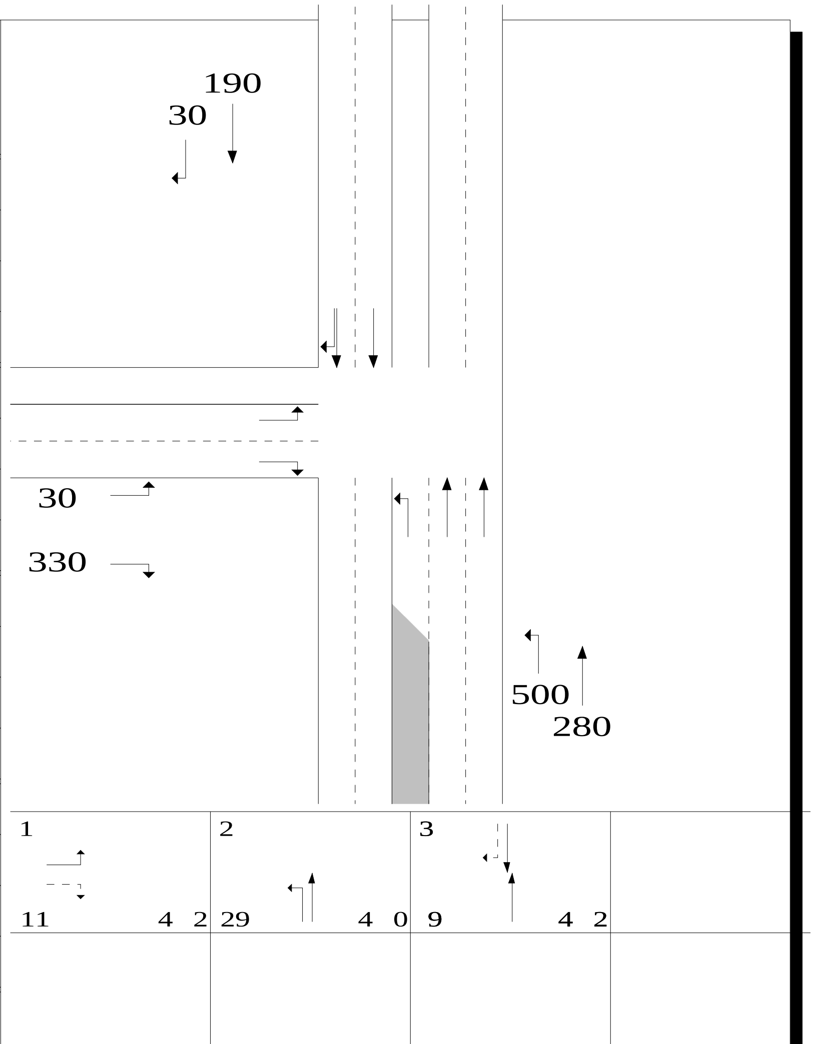
Intersection: Delay = 18.3 sec/veh | Int. LOS=B | X_c= 0.66 | * Critical Lane Group | Σ(v/s)Crit= 0.52

NETSIM Summary Results

Five Mile Align & Mary Signal
R Marvin
2035 PM Design Hour

Mary Street/Five Mile Align
02/24/2012
Case: Five Mile Align Mary Signal 2035

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	1 / 1	14.2	0.0
	R	1 / 2	22.9	0.0
	All		21.6	0.0
	All		14.7	0.0
NB	L	7 / 9	8.7	0.0
	T	1 / 2	24.3	0.0
	All		12.3	0.0
SB	TR	2 / 3	12.3	0.0
Intersect.			15.5	



HCM Analysis Summary

Five Mile Align 2035 Secondary Imp	Mary Street/Bitteroot	Area Type: Non CBD
R Marvin	12/19/2011	Analysis Duration: 15 mins.
Pm Design Hour	Case: FIVEMI~1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	1	1	LTR	12.0										
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	20	310	50	80	390	60	50	100	80	40	60	10
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	4	0	0	4	0	0	1	0	0	1	0
Lane Groups	L	TR		L	TR			LTR			LTR	
Arrival Type	3	3		3	3			3			3	
RTOR Vol (vph)	10			10			30			5		
Peds/Hour	5			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 60.0 Sec   Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP														
SB				LTP														
Green		33.0		17.0														0
Yellow	All Red	3.5	1.5	3.5	1.5													

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	L	437	0.028	0.550	L	0.050	6.5	A	8.7	A
	TR	997	0.210	0.550	TR	0.381	8.8	A		
WB										
	L	521	0.092	0.550	L	0.167	7.4	A	9.5	A
	* TR	997	0.264	0.550	TR	0.479	9.9	A		
NB										
	* LTR	465	0.132	0.283	LTR	0.467	18.0	B	18.0	B
SB										
	LTR	442	0.072	0.283	LTR	0.256	16.7	B	16.7	B

Intersection: Delay = 11.3 sec/veh   Int. LOS=B X_c= 0.48   * Critical Lane Group Σ(v/s)Crit= 0.40

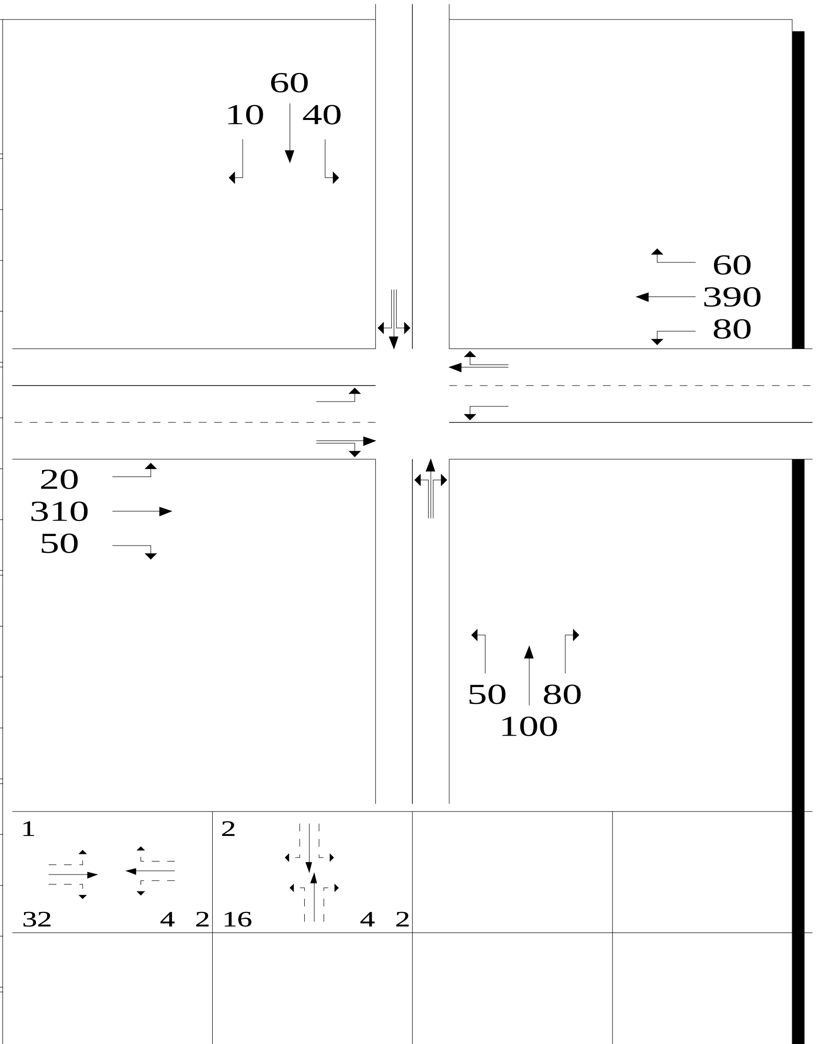
SIG/Cinema v3.08

NETSIM Summary Results

Five Mile Align 2035 Secondary Imp
R Marvin
Pm Design Hour

Mary Street/Bitteroot
12/19/2011
Case: FIVEMI~1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	0 / 1	24.7	0.0
	TR	4 / 5	16.7	0.0
	All		17.0	0.0
WB	L	1 / 2	17.8	0.0
	TR	5 / 6	17.2	0.0
	All		17.2	0.0
NB	LTR	2 / 3	14.3	0.0
	All		14.3	0.0
SB	LTR	2 / 2	12.2	0.0
	All		12.2	0.0
Intersect.			16.0	



HCM Analysis Summary

Year 2035 Five Mile Align	N Frontage Rd/Johnson Lane	Area Type: Non CBD
R Marvin	02/24/12	Analysis Duration: 15 mins.
Peak PM	Case: Five Mile Align N Frtg Signal 2035	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	3	2	L	12.0	T	12.0	TR	12.0						
SB	3	2	L	12.0	T	12.0	TR	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	135	25	215	25	20	5	190	785	30	5	600	90
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	4	2	8	2	2	2	8	4	2	2	4	2
Lane Groups	L	TR		L	TR		L	TR		L	TR	
Arrival Type	3	3		3	3		3	3		3	3	
RTOR Vol (vph)	40			0			5			20		
Peds/Hour	0			5			5			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 80.0 Sec — Lost Time Per Cycle: 8.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP																
WB	LTP																
NB			LTR		LTP												
SB					LTP												
Green	24.0		12.0		36.0												0
Yellow / All Red	0.0	0.0	3.0	0.0	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	389	0.113	0.300	L	0.378	22.3	C	22.8	C
	* TR	463	0.141	0.300	TR	0.469	23.1	C		
WB										
	L	237	0.034	0.300	L	0.114	20.4	C	20.1	C
	TR	543	0.015	0.300	TR	0.050	19.9	B		
NB	Lper	240	0.000	0.512					7.9	A
	* Lpro	251	0.124	0.150	L	0.422	9.1	A		
	TR	2203	0.255	0.637	TR	0.399	7.6	A		
SB										
	L	270	0.008	0.450	L	0.019	12.3	B	16.4	B
	* TR	1538	0.213	0.450	TR	0.473	16.4	B		

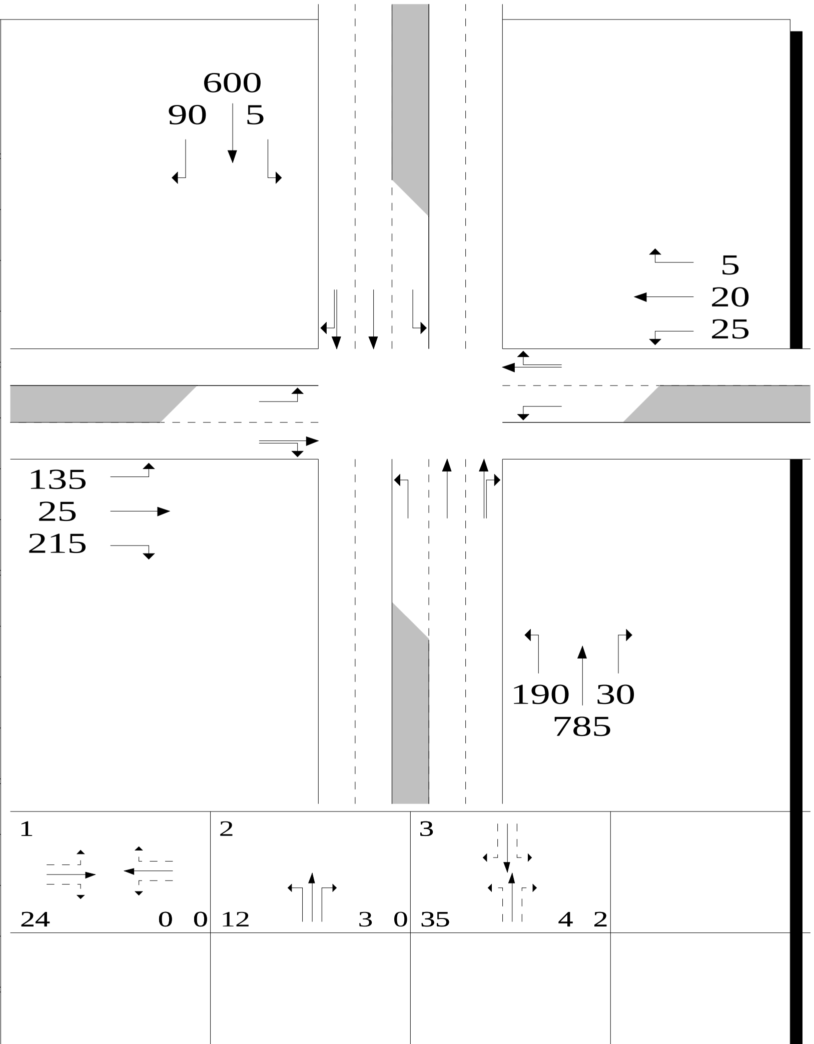
Intersection: Delay = 13.4 sec/veh — Int. LOS=B — X_c= 0.53 — * Critical Lane Group — Σ(v/s)Crit= 0.48

SIG/Cinema v3.08

NETSIM Summary Results

Year 2035 Five Mile Align	N Frontage Rd/Johnson Lane
R Marvin	02/24/12
Peak PM	Case: Five Mile Align N Frtg Signal 2035

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	3 / 5	6.7	0.0
	TR	3 / 5	18.2	0.0
	All		13.4	0.0
WB	L	0 / 1	6.7	0.0
	TR	1 / 1	15.5	0.0
	All		12.3	0.0
NB	L	3 / 5	10.8	0.0
	TR	3 / 7	20.3	0.0
	All		18.2	0.0
SB	L	0 / 1	11.6	0.0
	TR	4 / 6	14.4	0.0
	All		14.4	0.0
Intersect.			15.7	



APPENDIX 4

Alternative Intersection Control

Roundabout Capacity

LANE SUMMARY

Site: Mary Alignment Option 1
Intersection with Five Mile adn
Mary Street

Mary Alignment Option 1
Intersection of Mary Alignment with Mary Street & Five Mile Road
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Mary Street NB																
Lane 1	5	54	22	82	0.0	681	0.120	100	8.2	LOS A	0.5	12.0	1600	–	0.0	0.0
Approach	5	54	22	82	0.0		0.120		8.2	LOS A	0.5	12.0				
East: Mary Alignment WB																
Lane 1	22	460	0	482	3.8	1335	0.361	100	5.1	LOS A	2.6	67.0	1600	–	0.0	0.0
Lane 2	0	301	250	551	3.1	1528	0.361	100	5.3	LOS A	2.6	67.6	1600	–	0.0	0.0
Approach	22	761	250	1033	3.4		0.361		5.2	LOS A	2.6	67.6				
North: Five Mile Road SB																
Lane 1	185	11	5	201	1.9	627	0.321	100	15.9	LOS B	1.4	35.0	1600	–	0.0	0.0
Approach	185	11	5	201	1.9		0.321		15.9	LOS B	1.4	35.0				
West: Mary Alignment EB																
Lane 1	5	220	0	226	3.9	1101	0.205	100	5.8	LOS A	1.2	31.5	1600	–	0.0	0.0
Lane 2	0	247	5	252	3.9	1231	0.205	100	5.4	LOS A	1.3	32.2	1600	–	0.0	0.0
Approach	5	467	5	478	3.9		0.205		5.6	LOS A	1.3	32.2				
Intersection				1793	3.2		0.361		6.6	LOS A	2.6	67.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

LANE SUMMARY

Site: Mary Alignment Option 2
Intersection with Five Mile & Mary Street

Mary Alignment Option 2
Intersection of Mary Alignment with Mary Street & Five Mile Road
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Mary Street NB																
Lane 1	5	54	22	82	0.0	676	0.121	100	8.2	LOS A	0.5	12.1	1600	–	0.0	0.0
Approach	5	54	22	82	0.0		0.121		8.2	LOS A	0.5	12.1				
East: Mary Alignment WB																
Lane 1	22	450	0	471	3.8	1335	0.353	100	5.1	LOS A	2.5	65.1	1600	–	0.0	0.0
Lane 2	0	289	250	539	3.1	1527	0.353	100	5.3	LOS A	2.6	65.7	1600	–	0.0	0.0
Approach	22	739	250	1011	3.4		0.353		5.2	LOS A	2.6	65.7				
North: Five Mile Road SB																
Lane 1	185	11	5	201	1.9	634	0.317	100	15.8	LOS B	1.4	34.3	1600	–	0.0	0.0
Approach	185	11	5	201	1.9		0.317		15.8	LOS B	1.4	34.3				
West: Mary Alignment EB																
Lane 1	5	225	0	231	3.9	1101	0.210	100	5.8	LOS A	1.3	32.3	1600	–	0.0	0.0
Lane 2	0	253	5	258	3.9	1232	0.210	100	5.4	LOS A	1.3	33.1	1600	–	0.0	0.0
Approach	5	478	5	489	3.9		0.210		5.6	LOS A	1.3	33.1				
Intersection				1783	3.2		0.353		6.6	LOS A	2.6	65.7				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

LANE SUMMARY

Site: Mary Alignment Bitteroot Alt B 2035 PM

Mary Street Alignment Bitteroot Alternative B
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Bitteroot NB																
Lane 1	22	120	103	245	0.0	778	0.314	100	4.7	LOS A	1.4	35.5	200	–	0.0	0.0
Approach	22	120	103	245	0.0		0.314		4.7	LOS A	1.4	35.5				
East: Mary Alignment WB																
Lane 1	120	234	0	353	2.6	1201	0.294	100	7.9	LOS A	1.9	48.5	1600	–	0.0	0.0
Lane 2	0	331	54	386	3.4	1311	0.294	100	5.3	LOS A	1.9	49.6	1600	–	0.0	0.0
Approach	120	565	54	739	3.1		0.294		6.6	LOS A	1.9	49.6				
North: Bitteroot SB																
Lane 1	43	54	33	130	0.3	661	0.197	100	6.9	LOS A	0.8	19.8	1600	–	0.0	0.0
Approach	43	54	33	130	0.3		0.197		6.9	LOS A	0.8	19.8				
West: Mary Alignment EB																
Lane 1	11	184	0	195	3.8	1125	0.174	100	5.9	LOS A	0.9	24.5	1600	–	0.0	0.0
Lane 2	0	207	11	218	3.8	1255	0.174	100	5.4	LOS A	1.0	24.9	1600	–	0.0	0.0
Approach	11	391	11	413	3.8		0.174		5.7	LOS A	1.0	24.9				
Intersection				1527	2.5		0.314		6.0	LOS A	1.9	49.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

LANE SUMMARY

Site: North Frontage Road & Johnson Lane Year 2035 PM

N Frontage Johnson Lane Year 2035 PM
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	T veh/h	R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Johnson NB																
Lane 1	207	385	0	591	4.3	1075	0.550	100	6.0	LOS A	4.8	124.2	1600	–	0.0	0.0
Lane 2	0	626	33	659	4.0	1198	0.550	100	3.6	LOS A	4.9	127.4	1600	–	0.0	0.0
Approach	207	1011	33	1250	4.1		0.550		4.7	LOS A	4.9	127.4				
East: N Frontage WB																
Lane 1	27	22	5	54	1.0	369	0.147	100	11.9	LOS B	0.6	15.5	1600	–	0.0	0.0
Approach	27	22	5	54	1.0		0.147		11.9	LOS B	0.6	15.5				
North: Johnson SB																
Lane 1	5	411	0	417	4.0	1033	0.404	100	3.9	LOS A	2.8	72.3	1600	–	0.0	0.0
Lane 2	0	350	109	458	4.0	1135	0.404	100	3.9	LOS A	2.9	73.9	1600	–	0.0	0.0
Approach	5	761	109	875	4.0		0.404		3.9	LOS A	2.9	73.9				
West: N Frontage EB																
Lane 1	168	33	228	429	4.3	532	0.807	100	18.0	LOS B	7.0	180.6	1600	–	0.0	0.0
Approach	168	33	228	429	4.3		0.807		18.0	LOS B	7.0	180.6				
Intersection				2609	4.0		0.807		6.8	LOS A	7.0	180.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

LANE SUMMARY

Site: Five Mile Road Alignment
HWY 312 Intersection

Five Mile Road Alignment
Highway 312 Intersection Year 2035 PM Design Hour
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Five Mile Road NWB																
Lane 1	33	5	0	38	3.6	480	0.079	28[5]	15.4	LOS B	0.3	7.3	1600	–	0.0	0.0
Lane 2	0	0	250	250	3.0	891	0.281	100	7.9	LOS A	1.2	31.8	1600	–	0.0	0.0
Approach	33	5	250	288	3.1		0.281		8.9	LOS A	1.2	31.8				
North East: HWY 312 SWB																
Lane 1	174	74	0	248	3.0	1335	0.186	100	10.2	LOS B	1.1	28.1	1600	–	0.0	0.0
Lane 2	0	263	5	268	3.0	1445	0.186	100	4.5	LOS A	1.1	28.4	1600	–	0.0	0.0
Approach	174	337	5	516	3.0		0.186		7.3	LOS A	1.1	28.4				
North West: Access Road SEB																
Lane 1	5	5	5	16	1.0	753	0.022	100	8.1	LOS A	0.1	1.9	1600	–	0.0	0.0
Approach	5	5	5	16	1.0		0.022		8.1	LOS A	0.1	1.9				
South West: HWY 312 NEB																
Lane 1	5	249	0	254	3.0	1172	0.217	100	5.5	LOS A	1.2	31.0	1600	–	0.0	0.0
Lane 2	0	262	22	284	3.0	1310	0.217	100	5.3	LOS A	1.2	31.5	200	–	0.0	0.0
Approach	5	511	22	538	3.0		0.217		5.4	LOS A	1.2	31.5				
Intersection				1359	3.0		0.281		6.9	LOS A	1.2	31.8				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

LANE SUMMARY

Site: Five Mile Road Alignment
Mary Street Intersection

Five Mile Road Alignment
Mary Street Intersection Year 2035 PM Design Hour
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South East: Five Mile Align NWB																
Lane 1	543	0	0	543	4.0	1600	0.340	100	12.5	LOS B	2.4	61.6	1600	–	0.0	0.0
Lane 2	0	304	0	304	3.0	1320	0.231	68[5]	4.5	LOS A	1.4	36.0	1600	–	0.0	0.0
Approach	543	304	0	848	3.6		0.340		9.7	LOS A	2.4	61.6				
North West: Five Mile Align SEB																
Lane 1	0	109	0	109	2.0	853	0.128	100	7.5	LOS A	0.7	17.8	1600	–	0.0	0.0
Lane 2	0	98	33	130	1.7	1018	0.128	100	7.3	LOS A	0.7	18.7	1600	–	0.0	0.0
Approach	0	207	33	239	1.9		0.128		7.4	LOS A	0.7	18.7				
South West: Mary Street NEB																
Lane 1	33	0	0	33	1.0	638	0.051	100	14.0	LOS B	0.2	5.1	200	–	0.0	0.0
Lane 2	0	0	359	359	3.0	1087	0.330	100	6.8	LOS A	1.8	46.1	200	–	0.0	0.0
Approach	33	0	359	391	2.8		0.330		7.4	LOS A	1.8	46.1				
Intersection				1478	3.1		0.340		8.7	LOS A	2.4	61.6				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

5 Lane underutilisation determined by program

SIDRA INTERSECTION

LANE SUMMARY

Site: Five Mile Align Secondary Mary & Bitterroot

Five Mile Alignment Secondary Mary & Bitterroot 2035
Roundabout

Lane Use and Performance

	Demand Flows L veh/h	Demand Flows T veh/h	Demand Flows R veh/h	Total veh/h	HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Lane Length ft	SL Type	Cap. Adj. %	Prob. Block. %
South: Bitteroot NB																
Lane 1	54	109	87	250	0.0	763	0.328	100	6.1	LOS A	1.7	43.6	200	–	0.0	0.0
Approach	54	109	87	250	0.0		0.328		6.1	LOS A	1.7	43.6				
East: Mary Street WB																
Lane 1	87	424	65	576	2.9	1023	0.563	100	6.1	LOS A	4.7	121.5	1600	–	0.0	0.0
Approach	87	424	65	576	2.9		0.563		6.1	LOS A	4.7	121.5				
North: Bitteroot SB																
Lane 1	43	65	11	120	0.4	641	0.187	100	7.6	LOS A	0.9	23.8	1600	–	0.0	0.0
Approach	43	65	11	120	0.4		0.187		7.6	LOS A	0.9	23.8				
West: Mary Street EB																
Lane 1	22	337	54	413	3.3	1016	0.407	100	5.2	LOS A	2.8	70.8	1600	–	0.0	0.0
Approach	22	337	54	413	3.3		0.407		5.2	LOS A	2.8	70.8				
Intersection				1359	2.3		0.563		6.0	LOS A	4.7	121.5				

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

BILLINGS BYPASS EIS
NCPD 56(55)CN 4199

SECTION 4: Lighting Warrant Study Report

Billings Bypass

April, 2012

MONTANA MDT DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

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LIGHTING WARRANTS

Specific empirical criteria for roads and streets other than freeways are not readily available in either the MDT "Traffic Engineering Manual – Chapter Thirteen- Highway Lighting Design" or in AASHTO's "An Informational Guide for Roadway Lighting". Inclusion of lighting on MDT facilities is normally considered when lighting is economically feasible and an agreement with local agencies can be reached to install and maintain lighting. The MDT "Traffic Engineering Manual" presents seven considerations in the assessment of lighting needs on streets and highways other than freeways.

1. *Facilities With Raised Medians* – The proposed design section along the alternative alignments would not have raised medians throughout the length of the project, but would have curb & gutter at certain locations, specifically at roundabout intersection approaches and at intersections where raised medians or curb would be used to control access. There would also be curbed sections on secondary improvements to Mary Street associated with the Five Mile Road Alternative Alignment.
2. *Major Urban Arterials* - The project's alternative alignments north of the Yellowstone River Bridge would be considered as Major Urban Arterials. Mary Street is currently classified as a Principal Arterial Street within the Billings Transportation Plan.
3. *Intersections* - There are a number of intersections within the project alignments corridors. Due to multi-lane operation and relatively varying degrees of complexity at these intersections, lighting would enhance nighttime safety at all public street intersection locations. All roundabouts within curbed areas should have lighting, and consideration should be given to approach lighting at signalized intersections.
4. *High Conflict Locations* – Conflicts within the project corridor are generally limited to areas near intersections. While there are no specific limits associated with "high conflict locations", anticipated potential for conflict within the Urban Arterial sections would be substantially higher than for the rural portions of the project.

Roadway illumination would be justified at public street intersections and at locations where there are pedestrian and/or bicycle crossings. Continuous lighting along Mary Street as a secondary improvement associated with the Five Mile alternative should be considered because bike lanes would exist along the roadway with numerous existing driveways.

5. *Complex Roadway Geometry* – Geometric conditions within the majority of the project alignments would involve extended horizontal tangents and sweeping curves. The most complex geometries would occur at the interchange areas and at public street intersections, which would be illuminated as indicated above.
6. *Night/Day Accident Ratio* - The nighttime accident rate is not expected to be substantially greater than the daytime rate on any of the alignments and the night/day accident rate would not be a consideration for lighting on any of the alignments.
7. *Local Agency Needs* – The perceived benefits of lighting along this corridor do not provide an overwhelming justification for the inclusion of lighting throughout the entire corridor, yet some benefits could be realized by providing continuous lighting. Local governments and agencies still must be contacted and the needs and fiscal requirements of the lighting system must be agreed upon.

Johnson Lane Interchange

Warranting conditions for full and partial interchange lighting are detailed in both the AASHTO publication "An Informational Guide for Roadway Lighting" and the MDT "Traffic Engineering Manual". The existing interchange has continuous lighting on the crossroad (Johnson Lane) and standard gore area lighting (three luminaires) on Interstate 90. Continuous freeway lighting is generally not justified nor provided at MDT interchanges and the mainline traffic projections of 27,500 ADT west of Johnson Lane would not meet the 30,000 ADT criteria for continuous lighting. The following table presents the design year values for this interchange, which includes all proposed alternatives, and the minimum warranting values for partial interchange lighting:

Complete Interchange Lighting (Urban)

Criteria	**Design Value**	**Warrant Min.**	**Met?**
1 - Ramp Volume (2035 ADT)	8000	5000	Yes
2 – Crossroad Volume (2035 ADT)	22000	10000	Yes
3 - Land Development/ Lighting Conditions			Yes
4 – Night/Day Accident Ratio	na	na	No
5 – Local Agency Needs			?
6 – Continuous Freeway Lighting (2035 ADT)	27,500	30000	No

It can be seen that partial interchange lighting can be justified by virtue of the volume criteria and adjacent land development. Local needs will be considered to the extent of lighting that is desired at this location. Because of unique geometric conditions associated with some of the interchange design options, continuous lighting along the ramp sections should be considered, and all sections on the ramps and crossroads that have curb & gutter sections and/or raised medians should be illuminated.

LIGHTING DESIGN CRITERIA & RECOMMENDATIONS

Lighting criteria within the project will conform to AASHTO and MDT standards for roadway lighting. MDT standards require that "illuminance" criteria be used on state roadways. Figure 13.6B in the "Traffic Engineering Manual" indicates the appropriate lighting illuminance for sections of urban roadway. Where lighting is required, as previously noted, the roadway classification should be considered as Principal Urban Arterials. Residential areas would be along Mary Street as a secondary improvement associated with the Five Mile Road Alignment. Intersections on the Mary Street Alignment at US 87 would be considered Intermediate areas, and lighting along the Johnson Lane corridor would be considered Commercial areas.

Design criteria contained within the MDT Traffic Engineering manual shall be used to determine mounting height, pole spacing and luminaire type and distribution. With the recent advances in LEDs, use of LED luminaires should be considered as an option in final design. The design options should conform to MDT and AASHTO standards with regard to average foot-candles and uniformity ratios. Replacement of existing street lighting installation should be considered to match the light source and illumination levels of the new lighting system to provide a uniform appearance.

BILLINGS BYPASS EIS
NCPD 56(55)CN 4199

SECTION 5
FEIS Traffic Study Report

Billings Bypass

August 2013

MONTANA MDT DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

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INTRODUCTION

This report was prepared as a part of the Final Environmental Impact Statement (FEIS) and addresses traffic and transportation issues related to two-lane operations that would be associated with Phase 1 of the Billings Bypass Project NCPD 56(55) CN 4199. Traffic and transportation analysis addressed within this report are based upon operational differences between Phase 1 (two-lane) and the Full Buildout (aka Phase 2 or four-lane) alignments contained in the Draft Environmental Impact Study (DEIS) Traffic Report. Future design year (2035) traffic projections for Phase 1 alignment alternatives are presented along with traffic analysis results associated with existing and proposed alternative roadways and intersections.

This report is intended to supplement the data and analysis summarized in the Preliminary Traffic Study Report and is included as an extension of that report. Thus, this report does not include detailed descriptions of existing and future street systems, statistics, or analysis methods that have already been addressed in the DEIS Traffic Report.

All of the design alternatives presented within this report are based upon two-lane traffic operations and would provide acceptable operating conditions until the end of the Phase 1 useful design life, in the year 2035. It has been assumed that, Full Buildout improvements would be planned and construction of the four-lane roadway sections would commence on or before the year 2035.

PHASE 1 TRAFFIC PROJECTIONS

Traffic projection methodology that was used for the Full Buildout alternative alignments was also used for the Phase 1 two-lane traffic projections. Within that methodology travel time is the primary variable that determines travel route choice. Vehicular trips are assigned to the route with the least travel time. Therefore, the difference in travel time between two-lane and four-lane operations is directly related to the difference in Bypass travel demand. Travel time differences were input directly to the traffic model and traffic projections related to Phase 1 alignments were calculated.

Phase 1 – Alignment Travel Times

The analysis of travel time calculations associated with Phase 1, two-lane operations, was performed for each of the three Bypass alignment alternatives detailed in the Draft EIS. The average two-lane travel speeds and travel times presented herein are based upon a number of qualified assumptions that are commensurate with the basic parameters used within the Draft EIS traffic model for four-lane facilities. The objective of this analysis was to determine differences in travel times that can be applied to the traffic model in an effort to predict traffic volumes for Phase1 impact assessment in the Final EIS.

The Bypass traffic model was based on bypass alignment travel times relative to existing system routes between various origins and destinations. Any change in the alignment travel times would result in traffic volume assignment changes on the alternative alignments. Since two and four lane roadways have distinct operational differences, it was assumed that travel speeds for the two lane phase would result in travel time changes. The difference in travel times for each alignment alternative was input to the model to determine the resultant traffic volumes that could be assigned to each of the Phase 1 alternative alignments.

Travel Time Analysis Methodology

Analysis of alternative bypass alignment travel times on two lane road segments was performed by using uninterrupted flow modules of the 2010 Highway Capacity Manual (HCM). Input data for two lane highway operations in the 2010 Highway Capacity Software (HCS) program consists of: highway alignment or description of the terrain; classification of roadway; traffic volumes by direction; peak hour factor; roadway cross section dimensions; roadway segment length; vehicle mix; percentage of no passing zones; access-point density; and baseline travel speeds or measured travel speed data. The alignments and typical sections of the alternative alignments are known along with the relative terrain and roadway classifications. The remaining inputs are subject to a number of assumptions regarding traffic volumes and operational characteristics that would exist commensurate with the traffic model for year 2035 projections. The following assumptions were made in an effort to determine two lane travel speeds that are consistent with the original traffic model's travel time estimates:

- There were two distinct segments associated with Mary Street Option 1 and 2 alternative alignments. The roadside environment along these two segments determined operational speeds in the year 2035. The first segment, between Johnson Lane and Mary Street, is in a rural environment with rolling terrain. The model's travel speed was assumed to be 60 mph in this segment. The second segment, between Mary Street and Hwy 312, is in an urban environment with level terrain. The model's travel speed on that segment was assumed to be 45 mph. Two segments in the Five Mile Road alternative both have rural characteristics, which would be conducive to 60 mph travel speeds.
- Although there are intersections (Mary Street and Bitterroot Drive) that would interrupt traffic flow on each alternative alignment, it was assumed that the two-lane HCM methods to estimate travel speeds would be appropriate to estimate the difference in travel speeds along the alignments. Overall travel time was then determined by adding average intersection delays in the same manner as for the original model projections for the four lane facilities.
- The difference in travel time for the two lane facilities was then estimated by dividing the roadway segment lengths by the travel speeds and comparing the results to the original traffic model travel times.
- Since average travel times are the objective of the analysis, the average hour of the day was used as input to the HCS rather than

the peak design hour traffic typically used to determine capacity of two-lane roadway facilities. By examining hourly traffic variations on Main Street, it was determined that the daytime average hourly traffic volume is approximately 6% of average daily traffic (ADT). In addition, the directional traffic split is approximately 50%/50% at that hour.

- It was assumed that the two lane section would not substantially reduce the year 2035 traffic projections since sufficient capacity would generally be provided. Thus, 6% of the original year 2035 ADT projections for each alternative alignment were used as vehicles per hour inputs to the HCS module.
- Rather than using the model speeds of 60 mph and 45 mph as baseline design travel speeds in HCS, travel speeds based upon observations on similar two-lane facilities in the Billings area were used. This would be commensurate with the original model estimates of 60 mph and 45 mph where the actual free-flow speeds would most likely be higher than the speed limits.
- It was assumed that the level of secondary roadway improvements associated with each alternative alignment would be the same. Thus, travel time differences would only impact traffic projections on the primary alignment.

Percent No-passing

Estimates of the percentage of roadway that would be "no passing" were made according to AASHTO and MUTCD guidelines. The estimated percentage of "no-passing" was calculated based upon each segment's length and the length of allowable passing distances. Measurements were made along each alignment to determine passing zone lengths. Tabular summaries of each alternative alignment's geometry including lengths of horizontal curves, tangents, significant vertical influences, and intersection locations were used to determine percent no-passing values used in the HCS two-lane highway analysis.

HCS Two-Lane Travel Speed Results

Appendix A contains capacity calculation summaries for each of the alternative alignment segments based upon the assumptions contained herein. Table 1 provides a summary of the travel speeds and travel time results in comparison to the traffic model's travel speeds and travel times.

The greatest difference in two-lane travel speeds would be associated with the Mary Option 1 alternative alignment between Johnson Lane Interchange and the Mary Street intersection, which would experience average travel speeds 3.8 mph slower than the four-lane section. The result is an average travel time increase of 0.22 minutes. The greatest difference in two-lane travel times along the entire length of the alternative alignments would be 0.32 minutes for the Mary Option 2 alignment. This increase in travel time, less than 20 seconds, is unlikely to appreciably decrease traffic projections for the alternative alignments.

Table 1. Travel Time Difference Between 4 Lane and 2 Lane

Alternative Roadway Segments		4 Lane	2 Lane	Differences
Mary Street Option 1				
Johnson Inter. - Mary (3.2 miles)				
	Travel Speed (mph)	60.00	56.20	**-3.80**
	Travel Time (min)	3.20	3.42	**0.22**
Mary - Hwy 312 (1.7 miles)				
	Travel Speed (mph)	45.00	43.20	**-1.80**
	Travel Time (min)	2.27	2.36	**0.09**
Mary Street Option 1 Total Travel Times =		**5.47**	**5.78**	**0.31**
Mary Street Option 2				
Johnson Inter. - Mary (3.0 miles)				
	Travel Speed (mph)	60.00	56.40	**-3.60**
	Travel Time (min)	3.00	3.19	**0.19**
Mary - Hwy 312 (2.2 miles)				
	Travel Speed (mph)	45.00	43.10	**-1.90**
	Travel Time (min)	2.93	3.06	**0.13**
Mary Street Option 2 Total Travel Times =		**5.93**	**6.25**	**0.32**
Five Mile Road				
Johnson Inter. - Mary Street (3.0 miles)				
	Travel Speed (mph)	60.00	57.30	**-2.70**
	Travel Time (min)	3.00	3.14	**0.14**
Mary Street - Hwy 312 (1.4 miles)				
	Travel Speed (mph)	60.00	57.60	**-2.40**
	Travel Time (min)	1.40	1.46	**0.06**
Five Mile Road Total Travel Times =		**4.40**	**4.60**	**0.20**

Phase 1 Year 2035 Traffic Projections

Previous DEIS traffic projection methodologies were utilized for each of the alternative alignments. The first level traffic projection analysis indicated that the additional travel time associated with the two-lane facility would have no effect on trips exchange between a number of traffic analysis zones while trip exchange between other traffic analysis zones would have a reduction in trips utilizing the Bypass alignments. Table 2 summarizes the reduction in trips exchange between traffic analysis zones on key street segments for each of the three bypass alignments. These projections indicate that both Mary Street Alignment options would have the highest reduction in traffic demand which would amount to 360 less trips per day on the Bypass river crossing structure. Since secondary improvements would be made to Mary Street in conjunction with the Five Mile Road alignment, the total reduction in traffic demand for that alignment would only be 205 vehicles per day.

Table 2. Phase 1 Trip Reductions Between Origins & Destinations On Bypass Alignments

	Heights West % Distribution to				Heights East % Distribution to				Lockwood Commercial Traffic	Redistribute Huntley	
Alternative Alignments	Lock East	Lock West	I-90 / I-94	Westend	Lock East	Lock West	I-90 / I-94	Westend	Redistribute	Interchange	Totals
Mary Alignment Option 1											
Traffic Distribution	-67	-27	-13	-19	-91	-5	-17	-4	-18	-104	-364
Mary Align	-67	-27	-13	-19	-91	-5	-17	-4	-18	0	-260
FiveMile S of HWY 312	0	0	0	0	0	0	0	0	0	-104	-104
Bitteroot N of Mary	0	0	0	0	0	0	0	0	0	0	0
Bypass to Johnson Lane	-67	-27	-13	-19	-91	-5	-17	-4	-18	-104	-364
Mary Alignment Option 2											
Traffic Distribution	-67	-27	-13	-19	-91	-5	-17	-4	-15	-105	-362
Mary Align	-67	-27	-13	-19	-91	-5	-17	-4	-15	0	-257
FiveMile S of HWY 312	0	0	0	0	0	0	0	0	0	-105	-105
Bitteroot N of Mary	0	0	0	0	0	0	0	0	0	0	0
Bypass to Johnson Lane	-67	-27	-13	-19	-91	-5	-17	-4	-15	-105	-362
Five Mile Road Alignment											
Traffic Distribution	-29	0	-6	0	-25	-15	-5	-15	-5	-105	-205
Mary Existing Align	-29	0	-6	0	-25	-15	-5	-15	-5	0	-100
FiveMile S of HWY 312	0	0	0	0	0	0	0	0	0	-105	-105
Five Mile N of Mary	0	0	0	0	0	0	0	0	0	-105	-105
Five Mile/to Johnson Ln	-29	0	-6	0	-25	-15	-5	-15	-5	-105	-205

A second level of traffic projections was completed to determine average daily traffic (ADT) on the entire system of impacted streets and design hour volumes at key intersections. Figures 1 through 6, on the following pages, present a summary of year 2035 ADT and PM design hour traffic volumes on the existing system and at proposed intersections that would be associated with each of the Phase 1 alternative alignments. Comparisons between the ADT and design hour traffic projections in the DEIS Traffic Study and the Phase 1 traffic projections (Figures 11 thru 16) indicate that many of the streets would have minimal differences in traffic volumes. The most substantial changes would be on the Mary Street Alignments south of the river crossing (-360 ADT). On Main Street south of 6th Avenue N. and on US 87 east of Main Street, there would an increase of approximately 250 ADT associated with the Mary Street Alignments.

Since PM peak hour traffic volumes are considerably higher than the AM hour and operational measures of efficiency are worse during the PM hour, the PM peak hour volumes were used as design hour volumes. This is consistent with the DEIS traffic projections for the Full Buildout alternative alignments. Most of the alternative bypass intersections are considered to be operationally symmetrical and reversal of PM traffic flow patterns in the AM hour would result in the same or better (less traffic) levels of service during that time of the day.

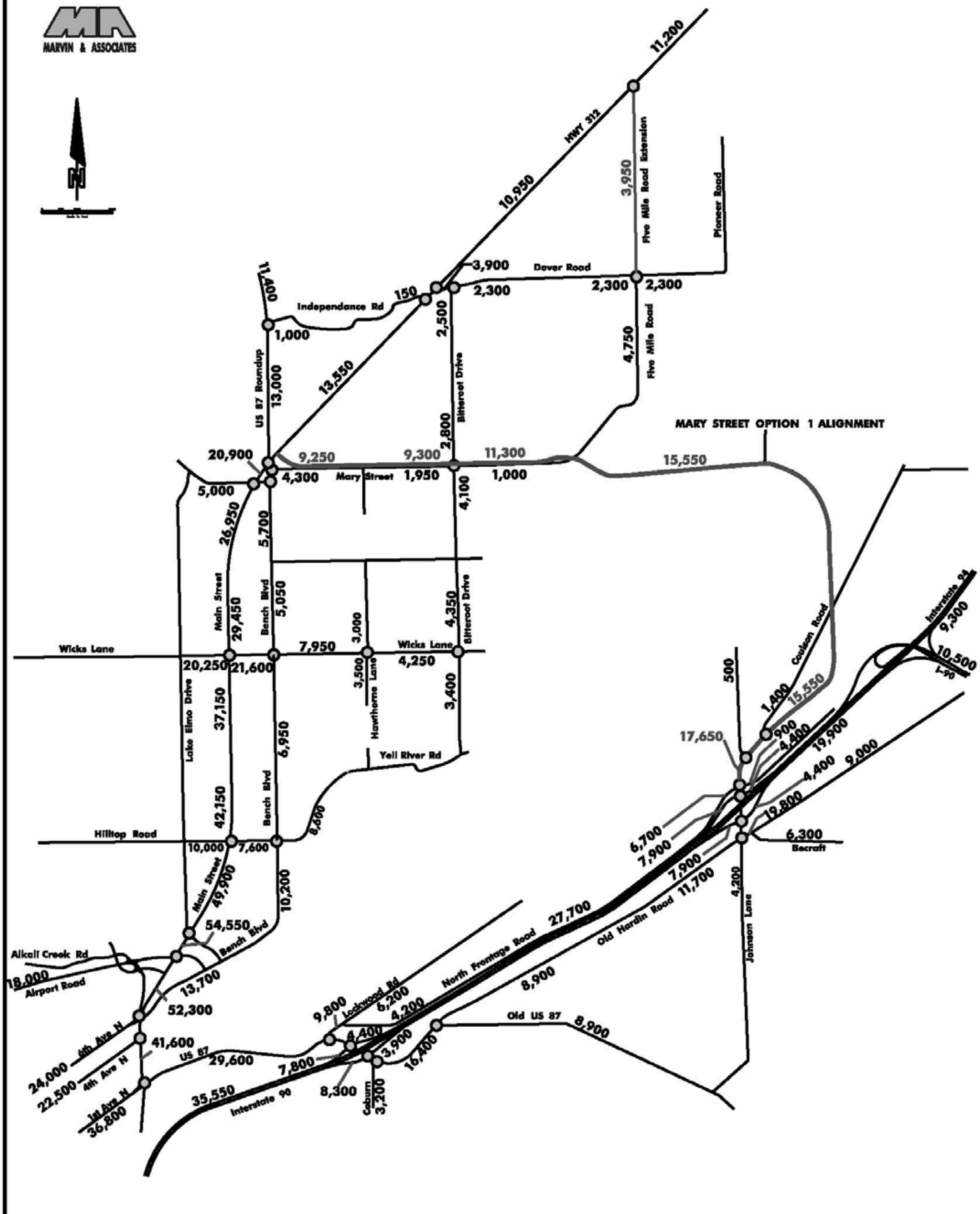


Figure 1. Mary Street Option 1 Phase 1 Two Lane Year 2035 ADT Volumes

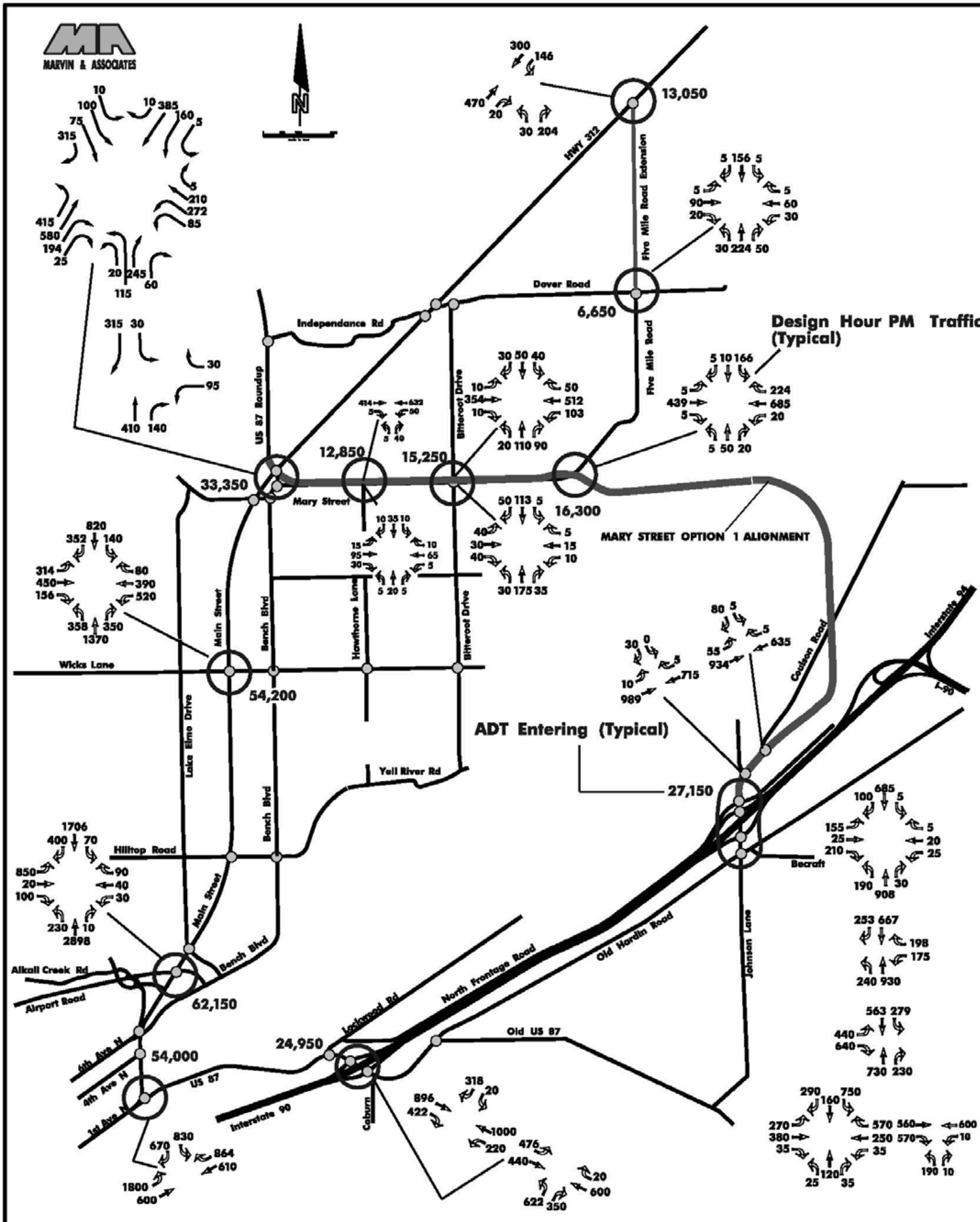


Figure 2. Mary Street Option 1 Phase 1 Two Lane Year 2035 PM Design Hour Traffic

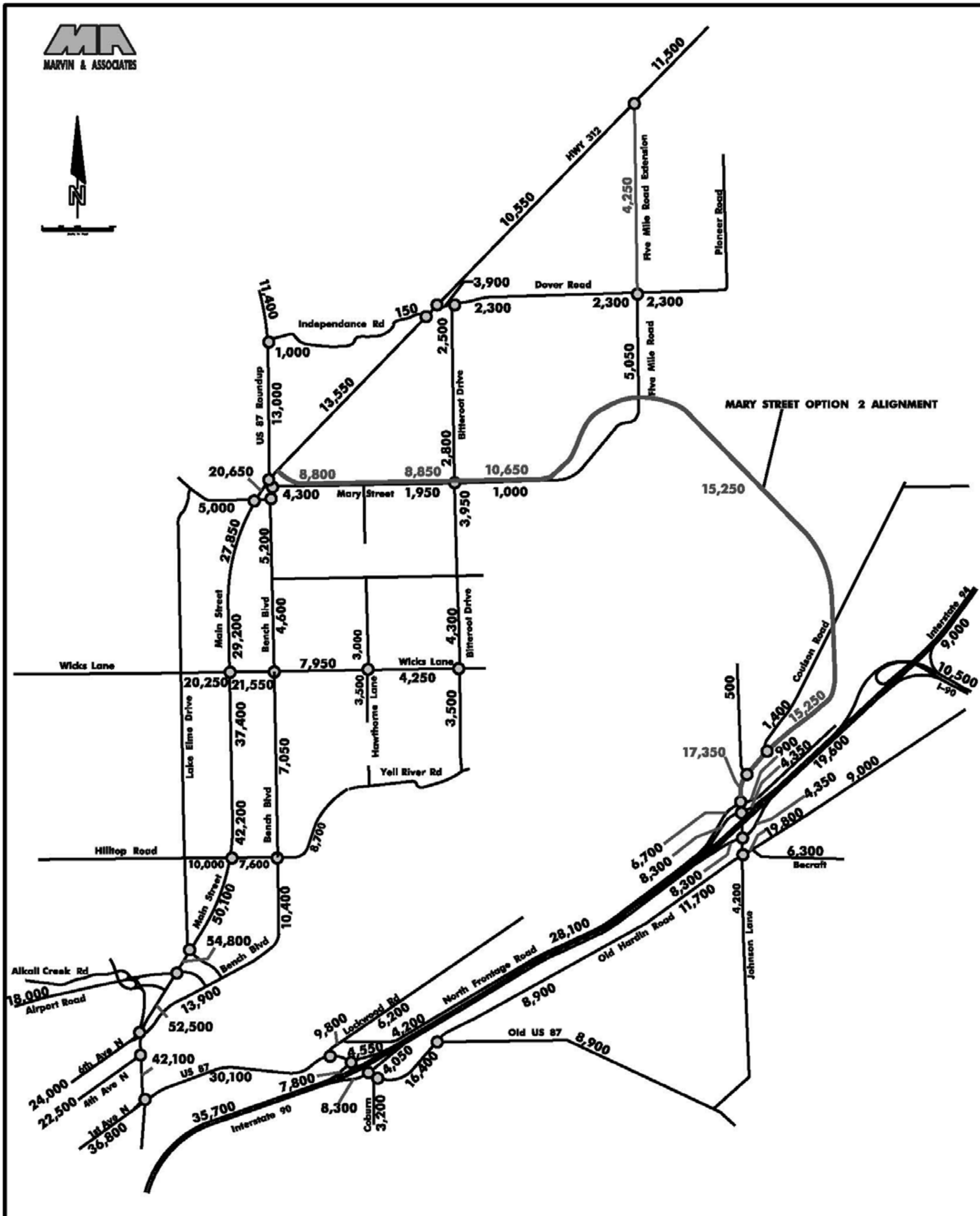


Figure 3. Mary Street Option 2 Phase 1 Two Lane Year 2035 ADT Volumes

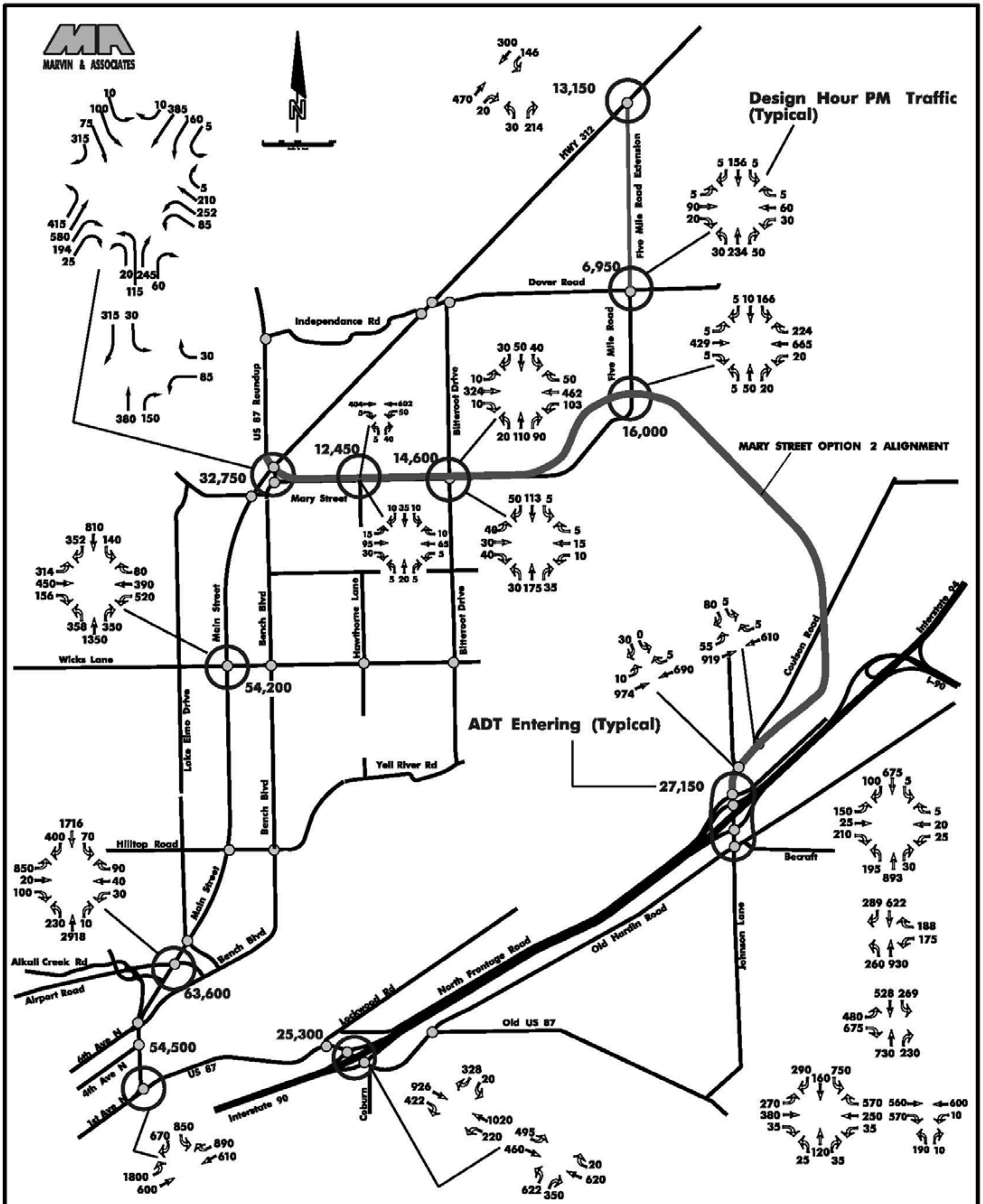


Figure 4. Mary Street Option 2 Phase 1 Two Lane Year 2035 PM Design Hour Traffic

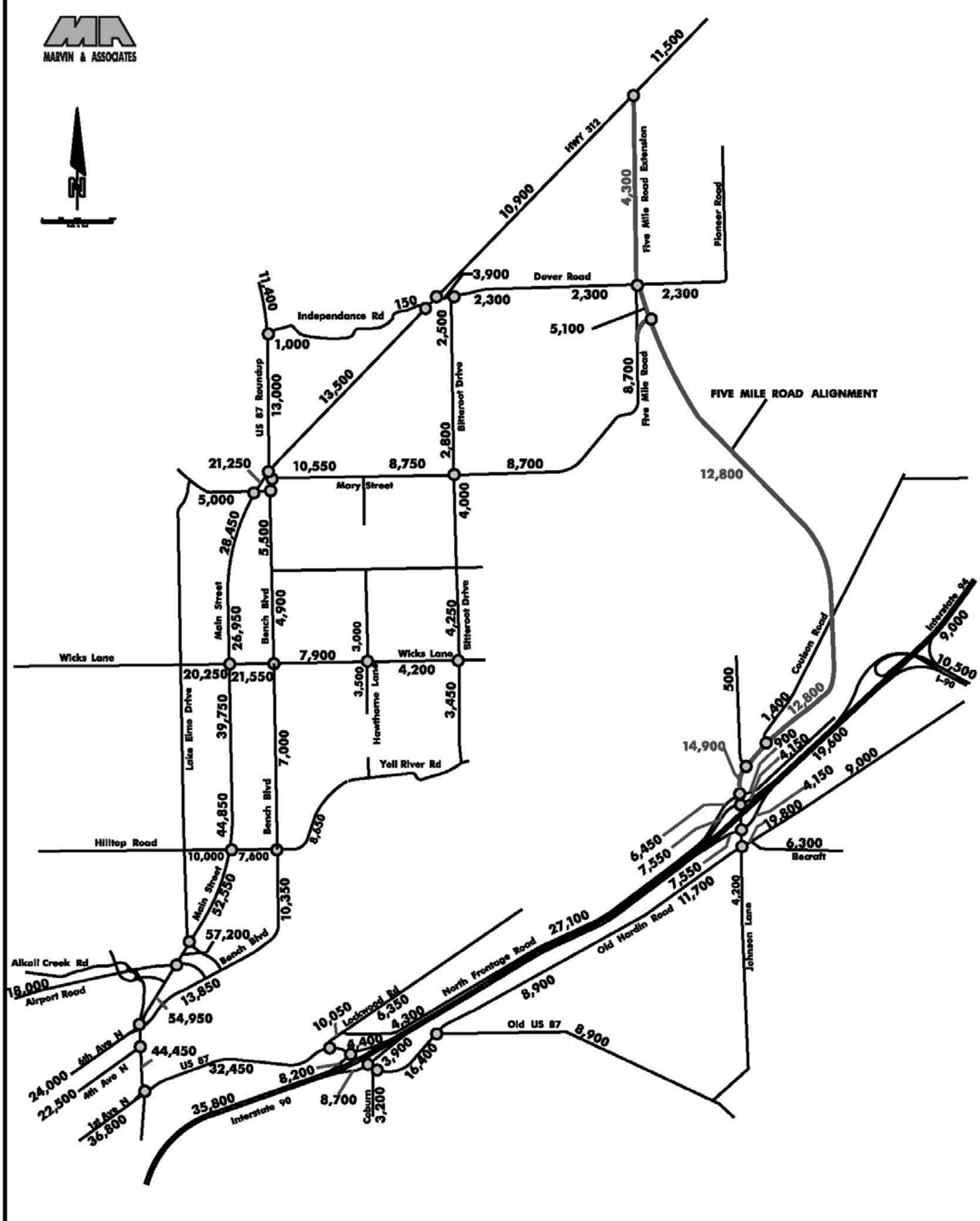


Figure 5. Five Mile Road Phase 1 Two Lane Year 2035 ADT Volumes

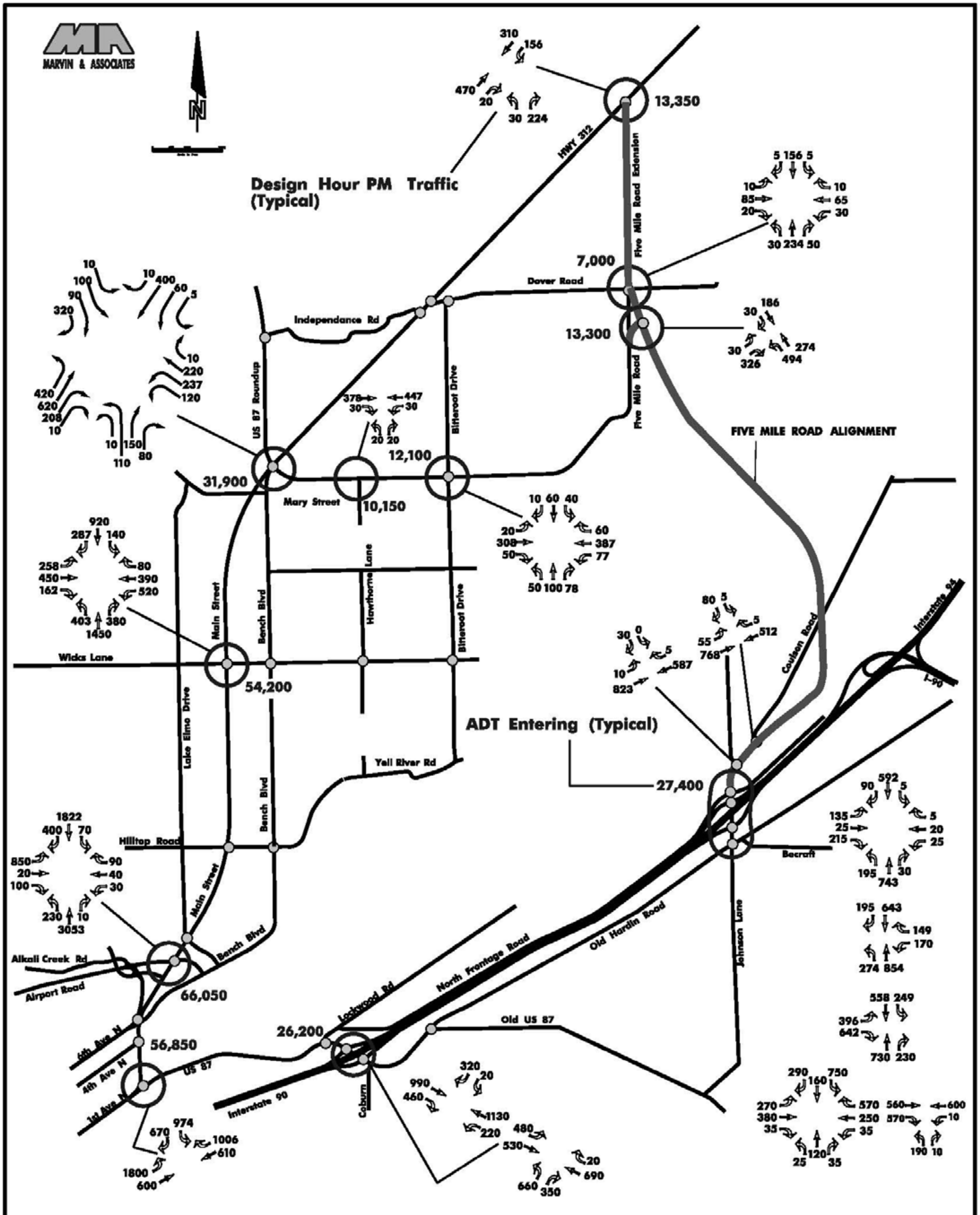


Figure 6. Five Mile Road Phase 1 Two Lane Year 2035 PM Design Hour Traffic

Phase 1 and Phase 2 Traffic Projections Significance

An analysis was performed to determine if the differences between Phase 1 (two lane facilities) traffic projections and Full Buildout (four lane facilities) traffic projections are statistically significant. To determine this, a statistical analysis using the "T" statistic was performed. The "T" statistical analysis compares two sample groups with normal distributions to determine whether there is a true difference in the average or median of the two groups. In order to provide relevant samples of traffic volumes, the Montana Department of Transportation Main Street permanent traffic count station data was used to replicate seasonal and daily traffic variations that would be associated with the Bypass alignment. Since there are 7 days in a week and 12 months in the year, a total of 84 (7x12) data points were used in the sample size for both two lane and four lane facilities. The analysis resulted in the following statistics for the Mary Street Option 2 Alignment (DEIS preliminary preferred alternative):

	4 Lane	*2 Lane*
Median ADT	*15,600*	*15,250*
Standard Deviation	*1,979*	*1,935*

The calculated "T" statistic was 0.84, which is substantially less than the "T" Statistic Table value of 1.99 and therefore it was confirmed that there is no statistical difference between the four lane and two lane traffic projections.

The statistical analysis confirms what would be a logical conclusion when examining the range of daily traffic volumes that would typically occur on the Bypass alignments. Main Street daily traffic volumes have a range between 72% of ADT to 124% of ADT over the course of a year. Thus applied to the Mary Street Option 2 Alignment, the daily traffic could range between 11,200 and 19,300 vehicles per day. Even with accurate traffic count samples, it is difficult to estimate the annual average daily traffic (AADT) within 10% of the actual number. Since the difference between the two lane and the four lane projections is only 350 ADT, or 2.2%, that volume of traffic would be well within the normal range of accuracy.

Given the above data and narratives, it is evident that there would be no significant differences between traffic projections for the two lane and four lane alignment sections. Traffic impacts associated with each alternative alignment will therefore be the same or have only minimal differences as a worst case scenario.

PHASE 1 STREET SYSTEM IMPACTS

Year 2035 Alternative Alignments Vehicle Miles Travel

Table 3 presents a summary of vehicle miles of travel (VMT) on the impacted roadway system for each of the alternative alignments as reported in the DEIS, including the No-Build alternative. The DEIS four-lane alignments are labeled “Phase 2” and additional columns are labeled Phase 1 representing the two-lane alignments. VMTs are based on ADTs projected for each alternative route segment.

The VMT for all of the Bypass alternatives are higher than the No-Build alternative VMT total because the Bypass would provide shorter travel times despite the longer travel distance. The most pertinent data in Table 3 is the difference between Phase 1 and Full Buildout VMTs for each alternative alignment. It can be seen that Phase 1 improvements would produce between 115 (Mary Street Option 1) and 136 (Five Mile Road) fewer vehicle miles of travel than Full Buildout or substantially less than 1% of the total VMT for the average day in 2035. Mary Street Option (DEIS preferred alternative) would have 124 fewer VMT for Phase 1 than Full Buildout.

It is important to note that the Mary Street Option 1 Alignment would have the highest ADT along the Bypass at the Yellowstone River and MRL railroad crossing, but the total VMT for that alternative would be less than the Five Mile Road Alignment. The smallest increase in VMT would be for the Phase 1 and Full Buildout Mary Street Option 2 Alignments with approximately 3,359 and 3,483 more VMTs than the No-Build alternative, respectively.

Table 3. Vehicle Miles Travel Comparison Between Phase 1 & Phase 2 (Full Buildout) Alternative Alignments

	Link		Existing	Length	Alternatives' Vehicle Miles Travel						
Route	From	To	ADT	Miles	No-Build	Mary 1 Phase 1	Mary 1 Phase 2	Mary 2 Phase 1	Mary 2 Phase 2	5 Mile Rd Phase 1	5 Mile Rd Phase 2
Highway 312	US 87	Dover Road	10900	1.32	21912	17886	17886	17886	17886	17820	17820
	Dover Road	Five Mile Road	8700	1.47	17346	16097	16097	15509	15509	16023	16023
	Five Mile Road	S-522 Huntley	6500	6.16	56056	64039	64680	65881	66528	65881	66528
US 87 North	Highway 312	Independence Lane	5900	0.96	12480	12480	12480	12480	12480	12480	12480
Main Street	1st Avenue N	4th/6th Avenues North	36100	0.32	17280	13310	13232	13470	13392	14222	14192
	4th/6th Avenues North	Airport Road	49200	0.40	24960	20916	20860	21016	20960	21998	21960
	Airport Road	Hilltop Road	42200	0.64	38400	31930	31840	32090	32000	33638	33600
	Hilltop Road	Wicks Lane	35200	1.02	50184	40434	40290	40638	40494	43156	43095
	Wicks Lane	US 87/312	19350	1.00	31300	28206	28350	28509	28650	27710	27750
Bench Boulevard	US 87	Wicks Lane	2900	1.03	5871	5511	5511	5047	5047	5356	5356
	Wicks Lane	Hilltop Road	4300	1.01	8585	7006	6969	7107	7070	7090	7070
	Hilltop Road	Main Street	na	1.36	19380	16255	16116	16527	16388	16470	16388
Bitterroot Drive	Dover Road	Mary Street	900	0.96	2400	2544	2544	2544	2544	2544	2544
	Mary Street	Wicks Lane	1800	1.00	3200	4133	4250	3983	4100	3995	4100
Mary Street	Bench Boulevard	Bitterroot Drive	1450	1.00	4000	3100	3100	3100	3100	9700	9700
	Bitterroot Drive	5 Mile Road	500	1.15	1150	1150	1150	1150	1150	10120	10120
5 Mile Road	Mary Street	Dover Road	100	0.65	325	3085	3153	3279	3348	5652	5720
Dover Road	HWY 312	Bitterroot Drive	1600	0.08	304	312	312	312	312	312	312
	Bitterroot Drive	5 Mile Road	1000	1.00	2400	2300	2300	2300	2300	2300	2300
Wicks Lane	Lake Elmo Road	Main Street	15500	0.24	4824	4860	4860	4860	4860	4860	4860
	Main Street	Bench Boulevard	15300	0.24	5256	5184	5184	5172	5172	5172	5172
	Bench Boulevard	Bitteroot Drive	4100	1.00	6400	6087	6050	6087	6050	6070	6050
Hilltop Road	Lake Elmo Road	Main Street	8900	0.24	2400	2400	2400	2400	2400	2400	2400
	Main Street	Bench Boulevard	6400	0.24	1824	1824	1824	1824	1824	1824	1824
Johnson Lane	Old Hardin Road	Johnson Interchange	12500	0.17	3196	3196	3196	3196	3196	3196	3196
	Johnson Interchange	Coulson Road	1400	0.29	609	5114	5220	5027	5133	4320	4379
US 87	Lockwood Interchange	Old Hardin Road	10900	0.58	9512	9512	9512	9512	9512	9512	9512
	1st Avenue N/Main	Lockwood Interchange	28000	1.25	52500	36991	36688	37616	37313	40556	40438
I-94	Huntley Interchange	Pinehill Interchange	7100	6.21	65826	57778	57132	55915	55269	55921	55269
I-90	S. 27th St. Interchange	Lockwood Interchange	24900	2.76	103224	98535	98118	98949	98532	98863	98808
	Lockwood Interchange	Johnson Ln Interchange	21800	1.27	41529	35180	34989	35688	35497	34550	34417
	Johnson Ln Interchange	Pinehill Interchange	14100	2.45	51940	48765	48510	48030	47775	48032	47775
Mary Street Option 1	Highway 312	Bitterroot Drive	0	0.97	0	8978	9118	0	0	0	0
	Bitterroot Drive	Five Mile Road	0	0.65	0	7338	7508	0	0	0	0
	Five Mile Road	Johnson Lane	0	3.08	0	47848	48972	0	0	0	0
Mary Street Option 2	Highway 312	Bitterroot Drive	0	0.97	0	0	0	8593	8730	0	0
	Bitterroot Drive	Five Mile Road	0	1.18	0	0	0	12558	12862	0	0
	Five Mile Road	Johnson Lane	0	2.75	0	0	0	41902	42900	0	0
Five Mile Road Align.	Highway 312	Dover Road	0	0.93	0	0	0	0	0	3994	4092
	Dover Road	Five Mile/Mary	100	0.45	225	0	0	0	0	2293	2340
	Five Mile/Mary	Johnson Lane	0	2.82	0	0	0	0	0	36082	36660
	ADT = Average Daily Traffic Along Entire Link		Totals =		666798	670283	670398	670157	670281	674113	674250
		Differences between Phase 1& 2 =				-115		-124		-136	
		Differences between No-Build =				3485	3600	3359	3483	7315	7452

Year 2035 Alternative Alignments Vehicle Hours of Travel

It has been determined that the average travel time savings for all traffic that would use the alternative alignments ranges between 4 and 6 minutes. If an average travel time savings of 5 minutes was applied to year 2035 traffic projections for the alternative alignments, the approximate annual travel time savings for Phase 1 and Full Buildout alignments would be:

Mary Street Option 1 Phase 1 Alignment	473,000 VHT Savings
Mary Street Option 1 Full Buildout Alignment	480,000 VHT Savings
Mary Street Option 2 Phase 1 Alignment	463,900 VHT Savings
Mary Street Option 2 Full Buildout Alignment	475,000 VHT Savings
Five Mile Road Phase 1 Alignment	389,300 VHT Savings
Five Mile Road Full Buildout Alignment	395,000 VHT Savings

The differences between Phase 1 and Full Buildout alignment VHTs range between 5,700 hours for the Five Mile Road Alternative and 11,100 hours for the Mary Street Option 2 Alternative on an annual basis. The Phase 1 calculations assume that the same average travel time of 5 minutes would apply and the reductions in ADT for each of the Phase 1 alternatives account for the small differences in travel time along the Bypass. The differences in Phase 1 VHT savings range between 1.4% and 2.3% of the Full Buildout VHTs.

Year 2035 Alternative Alignment Capacity & LOS

Capacity calculations along existing roads and streets that have the most probable impacts were completed for the Full Buildout alternative alignments based upon year 2035 traffic at critical intersections in the DEIS. Similar capacity calculations were completed for Phase 1 of the DEIS preliminary alignments using traffic volumes illustrated in Figures 2, 4, and 6 of this report. The capacity analysis calculations for each intersection can be found in Appendix B of this report. Capacity calculations at intersections along the two-lane Bypass alignment are discussed in a later section.

Table 4 presents a summary of LOS and delay (sec/vehicle) for each of the seven existing street system intersections associated with the Phase 1 alternative alignments. In comparing these intersections to the same intersections in Tables 8, 9, and 10 of the DEIS Traffic Report for the four lane facility, it can be seen that Phase 1 capacity calculations are almost identical to the Full Buildout facility. Only minor changes in delay would be evident at most of the intersections since the differences in traffic volumes between Phase 1 and Full Buildout are very minor in comparison to total traffic demand. Since there would be no differences in traffic volumes at the intersections along Dover Road for any of the alternatives, the Full Buildout capacity calculations would also apply to Phase 1 operations. As noted in the DEIS Traffic Study report, the existing street system would benefit from traffic diversion to the new Bypass alignments.

Table 4. Existing Street System Capacity for Phase 1 Alignments

Mary Street Option 1 Alignment

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
Highway 312 & Dover*	F	194					B	13
Dover & Bitterroot*	B	12					A	8
Main & Wicks Lane	F	105	D	45	D	45	F	103
Main & Airport Road	F	82	C	34	F	99	F	178
Main/1st Ave N/US 87			C	26	C	29	D	48
Lockwood US87/WB I-90 Ramps			C	30	C	30	B	16
Lockwood US87/EB I-90 Ramps	D	54			D	45	E	64

* Minimal Difference from No-Build Alt.

Mary Street Option 2 Alignment

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
Highway 312 & Dover*	F	194					B	13
Dover & Bitterroot*	B	12					A	8
Main & Wicks Lane	F	103	D	45	D	45	F	103
Main & Airport Road	F	85	C	35	F	99	F	178
Main/1st Ave N/US 87			C	28	C	29	D	49
Lockwood US87/WB I-90 Ramps			C	31	C	31	B	17
Lockwood US87/EB I-90 Ramps	D	50			D	51	E	68

* Minimal Difference from No-Build Alt.

Five Mile Road Alignment

	Intersection Approach							
	NB		SB		EB		WB	
Intersection	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)	LOS	Delay (s/v)
Highway 312 & Dover*	F	194					B	13
Dover & Bitterroot*	B	12					A	8
Main & Wicks Lane	F	96	D	42	E	57	F	104
Main & Airport Road	F	111	C	33	F	99	F	178
Main/1st Ave N/US 87			D	36	D	37	E	58
Lockwood US87/WB I-90 Ramps			C	33	C	35	B	17
Lockwood US87/EB I-90 Ramps	F	80			D	43	E	64

* Minimal Difference from No-Build Alt.

= LOS >C
= LOS D
= LOS E
= LOS F

Crash Projections

Table 5 represents a projection of future crash statistics that would be associated with the No-Build alternative and Phase 1 and Full Buildout of the preliminary alternative alignments if current crash and severity rates were applicable in the design year 2035. Crash and severity rates on the new alignments were estimated based upon historic crash data on similar facilities that were constructed using current design standards, including Old Hwy 312 from US 87 to Five Mile Road and Airport Road. The crash rates on the Phase 1 alignments were increased by an approximate factor of 1.5 times the Full Buildout rates due to differences in operational characteristics. A number of research reports indicate that crash rates for two lane roadways range between 20% and 70% higher than four lane facilities generally due to passing maneuvers. Though there were a number of conflicting results between studies, it was felt that a 50% increase by the year 2035 would provide a conservative estimate of conditions on a facility that would be at the end of its useful design life.

In comparing Phase 1 and Full Buildout total system crashes in the year 2035, the preliminary preferred Mary Option 2 alignment Phase 1 alternative is projected to have 514 total crashes while the Full Buildout alternative is projected to have 502, or approximately 2% more crashes with the two lane roadway. In comparison to the No-Build alternative, which would have 551 crashes, the Phase 1 two-lane roadway would still provide a net benefit of 37 fewer crashes and 13 fewer injury crashes in the year 2035. The number of fatalities would remain below two under Phase 1 of the Mary Option 2 alternative in 2035. Similar results comparing the Phase 1 and Full Buildout calculations can be noted for the Mary Street Option 1 and Five Mile Road alternative alignments.

Table 5. Annual Crash Projections on Existing Streets & Roads with Bypass for Phase 1 & Full Buildout - Year 2035

EXISTING STREET LINK SEGMENTS				No Build Projections					Mary Alignment Option 1: Phase 1 - Two Lane Roadway					Mary Alignment Option 1: Full Buildout 4 Lane Roadway				
ROUTE NAME	from	to	Length (miles)	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals
Interstate 94	Pinehill Interchange	Huntley Interchange	6.21	10600	23.6	5.4	6.9	0.0	9300	20.7	4.7	6.0	0.0	9200	20.5	4.7	6.0	0.0
Interstate 90	Johnson Lane	Lockwood	1.27	32700	22.2	6.0	9.6	0.0	27700	18.8	5.1	8.1	0.0	27550	18.7	5.1	8.1	0.0
Interstate 90	Pinehill Interchange	Johnson Lane	2.45	21200	2.1	0.3	0.3	0.0	19900	2.0	0.3	0.3	0.0	19800	2.0	0.3	0.3	0.0
Johnson Lane	I-90 Interchange	Coulson Road	0.29	6900	6.0	0.9	1.5	0.0	17650	15.3	2.3	3.8	0.0	18000	15.7	2.3	3.9	0.0
Johnson Lane	Old Hardin Road	I-90 Interchange	0.17	18000	3.0	0.6	1.5	0.0	18800	3.1	0.6	1.6	0.0	18800	3.1	0.6	1.6	0.0
(Old US 87)	Lockwood Interchang	Jct Old Hardin Road	0.58	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0
Highway 87	I-90 Lockwood Inter	1st Avenue N	1.25	42000	53.8	15.3	22.3	0.0	29600	37.9	10.8	15.7	0.0	29350	37.6	10.7	15.6	0.0
Main Street	1st Avenue N	6th Avenue N	0.35	54000	40.1	12.4	17.9	0.0	41600	30.9	9.5	13.8	0.0	41350	30.7	9.5	13.7	0.0
Main Street	6th Avenue N	Airport Road	0.37	62400	27.5	8.7	14.4	0.0	52300	23.1	7.3	12.1	0.0	52150	23.0	7.3	12.0	0.0
Main Street	Airport Road	Hilltop Road	0.64	62400	83.0	28.5	46.1	0.0	49900	66.3	22.8	36.8	0.0	49750	66.1	22.7	36.7	0.0
Main Street	Hilltop Road	Wicks Lane	1.02	49100	81.4	30.9	47.7	0.6	39650	65.7	24.9	38.5	0.5	39500	65.5	24.8	38.4	0.5
Main Street	Wicks Lane	HWY 312/Bench	1.00	30700	46.4	9.9	0.0	0.0	28200	42.7	9.1	0.0	0.0	28350	42.9	9.1	0.0	0.0
Highway 87	HWY 312/Bench	Independence Road	0.96	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0
Wicks Lane	Lake Elmo	Main Street	0.24	21000	5.3	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0
Wicks Lane	Main Street	Bench Boulevard	0.24	21900	13.1	4.7	5.5	0.0	21600	13.0	4.6	5.5	0.0	21600	13.0	4.6	5.5	0.0
Wicks Lane	Bench Boulevard	Bitterroot Drive	1.00	6400	15.1	2.7	4.1	0.0	6100	14.4	2.6	3.9	0.0	6050	14.3	2.6	3.9	0.0
Mary Street	Bench Boulevard	Five Mile Road	1.67	4500	5.4	0.0	0.0	0.0	2050	2.5	0.0	0.0	0.0	2050	2.5	0.0	0.0	0.0
Highway 312	US 87 (N16)	Dover Road	1.32	16600	6.2	0.9	0.9	0.3	13550	5.1	0.8	0.8	0.3	13550	5.1	0.8	0.8	0.3
Highway 312	Dover Road	Pioneer Road	2.20	13600	19.5	8.0	11.9	0.4	10950	15.7	6.5	9.6	0.3	10950	15.7	6.5	9.6	0.3
Highway 312	Pioneer Road	S-522 Huntley	5.43	9000	28.8	11.4	18.9	0.3	10400	33.3	13.2	21.8	0.3	10500	33.6	13.3	22.1	0.4
Bench Bld	Wicks Lane U-1012	US 87 (N16)	1.03	5800	24.0	8.4	10.8	0.0	5350	22.1	7.7	10.0	0.0	5350	22.1	7.7	10.0	0.0
Dover Road	HWY 312 CO56788	Pioneer Road	1.56	2300	2.3	0.4	0.4	0.0	3100	3.1	0.5	0.5	0.0	3100	3.1	0.5	0.5	0.0
Bitterroot Drive	Wicks (U-1012)	Mary Street	1.00	4000	10.5	1.8	3.1	0.0	4150	10.9	1.9	3.2	0.0	4250	11.1	2.0	3.3	0.0
Bitterroot Drive	Mary Street	Dover Road	0.96	2500	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0
5 Mile Road	Mary Street	Dover Road	0.65	500	0.7	0.7	0.7	0.0	4750	6.3	6.3	6.3	0.0	4850	3.2	3.2	3.2	0.0
Pioneer Road	Dover Road	HWY 312 CO56788	1.50	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0
Huntley Main St	I-94 Huntley Inter	CO56788 (HWY 312)	2.37	5500	8.6	4.2	4.8	0.0	4700	7.4	3.6	4.1	0.0	4800	7.5	3.6	4.2	0.0
Mary St Opt 1	Highway 312	Bitterroot Drive	0.97						9250	3.8	0.6	0.8	0.1	9400	2.6	0.4	0.5	0.1
	Bitterroot Drive	Five Mile Road	0.65						11300	3.1	0.5	0.6	0.1	11550	2.1	0.3	0.4	0.0
	Five Mile Road	Johnson Lane	3.08						15550	20.3	3.1	4.1	0.4	15900	13.9	2.1	2.8	0.3
Mary St Opt 2	Highway 312	Bitterroot Drive	0.97															
	Bitterroot Drive	Five Mile Road	1.18															
	Five Mile Road	Johnson Lane	2.75															
5 Mile Rd Align	Highway 312	Dover Road	0.93															
	Dover Road	Five Mile/Mary	0.45															
	Five Mile/Mary	Johnson Lane	2.82															
Totals =			51.53	19756	551.3	170.3	241.8	1.6	17003	515.4	157.4	220.4	1.9	17013	503.3	152.9	215.4	1.7
				Avg					Avg					Avg				

EXISTING STREET LINK SEGMENTS			Mary Alignment Option 2: Phase 1 - Two Lane Roadway					Mary Alignment Option 2: Full Buildout 4 Lane Roadway				
ROUTE NAME	from	to	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals
Interstate 94	Pinehill Interchange	Huntley Interchange	9000	20.0	4.6	5.8	0.0	8900	19.8	4.5	5.8	0.0
Interstate 90	Johnson Lane	Lockwood	28100	19.1	5.2	8.2	0.0	27950	19.0	5.1	8.2	0.0
Interstate 90	Pinehill Interchange	Johnson Lane	19600	1.9	0.3	0.3	0.0	19500	1.9	0.3	0.3	0.0
Johnson Lane	I-90 Interchange	Coulson Road	17350	15.1	2.3	3.8	0.0	17700	15.4	2.3	3.8	0.0
Johnson Lane	Old Hardin Road	I-90 Interchange	18800	3.1	0.6	1.6	0.0	18800	3.1	0.6	1.6	0.0
(Old US 87)	Lockwood Interchang	Jct Old Hardin Road	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0
Highway 87	I-90 Lockwood Inter	1st Avenue N	30100	38.5	10.9	16.0	0.0	29850	38.2	10.9	15.8	0.0
Main Street	1st Avenue N	6th Avenue N	42100	31.3	9.6	13.9	0.0	41850	31.1	9.6	13.8	0.0
Main Street	6th Avenue N	Airport Road	52500	23.2	7.4	12.1	0.0	52400	23.1	7.3	12.1	0.0
Main Street	Airport Road	Hilltop Road	50100	66.6	22.9	37.0	0.0	50000	66.5	22.8	36.9	0.0
Main Street	Hilltop Road	Wicks Lane	39800	66.0	25.0	38.7	0.5	39700	65.8	25.0	38.6	0.5
Main Street	Wicks Lane	HWY 312/Bench	28500	43.1	9.2	0.0	0.0	28650	43.3	9.2	0.0	0.0
Highway 87	HWY 312/Bench	Independence Road	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0
Wicks Lane	Lake Elmo	Main Street	20250	5.1	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0
Wicks Lane	Main Street	Bench Boulevard	21550	12.9	4.6	5.5	0.0	21550	12.9	4.6	5.5	0.0
Wicks Lane	Bench Boulevard	Bitterroot Drive	6000	14.1	2.6	3.9	0.0	6050	14.3	2.6	3.9	0.0
Mary Street	Bench Boulevard	Five Mile Road	2050	2.5	0.0	0.0	0.0	2050	2.5	0.0	0.0	0.0
Highway 312	US 87 (N16)	Dover Road	13550	5.1	0.8	0.8	0.3	13550	5.1	0.8	0.8	0.3
Highway 312	Dover Road	Pioneer Road	10450	15.0	6.2	9.1	0.3	10550	15.2	6.2	9.2	0.3
Highway 312	Pioneer Road	S-522 Huntley	10700	34.2	13.6	22.5	0.4	10800	34.6	13.7	22.7	0.4
Bench Bld	Wicks Lane U-1012	US 87 (N16)	4900	20.3	7.1	9.1	0.0	4900	20.3	7.1	9.1	0.0
Dover Road	HWY 312 CO56788	Pioneer Road	3100	3.1	0.5	0.5	0.0	3100	3.1	0.5	0.5	0.0
Bitterroot Drive	Wicks (U-1012)	Mary Street	4000	10.5	1.8	3.1	0.0	4100	10.7	1.9	3.2	0.0
Bitterroot Drive	Mary Street	Dover Road	2650	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0
5 Mile Road	Mary Street	Dover Road	5050	6.7	6.7	6.7	0.0	5150	3.4	3.4	3.4	0.0
Pioneer Road	Dover Road	HWY 312 CO56788	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0
Huntley Main St	I-94 Huntley Inter	CO56788 (HWY 312)	4300	6.7	3.3	3.7	0.0	4200	6.6	3.2	3.6	0.0
Mary St Opt 1	Highway 312	Bitterroot Drive										
	Bitterroot Drive	Five Mile Road										
	Five Mile Road	Johnson Lane										
Mary St Opt 2	Highway 312	Bitterroot Drive	8850	3.6	0.5	0.7	0.1	9000	2.5	0.4	0.5	0.0
	Bitterroot Drive	Five Mile Road	10650	5.3	0.8	1.1	0.1	10900	3.6	0.5	0.7	0.1
	Five Mile Road	Johnson Lane	15250	17.8	2.7	3.6	0.4	15600	12.1	1.8	2.4	0.2
5 Mile Rd Align	Highway 312	Dover Road										
	Dover Road	Five Mile/Mary										
	Five Mile/Mary	Johnson Lane										
Totals =			16968	513.8	157.3	220.2	1.9	16983	501.9	152.6	215.0	1.7
			Avg					Avg				

EXISTING STREET LINK SEGMENTS			Five Mile Road Alignment: Phase 1 - Two Lane Roadway					Five Mile Road Alignment: Full Buildout 4 Lane Roadway				
ROUTE NAME	from	to	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals	2035 ADT	No. Crash	Injury Crash	No. Inury	No. Fatals
Interstate 94	Pinehill Interchange	Huntley Interchange	9000	20.0	4.6	5.8	0.0	8900	19.8	4.5	5.8	0.0
Interstate 90	Johnson Lane	Lockwood	27100	18.4	5.0	8.0	0.0	27100	18.4	5.0	8.0	0.0
Interstate 90	Pinehill Interchange	Johnson Lane	19600	1.9	0.3	0.3	0.0	19500	1.9	0.3	0.3	0.0
Johnson Lane	I-90 Interchange	Coulson Road	14900	13.0	1.9	3.2	0.0	15100	13.1	2.0	3.3	0.0
Johnson Lane	Old Hardin Road	I-90 Interchange	18800	3.1	0.6	1.6	0.0	18800	3.1	0.6	1.6	0.0
(Old US 87)	Lockwood Interchang	Jct Old Hardin Road	16400	5.1	2.4	4.5	0.0	16400	5.1	2.4	4.5	0.0
Highway 87	I-90 Lockwood Inter	1st Avenue N	32450	41.5	11.8	17.2	0.0	32350	41.4	11.8	17.2	0.0
Main Street	1st Avenue N	6th Avenue N	44450	33.0	10.2	14.7	0.0	44350	33.0	10.2	14.7	0.0
Main Street	6th Avenue N	Airport Road	54950	24.2	7.7	12.7	0.0	54900	24.2	7.7	12.7	0.0
Main Street	Airport Road	Hilltop Road	52550	69.9	24.0	38.8	0.0	52500	69.8	24.0	38.8	0.0
Main Street	Hilltop Road	Wicks Lane	42300	70.1	26.6	41.1	0.5	42250	70.0	26.6	41.0	0.5
Main Street	Wicks Lane	HWY 312/Bench	27700	41.9	8.9	0.0	0.0	27750	42.0	8.9	0.0	0.0
Highway 87	HWY 312/Bench	Independence Road	13000	15.7	3.6	5.8	0.0	13000	15.7	3.6	5.8	0.0
Wicks Lane	Lake Elmo	Main Street	20250	5.1	1.1	1.1	0.0	20250	5.1	1.1	1.1	0.0
Wicks Lane	Main Street	Bench Boulevard	21550	12.9	4.6	5.5	0.0	21550	12.9	4.6	5.5	0.0
Wicks Lane	Bench Boulevard	Bitterroot Drive	6050	14.3	2.6	3.9	0.0	6050	14.3	2.6	3.9	0.0
Mary Street	Bench Boulevard	Five Mile Road	9200	11.0	0.0	0.0	0.0	9250	11.1	0.0	0.0	0.0
Highway 312	US 87 (N16)	Dover Road	13500	5.0	0.8	0.8	0.3	13500	5.0	0.8	0.8	0.3
Highway 312	Dover Road	Pioneer Road	10900	15.7	6.4	9.5	0.3	10900	15.7	6.4	9.5	0.3
Highway 312	Pioneer Road	S-522 Huntley	10700	34.2	13.6	22.5	0.4	10800	34.6	13.7	22.7	0.4
Bench Bld	Wicks Lane U-1012	US 87 (N16)	5200	21.5	7.5	9.7	0.0	5200	21.5	7.5	9.7	0.0
Dover Road	HWY 312 CO56788	Pioneer Road	3100	3.1	0.5	0.5	0.0	3100	3.1	0.5	0.5	0.0
Bitterroot Drive	Wicks (U-1012)	Mary Street	4100	10.7	1.9	3.2	0.0	4100	10.7	1.9	3.2	0.0
Bitterroot Drive	Mary Street	Dover Road	2650	0.0	0.0	0.0	0.0	2650	0.0	0.0	0.0	0.0
5 Mile Road	Mary Street	Dover Road	0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
Pioneer Road	Dover Road	HWY 312 CO56788	400	2.0	1.2	1.2	0.0	400	2.0	1.2	1.2	0.0
Huntley Main St	I-94 Huntley Inter	CO56788 (HWY 312)	4300	6.7	3.3	3.7	0.0	4200	6.6	3.2	3.6	0.0
Mary St Opt 1	Highway 312	Bitterroot Drive										
	Bitterroot Drive	Five Mile Road										
	Five Mile Road	Johnson Lane										
Mary St Opt 2	Highway 312	Bitterroot Drive										
	Bitterroot Drive	Five Mile Road										
	Five Mile Road	Johnson Lane										
5 Mile Rd Align	Highway 312	Dover Road	4300	1.7	0.3	0.3	0.0	4400	1.2	0.2	0.2	0.0
	Dover Road	Five Mile/Mary	5100	1.0	0.1	0.2	0.0	5200	0.7	0.1	0.1	0.0
	Five Mile/Mary	Johnson Lane	12800	15.3	2.3	3.1	0.3	13000	10.4	1.6	2.1	0.2
Totals =			16910	518.3	153.6	218.7	1.8	17957	512.3	152.7	217.5	1.6
			Avg					Avg				

ALTERNATIVE PHASE 1 ALIGNMENT INTERSECTIONS

This section of the report deals with Phase 1 intersections located along each of the three alternative two lane roadway alignments. The intersection design concepts presented herein were developed specifically for the two lane roadway sections and represent the minimum geometric and traffic control devices necessary to provide acceptable operations based on year 2035 design hour traffic projections. In all cases the intersections would operate at level of service (LOS) "C" or better under the two lane alignment alternatives. In some cases, the LOS on individual movements would operate just below LOS "C" even though the approach leg would operate at LOS "C". This ideally would represent conditions that would typically occur at the end of the project's design life. It should also be understood that the intersections evaluated herein do not necessarily represent the final design configurations. Rather, the concepts serve to illustrate that acceptable intersection designs can be implemented within the project's defined right of way limits. All capacity calculations for the intersections presented in this section of the report can be found in Appendix C.

Johnson Lane Interchange

The existing Johnson Lane Interchange is a conventional diamond type interchange that was constructed to serve residential and commercial areas in the community of Lockwood. There are a number of geometric and land use conditions that limit substantial traffic growth. The DEIS Traffic Study details a number of interchange concept alternatives that would serve traffic demands beyond the year 2035. Phase 1 improvement concepts were based on a desire to use the existing overpass structures in-place. Columns beneath the I-90 structures are separated by a distance of approximately 40 feet which limits the Johnson Lane roadway section to three lanes. A number of configurations were conceived and tested prior to development of the concept illustrated in Figure 7.

The Phase 1 concept involves multiple approach lanes and traffic signal control at the interchange ramps and at the adjacent intersections. Use of roundabouts at the intersections was considered, but was found to not be feasible due the proximity of the intersections on the north side of the overpass structures. Johnson Lane, beneath the overpass, would have two northbound lanes and one southbound lane, which fits the unbalanced directional traffic flows during all hours of the day. Improvements at intersections along Old Hardin Road match those considered for Full Buildout because it was assumed that those improvements would be required prior to the year 2035 and would be completed either by the Phase 1 project or by local funding in subsequent years. Capacity calculations for the ramp and North Frontage Road intersections associated with this design option can be found in Appendix C of this report. All intersections would operate at LOS "C" and all movements would operate at LOS "C" or better. Note that the Phase 1 design option has the same turning movements at the Old Hardin Road and Becraft intersections as those in Full Buildout. Thus, capacity calculations contained in the DEIS Traffic Study also apply to Phase 1 at those intersections.

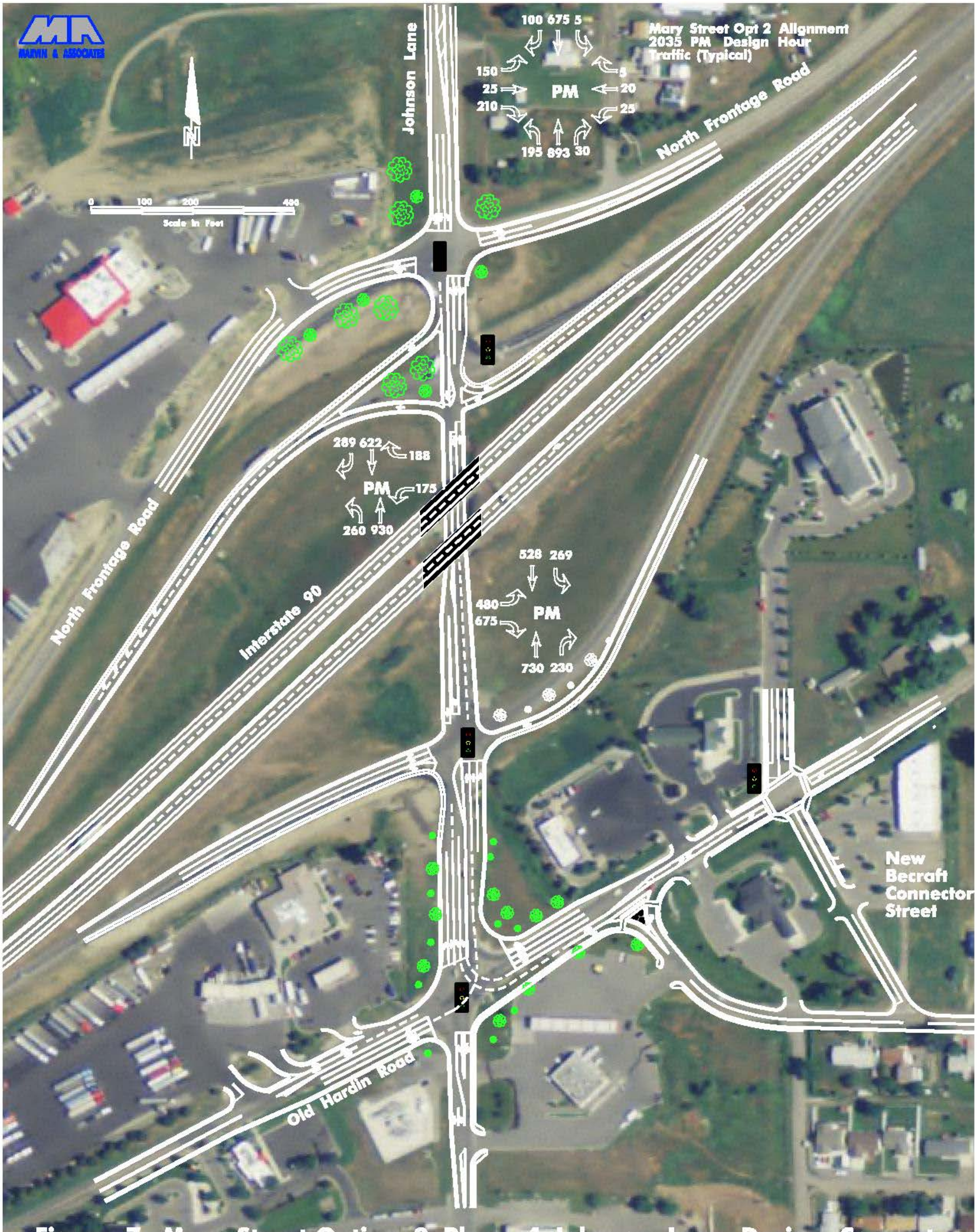


Figure 7. Mary Street Option 2 Phase 1 Johnson Lane Design Concept

Johnson Lane/Coulson Road Intersections

Figure 8 Illustrates the proposed geometry associated with the intersections of Coulson Road and Johnson Lane with the Phase 1 alternatives' alignment. The Johnson Lane intersection with the new alignment would be a "T"-intersection on the outside of a curve. The Coulson Road intersection would have four approach legs. Both intersections would have stop control for approaches accessing the Bypass alignment. The Phase 1 concept is essentially the same as what was set forth in the DEIS Traffic Report except that the alignment would have three lanes at the intersections instead of five lanes.

Capacity calculations (Appendix C) indicate that all approaches at the Johnson Lane intersection would operate at LOS "B" or better in the year 2035, while the minor approach at the Coulson Road intersection would operate at LOS "C".

Mary Street Alignment Intersections

There are four intersections on the Mary Street Alignments that are detailed within this section of the report. Mary Street Options 1 & 2 Alignments intersect with Five Mile Road at two different locations, but both Mary Street Alignments intersect Bitterroot Drive and Hawthorne Lane at the same locations, and thus, both alignments are covered by the same concept designs.

Mary Option 1 & Five Mile Road

Figure 9 illustrates the proposed design geometry and operational controls for the intersection of Mary Street Option 1 Phase 1 Alignment and the existing Mary Street/Five Mile Road corridor. The same basic roundabout location and access controls are used for the Phase 1 concept except that there are only single lane approaches on the Bypass alignment and the roundabout only has single circulation lanes.

Capacity calculations (Appendix C) indicate that all approaches to this intersection would operate at a LOS "B" or better in the year 2035.

Mary Option 2 & Five Mile Road

Figure 10 is similar to Mary Option 1 and Five Mile Road in that the Phase 1 roundabout would be at the same location and all approaches would have a single lane and there would be a single circulation lane. The Mary Street Option 2 Phase 1 Alignment intersection with Five Mile Road would provide the same safety benefits associated with the dual lane approaches detailed for the Full Buildout concept.

Capacity calculations (Appendix C) indicate that all approaches to this intersection would operate at a LOS "B" or better in the year 2035.

Figure 8. Mary Opt 2 Johnson Lane – Coulson Road Intersections Phase 1

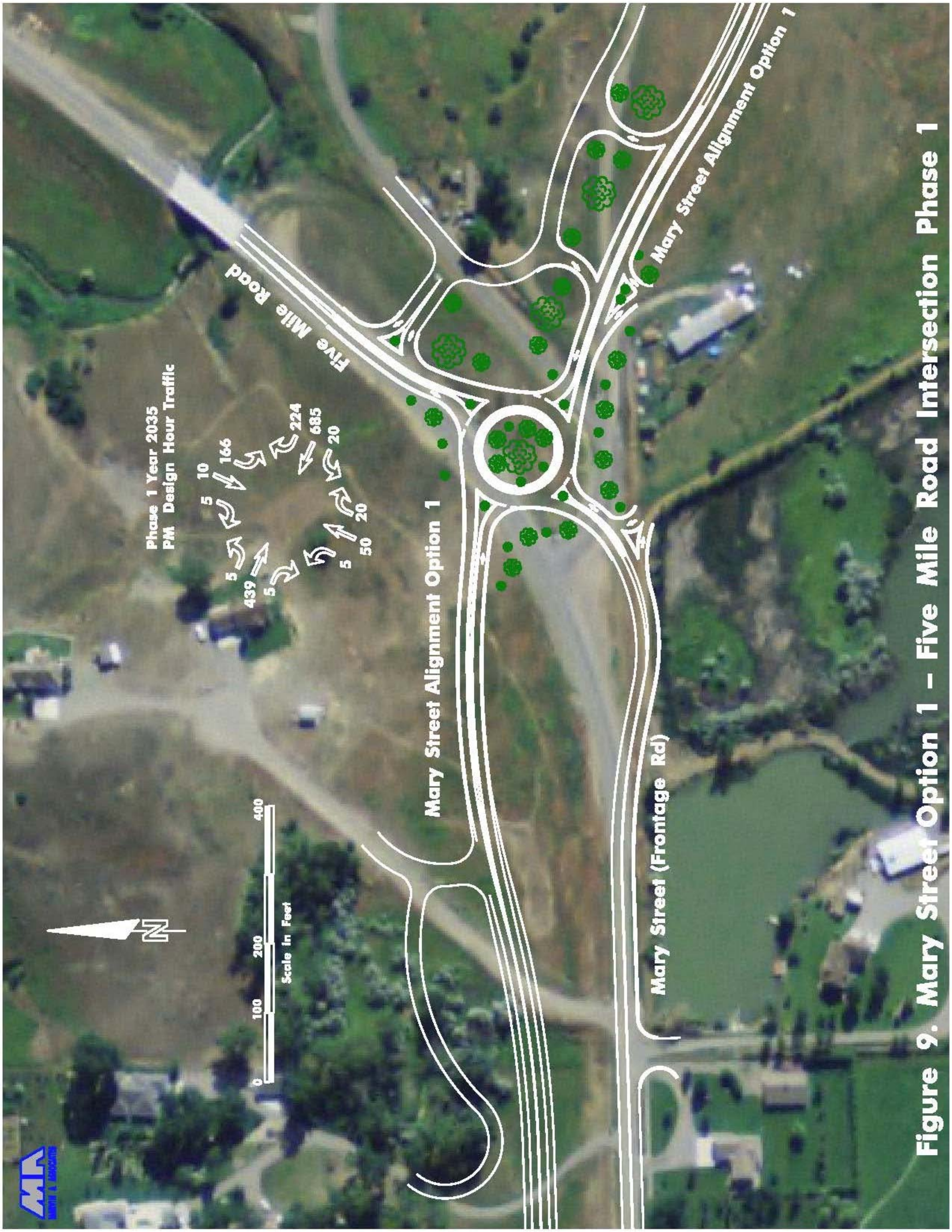


Figure 9. Mary Street Option 1 – Five Mile Road Intersection Phase 1

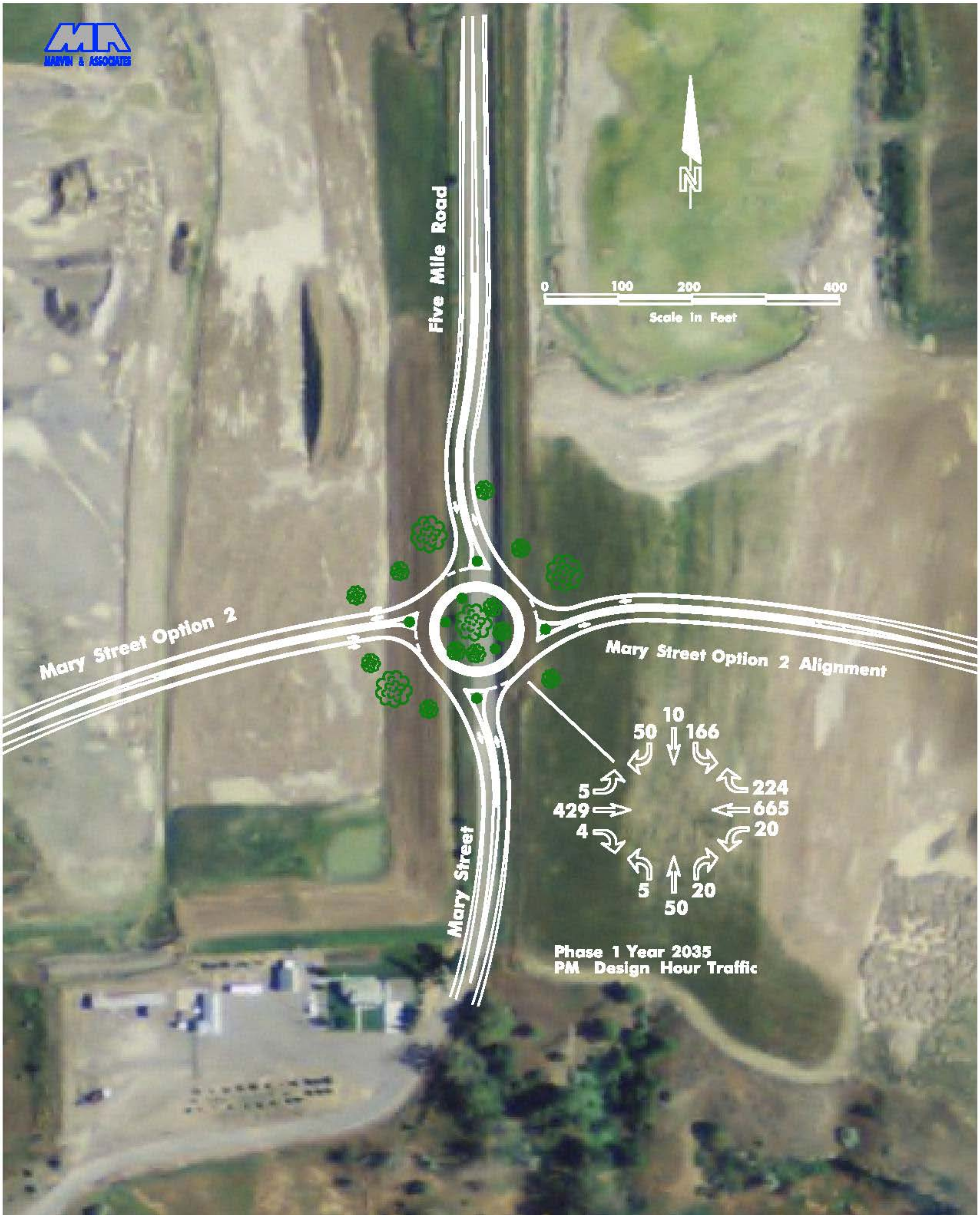


Figure 10. Mary Alignment Option 2 – Five Mile Road Intersection Phase 1

Mary Street Alignment & Bitterroot Drive

There were a number of alternative concepts presented for the Phase 2 Mary Street alignments that could be considered during design of the project. For purposes of the Phase 1 (two lane) alignment the roundabout option was evaluated to determine if the two lane alignment would operate efficiently. Figure 11 illustrates this Phase 1 concept intersection that was evaluated using single approach lanes and single circulation lanes within the roundabout. A two-way stop controlled intersection on Mary Street and Bitterroot Drive was used adjacent to the alignment intersection.

Capacity calculations (Appendix C) indicate that all approaches for the alignment intersection would operate at LOS “B” or better in the design year 2035. The two-way stop intersection of Mary Street and Bitterroot Drive would operate at LOS “C” for the eastbound approach and LOS “B” for the westbound approach.

Mary Options 1 & 2 & Hawthorne Lane

Figure 12 shows the Phase 1 concept that is the same as the Phase 2 concept discussed in the DEIS Traffic Study except that the Mary Street alignments would have three lanes instead of five. Capacity calculations (Appendix C) indicate that stop control on the northbound approach to the Mary Street alignment would operate at LOS “B”. The intersection of Hawthorne Lane and existing Mary Street would have the same configuration and traffic volumes that were evaluated in the Phase 2 DEIS Traffic Study and both approaches would operate at LOS “B” or better in the year 2035.

Five Mile Road Alignment & Old Hwy 312

There were a number of design options and intersection locations investigated in the DEIS Traffic Study for the Five Mile Road alignment and Old Highway 312. For the purposes of the Phase 1 two lane alignment investigation it was assumed that a signalized intersection would be the most likely intersection control that would be implemented. Figure 13 shows the concept for Phase 1 construction. It incorporates a two lane section of the Five Mile Road Alignment with an auxiliary right-turn lane at its intersection with Hwy 312. It was also assumed that Hwy 312 at its intersection with Five Mile Road would be reconstructed to extend east beyond this intersection.

Capacity calculations (see Appendix C) for the Phase 1 concepts were completed for a stop controlled intersection that would likely exist prior to the year 2035. In that scenario the northbound left-turn lane would operate at LOS “E” and the southbound approach would operate at LOS “D”. Thus, a traffic signal would likely be warranted prior to the year 2035.

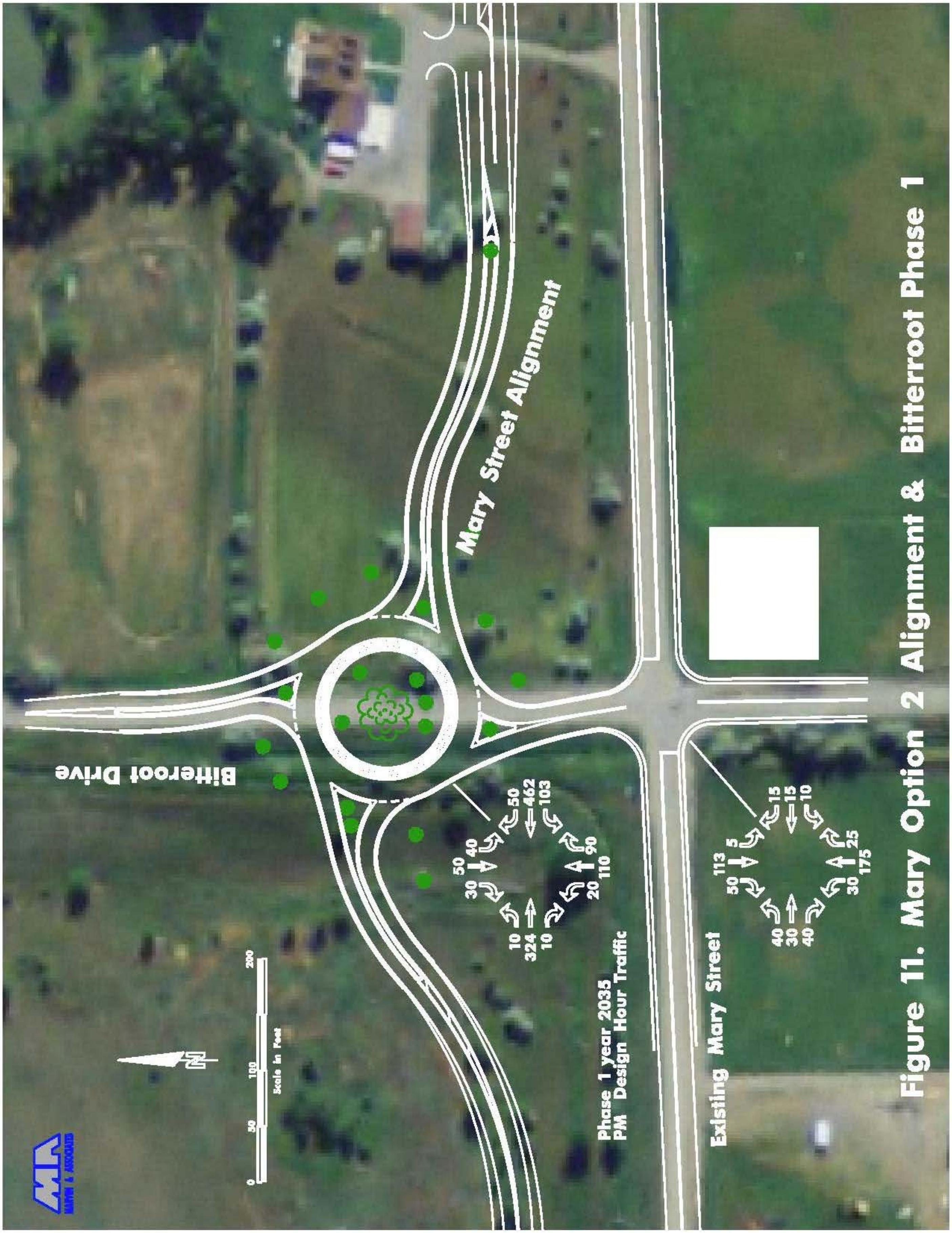


Figure 11. Mary Option 2 Alignment & Bitterroot Phase 1

Figure 12. Mary Street 2 Alignment – Hawthorne Lane Phase 1

Figure 13. Five Mile Road Alternative & Old Hwy 312 Phase 1

Five Mile Road and Dover Road

Operations at the intersection of Five Mile Road and Dover Road for the Five Mile Road Alignment were investigated in the DEIS Traffic Study and capacity calculations indicated that stop control on the Dover Road approaches would result in LOS "C" in all cases. Even with one less travel lane in both directions on the Five Mile Road alignment, all of the approaches would still operate at LOS "C" or better in the year 2035 with stop control (see Appendix C).

Five Mile Road & Mary Street

Figure 14 shows the proposed design geometry and operational controls for the intersection of Five Mile Road Alignment and existing Mary Street. This intersection is basically the same as the Full Buildout roundabout except that instead of having two thru-lanes at each approach with two circulation lanes in the roundabout, there would only be one lane in each direction at each approach and a single circulation lane in the roundabout.

Capacity calculations (Appendix C) indicate that all approaches to this intersection would operate at a LOS "B" or better in the year 2035.

Mary Street Alignments & US 87/ Old Hwy 312 Intersection

The Phase 1 concept drawing for the intersection of US 87/Old Hwy 312 is contained in Figure 15. This concept is substantially different than the Full Buildout concepts discussed in the DEIS Traffic Study since it incorporates two adjacent signalized intersections. MDT is currently in the process of finalizing plans for reconstruction and signalization of the Main Street and Bench Boulevard intersection and the anticipated implementation date is within the next two years. One feature of that project involves construction of a raised median in Bench Boulevard which will change traffic operations at the intersection of Mary Street and Bench Boulevard so that access to Mary Street from Bench Boulevard will only accommodate right-in and right-out movements. That feature of the MDT project was approved by the City of Billings. Since it is anticipated that the Phase 1 alignment would be constructed a few years after the Main Street and Bench intersection is complete, it was decided that the Mary Street Alignment intersection with Hwy 312 could be designed to incorporate the majority of improvements that are associated with the Main Street and Bench Boulevard project. Thus, with that being the basis of the Phase 1 concept, it was determined that northbound and southbound traffic could be split so that southbound traffic on US 87 would enter Bench Boulevard, directly at the Main Street intersection, and would access the Mary Street Alignment, directly at the Hwy 312 intersection. Northbound US 87 traffic would originate from the Mary Street Alignment as a through movement at the Hwy 312 intersection and as a left-turn movement from Main Street. Travel distance for northbound US 87 traffic originating at Bench Boulevard would be approximately the same as with the Full Buildout roundabout concepts.

Figure 14. Five Mile Road Alignment – Mary Street Phase 1

Figure 15. Mary Street Alignments US 87 HWY 312 Bench Blvd. Phase 1 Intersection

There is a possibility that the two signals could be controlled by the same controller or two controllers could be coordinated to provide desired operations. Capacity calculations (Appendix C) indicate that the Mary Street Alignment intersection would operate at LOS “C” and the US 87/Bench Boulevard intersection would operate at LOS “B” for year 2035 traffic volumes. However there would be a number of movements at the Mary Alignment and Hwy 312 intersection that would operate at LOS “D”. This would indicate that this design concept has a limited design life and that the entire intersection would need to be reconfigured when Full Buildout improvements are constructed.

SUMMARY & CONCLUSIONS

Traffic projections for Phase 1 construction of alternative alignments with only two through traffic lanes instead of four are not significantly different for any of the alternative alignments. Analysis of existing street system impacts based upon Phase 1 traffic projections for the preliminary alignment alternatives were completed and it was determined that there would be no significant difference in operations between Phase 1 and Full Buildout for any of the three alternatives. In addition, the differences in VMT and VHT between Phase 1 and Full Buildout conditions would be minimal. Analysis of crash impacts provided the greatest differences simply due to a theoretical variance between two lane and four lane operations on the alternative alignments. Even so, the difference in the number of crashes on the impacted street system would only be approximately 2% for each alternative alignment. The Phase 1 Alignments would still provide safety benefits by reducing traffic on existing streets and diverting traffic to a newer, safer facility.

This study evaluated concept intersections that could be considered in design along each of the alternative alignments. These intersections are all on the primary alignments, since it was assumed that secondary improvements associated with Phase 1 would be identical to those presented in the DEIS Traffic Study. It was determined that acceptable Phase 1 intersection designs would be possible for all of the alternative alignments within the right-of-way limits established in the DEIS. The intersection concepts presented herein were developed as minimal improvements that could easily be expanded at such time when Full Buildout construction is considered necessary, but the concepts do not necessarily commit Phase 1 designers to replicate their features in final design considerations.

APPENDIX A

Phase 1

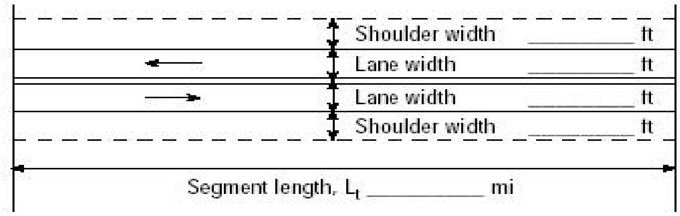
Two Lane Corridor Capacity

DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway / Direction of Travel	*Mary Option 1*
Agency or Company	*Marvin Associates*	From/To	*Johnson Lane to Mary Street*
Date Performed	*4/24/2013*	Jurisdiction	*MDT*
Analysis Time Period	*Average Daytime Hour*	Analysis Year	*2035*

Project Description: *Billings Bypass*

Input Data



Analysis direction vol., V_d *475*veh/h
Opposing direction vol., V_o *475*veh/h
Shoulder width ft *10.0*
Lane Width ft *12.0*
Segment Length mi *3.2*

☐ Class I highway ☐ Class II highway ☑ Class III highway
Terrain ☐ Level ☑ Rolling
Grade Length mi Up/down
Peak-hour factor, PHF *0.95*
No-passing zone *35%*
% Trucks and Buses , P_T *4 %*
% Recreational vehicles, P_R *2%*
Access points *mi* *1/mi*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.8*	*1.8*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.1*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.967*	*0.967*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*0.95*	*0.95*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*544*	*544*

Free-Flow Speed from Field Measurement		Estimated Free-Flow Speed	
Mean speed of sample[3], S_{FM}	*60*	Base free-flow speed[4], BFFS	*mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.7 mi/h*	Free-flow speed, FFS $(FSS=BFFS-f_{LS}-f_A)$	*66.3 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*56.2 mi/h*
		Percent free flow speed, PFFS	*84.8 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.4*	*1.4*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.984*	*0.984*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*0.96*	*0.96*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*529*	*529*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*53.5*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*31.9*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*69.4*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*B*
Volume to capacity ratio, *v/c*	*0.32*

Capacity, $C_{d,ATS}$ (Equation 15-12) pc/h	*1578*
Capacity, $C_{d,PTSF}$ (Equation 15-13) pc/h	*1619*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*84.8*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*500.0*
Effective width, Wv (Eq. 15-29) ft	*32.00*
Effective speed factor, S_t (Eq. 15-30)	*4.94*
Bicycle level of service score, BLOS (Eq. 15-31)	*0.85*
Bicycle level of service (Exhibit 15-4)	*A*

Notes

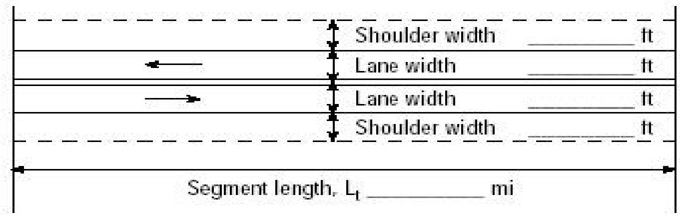
1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway / Direction of Travel	*Mary Option 1*
Agency or Company	*Marvin Associates*	From/To	*Mary St - HWY 312*
Date Performed	*4/24/2013*	Jurisdiction	*MDT*
Analysis Time Period	*Average Daytime Hour*	Analysis Year	*2035*

Project Description: *Billings Bypass*

Input Data



Analysis direction vol., V_d	*315*veh/h
Opposing direction vol., V_o	*315*veh/h
Shoulder width ft	*10.0*
Lane Width ft	*12.0*
Segment Length mi	*1.7*

☐ Class I highway ☐ Class II highway ☑ Class III highway

Terrain ☑ Level ☐ Rolling

Grade Length mi	Up/down
Peak-hour factor, PHF	*0.95*
No-passing zone	*25%*
% Trucks and Buses , P_T	*4 %*
% Recreational vehicles, P_R	*2%*
Access points *mi*	*1/mi*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.4*	*1.4*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.984*	*0.984*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF* f_{g,ATS} * f_{HV,ATS})$	*337*	*337*

Free-Flow Speed from Field Measurement		Estimated Free-Flow Speed	
Mean speed of sample[3], S_{FM}	*45*	Base free-flow speed[4], BFFS	*mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.3 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*49.7 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*43.2 mi/h*
		Percent free flow speed, PFFS	*87.0 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.1*	*1.1*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.996*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*333*	*333*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*36.0*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*38.9*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*55.5*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*B*
Volume to capacity ratio, *v/c*	*0.20*

Capacity, $C_{d,ATS}$ (Equation 15-12) pc/h	*1673*
Capacity, $C_{d,PTSF}$ (Equation 15-13) pc/h	*1693*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*87.0*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*331.6*
Effective width, Wv (Eq. 15-29) ft	*32.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*0.43*
Bicycle level of service (Exhibit 15-4)	*A*

Notes

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

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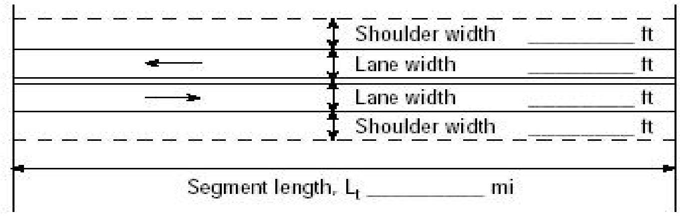
DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway / Direction of Travel	*Mary Option 2*
Agency or Company	*Marvin Associates*	From/To	*Johnson Lane to Mary Street*
Date Performed	*4/24/2013*	Jurisdiction	*MDT*
Analysis Time Period	*Average Daytime Hour*	Analysis Year	*2035*

Project Description: *Billings Bypass*

Input Data



☐ Class I highway ☐ Class II highway ☑ Class III highway

Terrain ☐ Level ☑ Rolling

Analysis direction vol., V_d	*470*veh/h
Opposing direction vol., V_o	*470*veh/h
Shoulder width ft	*10.0*
Lane Width ft	*12.0*
Segment Length mi	*3.0*
Grade Length mi	Up/down
Peak-hour factor, PHF	*0.95*
No-passing zone	*24%*
% Trucks and Buses , P_T	*4 %*
% Recreational vehicles, P_R	*2%*
Access points *mi*	*1/mi*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.8*	*1.8*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.1*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.967*	*0.967*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*0.95*	*0.95*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF^* f_{g,ATS} * f_{HV,ATS})$	*539*	*539*

Free-Flow Speed from Field Measurement		Estimated Free-Flow Speed	
Mean speed of sample[3], S_{FM}	*60*	Base free-flow speed[4], BFFS	mi/h
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	mi/h
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	mi/h
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.5* mi/h	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*66.3* mi/h
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*56.4* mi/h
		Percent free flow speed, PFFS	*85.1* %

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.4*	*1.4*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.984*	*0.984*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*0.96*	*0.96*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF^*f_{HV,PTSF}^* f_{g,PTSF})$	*524*	*524*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*53.4*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*29.2*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*68.0*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*B*
Volume to capacity ratio, *v/c*	*0.32*

Capacity, $C_{d,ATS}$ (Equation 15-12) pc/h	*1562*
Capacity, $C_{d,PTSF}$ (Equation 15-13) pc/h	*1619*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*85.1*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*494.7*
Effective width, Wv (Eq. 15-29) ft	*32.00*
Effective speed factor, S_t (Eq. 15-30)	*4.94*
Bicycle level of service score, BLOS (Eq. 15-31)	*0.85*
Bicycle level of service (Exhibit 15-4)	*A*

Notes

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

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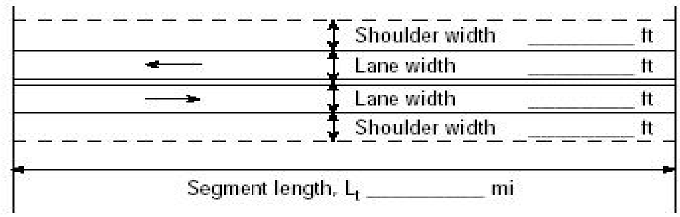
DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway / Direction of Travel	*Mary Option 2*
Agency or Company	*Marvin Associates*	From/To	*Mary St - HWY 312*
Date Performed	*4/21/2013*	Jurisdiction	*MDT*
Analysis Time Period	*Average Daytime Hour*	Analysis Year	*2035*

Project Description: *Billings Bypass*

Input Data



Analysis direction vol., V_d	*300*veh/h
Opposing direction vol., V_o	*300*veh/h
Shoulder width ft	*10.0*
Lane Width ft	*12.0*
Segment Length mi	*2.2*

☐ Class I highway ☐ Class II highway ☑ Class III highway

Terrain ☑ Level ☐ Rolling

Grade Length mi	Up/down
Peak-hour factor, PHF	*0.92*
No-passing zone	*32%*
% Trucks and Buses , P_T	*4 %*
% Recreational vehicles, P_R	*2%*
Access points *mi*	*1/mi*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.4*	*1.4*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/ (1+ P_T(E_T-1)+P_R(E_R-1))$	*0.984*	*0.984*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i / (PHF^* f_{g,ATS} * f_{HV,ATS})$	*331*	*331*

Free-Flow Speed from Field Measurement		Estimated Free-Flow Speed	
Mean speed of sample[3], S_{FM}	*45*	Base free-flow speed[4], BFFS	*mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/ f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.5 mi/h*	Free-flow speed, FFS $(FSS=BFFS-f_{LS}-f_A)$	*49.7 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS} + v_{o,ATS}) - f_{np,ATS}$	*43.1 mi/h*
		Percent free flow speed, PFFS	*86.7 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.1*	*1.1*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/ (1+ P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.996*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF^*f_{HV,PTSF}{}^* f_{g,PTSF})$	*327*	*327*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*35.7*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*42.3*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF} *(v_{d,PTSF} / v_{d,PTSF} + v_{o,PTSF})$	*56.8*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*B*
Volume to capacity ratio, *v/c*	*0.19*

Capacity, $C_{d,ATS}$ (Equation 15-12) pc/h	*1673*
Capacity, $C_{d,PTSF}$ (Equation 15-13) pc/h	*1693*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*86.7*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*326.1*
Effective width, Wv (Eq. 15-29) ft	*32.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*0.42*
Bicycle level of service (Exhibit 15-4)	*A*

Notes

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

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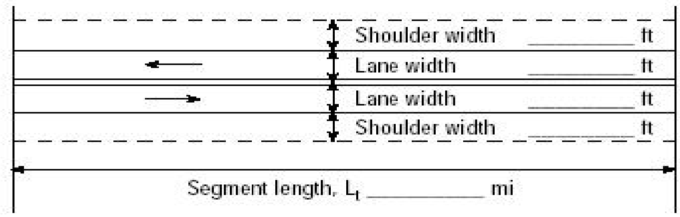
DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway / Direction of Travel	*Five Mile Rd Alt*
Agency or Company	*Marvin Associates*	From/To	*Johnson Lane to Mary*
Date Performed	*4/24/2013*	Jurisdiction	*MDT*
Analysis Time Period	*Average Daytime Hour*	Analysis Year	*2035*

Project Description: *Billings Bypass*

Input Data



☐ Class I highway ☐ Class II highway ☑ Class III highway

Terrain ☐ Level ☑ Rolling

Grade Length mi Up/down

Analysis direction vol., V_d	*390*veh/h
Opposing direction vol., V_o	*390*veh/h
Shoulder width ft	*10.0*
Lane Width ft	*12.0*
Segment Length mi	*3.0*
Peak-hour factor, PHF	*0.92*
No-passing zone	*14%*
% Trucks and Buses , P_T	*4 %*
% Recreational vehicles, P_R	*2%*
Access points *mi*	*1/mi*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*2.0*	*2.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.1*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.960*	*0.960*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*0.91*	*0.91*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF^* f_{g,ATS} * f_{HV,ATS})$	*485*	*485*

Free-Flow Speed from Field Measurement		Estimated Free-Flow Speed	
Mean speed of sample[3], S_{FM}	*60*	Base free-flow speed[4], BFFS	*mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.5 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*66.3 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*57.3 mi/h*
		Percent free flow speed, PFFS	*86.4 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.4*	*1.4*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.984*	*0.984*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*0.91*	*0.91*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF^*f_{HV,PTSF}{}^* f_{g,PTSF})$	*473*	*473*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*49.4*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*25.8*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*62.3*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*B*
Volume to capacity ratio, *v/c*	*0.29*

Capacity, $C_{d,ATS}$ (Equation 15-12) pc/h	*1539*
Capacity, $C_{d,PTSF}$ (Equation 15-13) pc/h	*1573*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*86.4*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*423.9*
Effective width, Wv (Eq. 15-29) ft	*32.00*
Effective speed factor, S_t (Eq. 15-30)	*4.94*
Bicycle level of service score, BLOS (Eq. 15-31)	*0.77*
Bicycle level of service (Exhibit 15-4)	*A*

Notes

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

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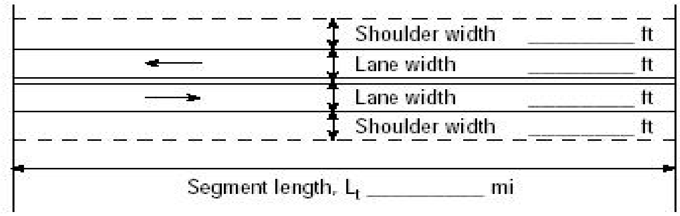
DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	*R Marvin*	Highway / Direction of Travel	*Five Mile Rd Alt*
Agency or Company	*Marvin Associates*	From/To	*Mary to HWY 312*
Date Performed	*4/24/2013*	Jurisdiction	*MDT*
Analysis Time Period	*Average Daytime Hour*	Analysis Year	*2035*

Project Description: *Billings Bypass*

Input Data



☐ Class I highway ☐ Class II highway ☑ Class III highway

Terrain ☑ Level ☐ Rolling

Analysis direction vol., V_d	*145*veh/h
Opposing direction vol., V_o	*145*veh/h
Shoulder width ft	*10.0*
Lane Width ft	*12.0*
Segment Length mi	*3.0*
Grade Length mi	Up/down
Peak-hour factor, PHF	*0.92*
No-passing zone	*41%*
% Trucks and Buses , P_T	*4* %
% Recreational vehicles, P_R	*2%*
Access points *mi*	*1*/mi

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.7*	*1.7*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/ (1+ P_T (E_T -1)+P_R (E_R -1))$	*0.973*	*0.973*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i / (PHF^* f_{g,ATS} * f_{HV,ATS})$	*162*	*162*

Free-Flow Speed from Field Measurement		Estimated Free-Flow Speed	
		Base free-flow speed[4], BFFS	*mi/h*
		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*mi/h*
Mean speed of sample[3], S_{FM}	*60*	Adj. for access points[4], f_A (Exhibit 15-8)	*mi/h*
Total demand flow rate, both directions, *v*		Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*62.8 mi/h*
Free-flow speed, FFS=S_{FM}+0.00776(*v*/ $f_{HV,ATS}$)		Average travel speed, ATS_d=FFS-0.00776($v_{d,ATS}$ + $v_{o,ATS}$) - $f_{np,ATS}$	*57.6 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*2.7 mi/h*	Percent free flow speed, PFFS	*91.7 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.1*	*1.1*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/ (1+ P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.996*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF^*f_{HV,PTSF}* f_{g,PTSF})$	*158*	*158*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*17.5*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*50.0*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF} *(v_{d,PTSF} / v_{d,PTSF} + v_{o,PTSF})$	*42.5*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*B*
Volume to capacity ratio, *v/c*	*0.10*

Capacity, $C_{d,ATS}$ (Equation 15-12) pc/h	*1654*
Capacity, $C_{d,PTSF}$ (Equation 15-13) pc/h	*1693*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*91.7*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*157.6*
Effective width, Wv (Eq. 15-29) ft	*38.05*
Effective speed factor, S_t (Eq. 15-30)	*4.94*
Bicycle level of service score, BLOS (Eq. 15-31)	*-1.85*
Bicycle level of service (Exhibit 15-4)	*A*

Notes

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

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APPENDIX B

Phase 1

System Intersections Capacity

HCM Analysis Summary

Mary Option 1 Alt 2035 Phase 1 | Wicks Lane/Main Street | Area Type: Non CBD
R Marvin | 8/15/13 | Analysis Duration: 15 mins.
PM | Case: Wicks Main Mary Op1 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	314	450	156	520	390	80	358	1370	350	140	820	352
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			30			100			120		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 125.0 Sec | Lost Time Per Cycle: 18.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB				LTR					
WB			LTP						
NB	L	TP							
SB	L	TP							
Green	16.0	38.0	24.0	29.0					0
Yellow / All Red	3.0 / 0.0	3.5 / 1.5	3.5 / 1.5	3.5 / 1.5					

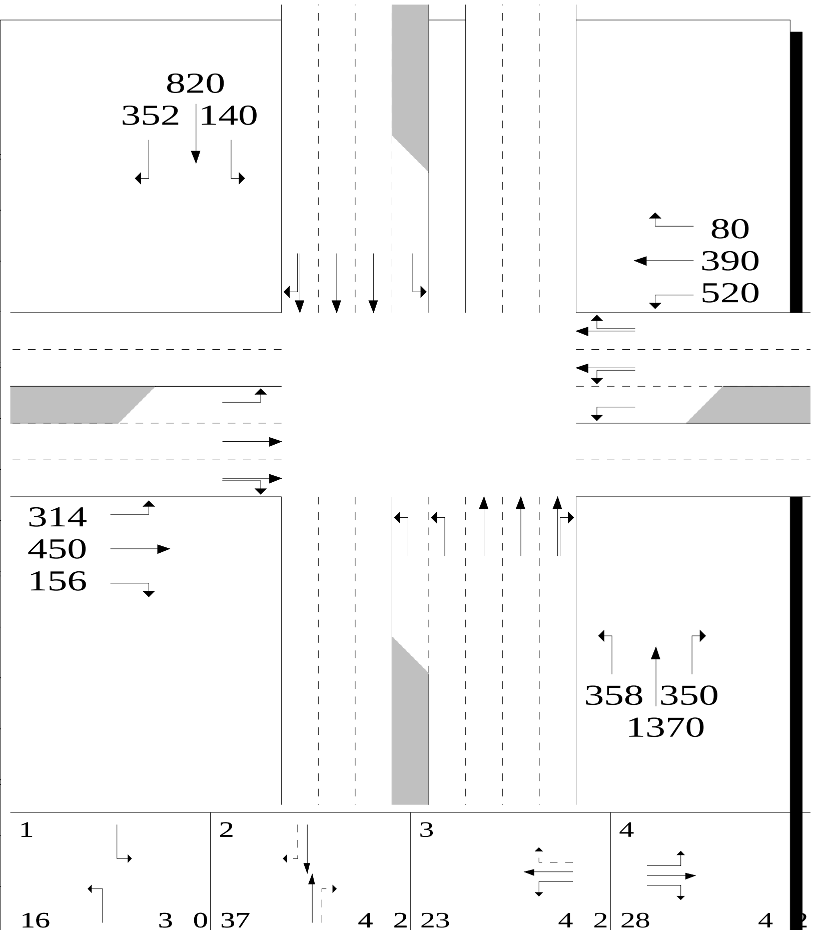
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	419	0.189	0.232	L	0.814	52.1	D	44.5	D
	TR	819	0.162	0.232	TR	0.698	40.0	D		
WB										
	* L	347	0.224	0.192	L	1.164	151.4	F	102.8	F
	LTR	675	0.182	0.192	LTR	0.947	72.1	E		
NB										
	* L	448	0.111	0.128	L	0.868	68.1	E	105.3	F
	* TR	1509	0.355	0.304	TR	1.167	113.5	F		
SB										
	L	231	0.084	0.128	L	0.658	65.7	E	45.0	D
	TR	1508	0.230	0.304	TR	0.758	42.3	D		

Intersection: Delay = 80.1 sec/veh   Int. LOS=F X_c= 1.03   * Critical Lane Group Σ(v/s)Crit= 0.88

NETSIM Summary Results

Mary Option 1 Alt 2035 Phase 1	Wicks Lane/Main Street
R Marvin	8/15/13
PM	Case: Wicks Main Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	9 / 14	4.8	0.0
	TR	3 / 5	13.5	0.0
	All		9.0	0.0
WB	L	11 / 13	4.1	0.0
	LTR	11 / 14	5.9	0.0
	All		5.4	0.0
NB	L	7 / 9	3.9	0.0
	TR	16 / 29	4.5	4.1
	All		4.3	4.1
SB	L	8 / 10	3.2	0.0
	TR	9 / 13	7.3	0.0
	All		6.4	0.0
Intersect.			5.5	



HCM Analysis Summary

Mary Opt 1 Alt 2035 Phase 1 — Airport Road/Main Street — Area Type: Non CBD
R Marvin — 8/15/13 — Analysis Duration: 15 mins.
PM Design Hour — Case: Airport Main Mary Op1 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	2898	10	70	1706	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated — Operational Analysis — Cycle Length: 150.0 Sec — Lost Time Per Cycle: 20.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LTP				R												
WB			LTP														
NB					LTP		TP										
SB							TP		LTR								
Green	39.0		6.0		20.0		56.0		6.0								0
Yellow / All Red	3.5	1.5	3.5	1.5	3.0	0.0	3.5	1.5	3.5	1.5							

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	460	0.292	0.260	L	1.122	135.1	F	99.3	F
	LT	462	0.225	0.260	LT	0.866	68.1	E		
	R	639	0.054	0.413	R	0.131	27.3	C		
WB										
	* LT	74	0.040	0.040	LT	1.000	176.6	F	177.5	F
	R	64	0.039	0.040	R	0.984	178.5	F		
NB										
	L	236	0.137	0.133	L	1.025	123.7	F	82.1	F
	* TR	2677	0.603	0.527	TR	1.144	78.8	E		
SB										
	* L	72	0.041	0.040	L	1.028	184.0	F	34.4	C
	TR	2219	0.425	0.447	TR	0.952	29.2	C		

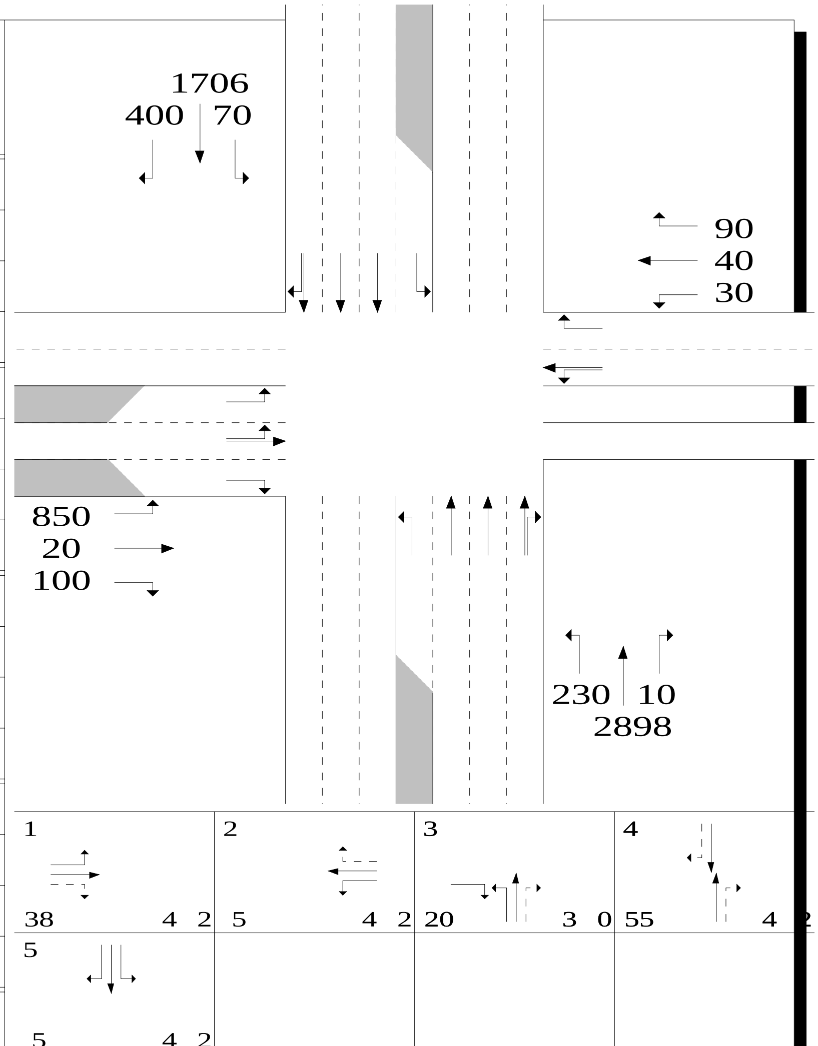
Intersection: Delay = 70.9 sec/veh — Int. LOS=E — X_c= 1.13 — * Critical Lane Group — Σ(v/s)Crit= 0.98

NETSIM Summary Results

Mary Opt 1 Alt 2035 Phase 1
R Marvin
PM Design Hour

Airport Road/Main Street
8/15/13
Case: Airport Main Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	18 / 18	4.2	0.0
	LT	17 / 17	5.7	0.0
	R	2 / 3	17.3	0.0
	All		5.3	0.0
WB	LT	3 / 3	5.1	0.0
	R	3 / 4	9.6	0.0
	All		7.4	0.0
NB	L	13 / 16	2.9	0.0
	TR	28 / 30	6.2	21.7
	All		5.8	21.7
SB	L	4 / 7	4.7	0.0
	TR	11 / 17	9.8	0.0
	All		9.5	0.0
Intersect.			6.6	



HCM Analysis Summary

Mary Option 1 Alt 2035 Phase 1	1st Ave N/	Area Type: Non CBD
R Marvin	8/15/13	Analysis Duration: 15 mins.
PM design Hour	Case: US 87 MAIN FIRST Mary Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	864	0	0	0	830	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			250			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 130.0 Sec Lost Time Per Cycle: 15.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LT																
WB			TP		R												
NB																	
SB	R				L P												
Green	52.0		26.0		37.0												0
Yellow / All Red	3.5	1.5	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	2060	0.368	0.400	L	0.920	28.7	C	29.4	C
	T	745	0.339	0.400	T	0.848	31.2	C		
WB										
	* T	708	0.181	0.200	T	0.907	65.9	E	48.1	D
	R	812	0.416	0.523	R	0.796	30.4	C		
SB										
	* L	958	0.260	0.285	L	0.912	47.3	D	26.4	C
	R	2015	0.253	0.723	R	0.350	0.5	A		

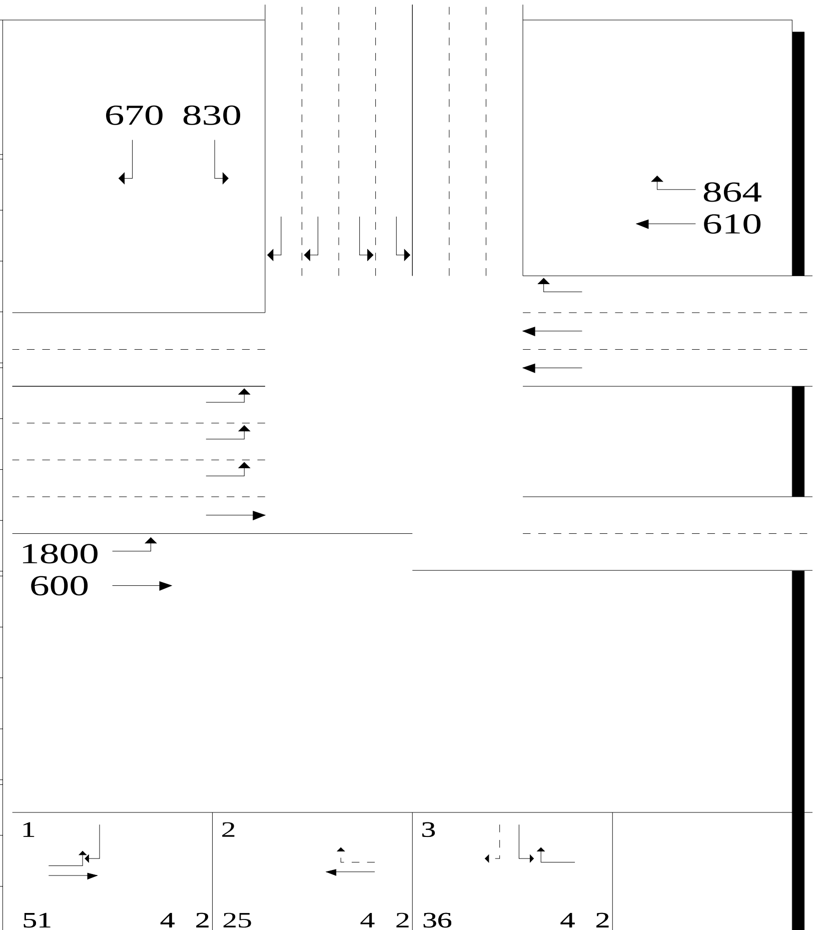
Intersection: Delay = 33.0 sec/veh Int. LOS=C X_c = 0.91 * Critical Lane Group Σ(v/s)Crit= 0.81

NETSIM Summary Results

Mary Option 1 Alt 2035 Phase 1
R Marvin
PM design Hour

1st Ave N/
8/15/13
Case: US 87 MAIN FIRST Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	18 / 26	4.5	1.2
	T	12 / 17	6.8	0.2
	All		5.0	1.2
WB	T	11 / 13	6.0	0.0
	R	17 / 26	7.0	2.4
	All		6.6	2.4
	All		6.5	0.0
SB	L	16 / 18	4.0	0.0
	R	1 / 2	21.7	0.0
Intersect.			5.8	



HCM Analysis Summary

Mary Opt 1 2035 Phase 1	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	8/15/13	Analysis Duration: 15 mins.
PM Design Hour	Case: EB Ramps US 87 Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	476	440	0	0	600	20	622	350	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 120.0 Sec   Lost Time Per Cycle: 9.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB	LT		LT														
WB			TR														
NB					LTP												
SB																	
Green	32.0		25.0		49.0												0
Yellow / All Red	4.0	0.0	3.5	1.5	3.5	1.5											

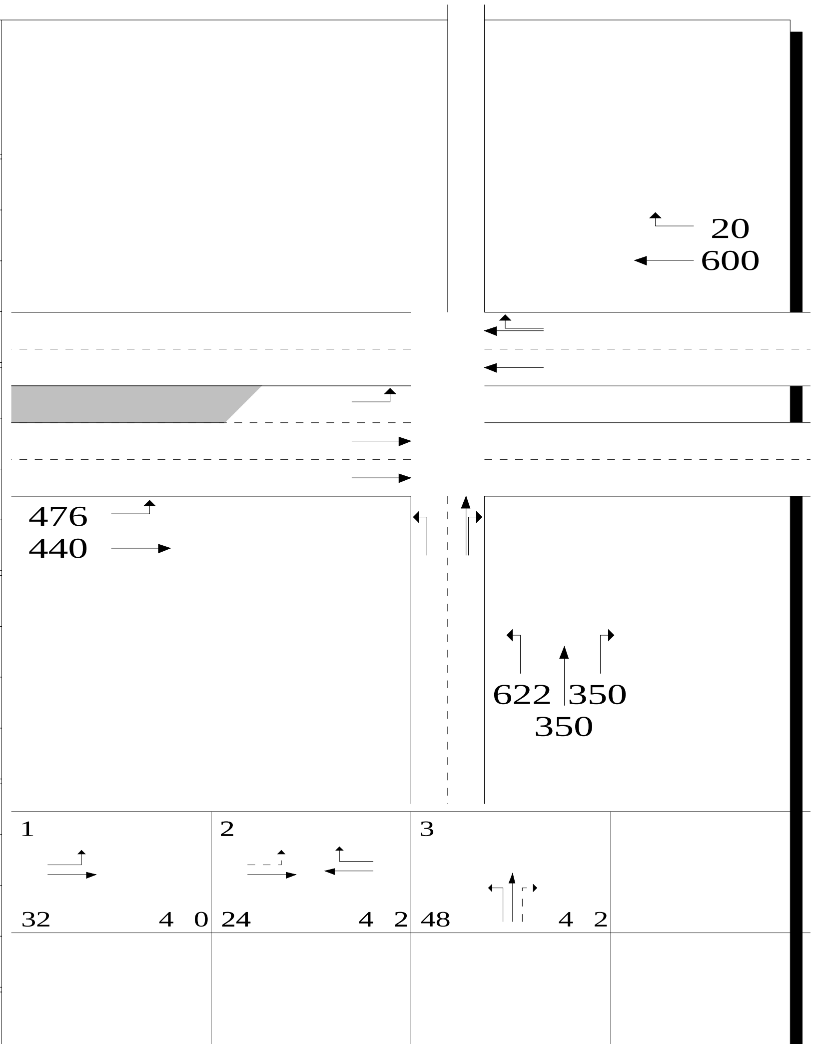
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	61	0.221	0.250					45.0	D
	* Lpro	463	0.267	0.267	L	0.987	70.8	E		
	T	1817	0.134	0.508	T	0.263	17.1	B		
WB										
	TR	735	0.189	0.208	TR	0.909	63.6	E	63.6	E
NB										
	* L	699	0.395	0.408	L	0.967	60.6	E	54.4	D
	TR	720	0.370	0.408	TR	0.906	48.0	D		

Intersection: Delay = 53.3 sec/veh   Int. LOS=D X_c= 0.95   * Critical Lane Group Σ(v/s)Crit= 0.88

NETSIM Summary Results

Mary Opt 1 2035 Phase 1	Old US 87/I90 EB Off Ramp
R Marvin	8/15/13
PM Design Hour	Case: EB Ramps US 87 Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	23 / 28	2.5	44.1
	T	5 / 8	9.2	3.4
	All		5.4	44.1
WB	TR	9 / 11	6.8	0.0
	All		6.8	0.0
NB	L	24 / 27	4.3	2.3
	TR	26 / 29	4.1	4.7
	All		4.2	4.7
Intersect.			5.0	



HCM Analysis Summary

Mary Op1 Alt 2035 Phase 1	Old US 87/I90 WB On Ramp	Area Type: Non CBD
R Marvin	8/15/13	Analysis Duration: 15 mins.
PM Design Hour	Case: WB Ramps US 87 Mary Op1 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	896	422	220	1000	0	0	0	0	20	1	318
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)	150			0			0			100		
Peds/Hour	0			5			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 80.0 Sec   Lost Time Per Cycle: 14.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB				TR														
WB		LT		LT														
NB																		
SB						LTR												
Green		10.0		36.0		20.0												0
Yellow	All Red	4.0	0.0	3.5	1.5	3.5	1.5											

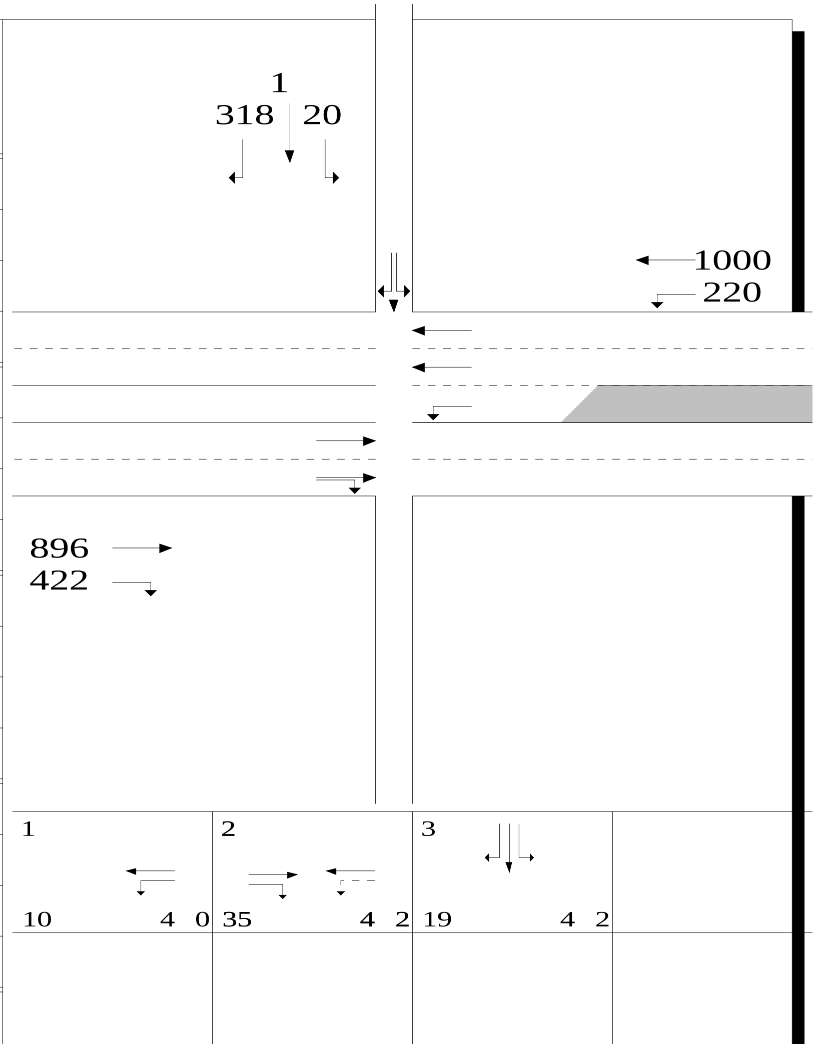
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1493	0.383	0.450	TR	0.851	29.5	C	29.5	C
WB	Lper	94	0.087	0.512					16.4	B
	* Lpro	223	0.125	0.125	L	0.754	33.3	C		
	T	2149	0.316	0.625	T	0.506	12.7	B		
SB										
	* LTR	395	0.165	0.250	LTR	0.658	30.1	C	30.1	C

Intersection: Delay = 23.5 sec/veh   Int. LOS=C X_c= 0.81   * Critical Lane Group Σ(v/s)Crit= 0.67

NETSIM Summary Results

Mary Op1 Alt 2035 Phase 1	Old US 87/I90 WB On Ramp
R Marvin	8/15/13
PM Design Hour	Case: WB Ramps US 87 Mary Op1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 13	12.3	0.0
	All		12.3	0.0
WB	L	5 / 6	4.9	0.0
	T	4 / 6	17.6	0.0
	All		14.2	0.0
	All		12.5	0.0
SB	LTR	4 / 7	12.5	0.0
Intersect.			13.0	



HCM Analysis Summary

Mary Option 2 Alt 2035 | Wicks Lane/Main Street | Area Type: Non CBD
R Marvin | 10/12/2011 | Analysis Duration: 15 mins.
Phase 1 PM | Case: WICKS MAIN MARY OP2 2035 PHASE 1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	314	450	156	520	390	80	358	1350	350	140	810	352
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			30			100			120		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 125.0 Sec | Lost Time Per Cycle: 18.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB							LTR										
WB					LTP												
NB	L		TP														
SB	L		TP														
Green	16.0		38.0		24.0		29.0										0
Yellow | All Red	3.0	0.0	3.5	1.5	3.5	1.5	3.5	1.5									

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	419	0.189	0.232	L	0.814	52.1	D	44.5	D
	TR	819	0.162	0.232	TR	0.698	40.0	D		
WB										
	* L	347	0.224	0.192	L	1.164	151.4	F	102.8	F
	LTR	675	0.182	0.192	LTR	0.947	72.1	E		
NB										
	* L	448	0.111	0.128	L	0.868	68.1	E	100.5	F
	* TR	1508	0.350	0.304	TR	1.153	107.8	F		
SB										
	L	231	0.084	0.128	L	0.658	65.7	E	44.8	D
	TR	1508	0.228	0.304	TR	0.751	42.0	D		

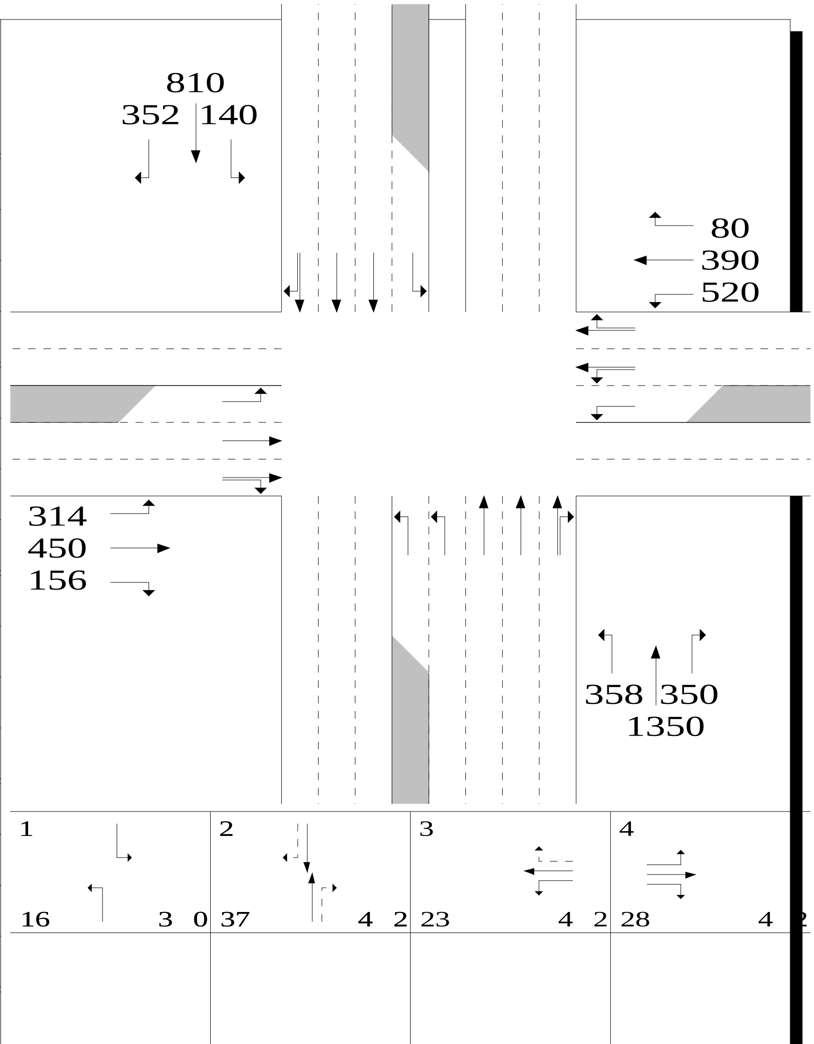
Intersection: Delay = 78.1 sec/veh | Int. LOS=E | X_c= 1.02 | * Critical Lane Group | Σ(v/s)Crit= 0.87

NETSIM Summary Results

Mary Option 2 Alt 2035
R Marvin
Phase 1 PM

Wicks Lane/Main Street
10/12/2011
Case: WICKS MAIN MARY OP2 2035 PHASE 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	9 / 14	4.6	0.0
	TR	3 / 8	12.9	0.0
	All		8.8	0.0
WB	L	12 / 13	3.8	0.0
	LTR	12 / 13	5.6	0.0
	All		5.0	0.0
NB	L	7 / 9	3.7	0.0
	TR	13 / 23	5.5	0.4
	All		5.1	0.4
SB	L	8 / 10	3.2	0.0
	TR	9 / 14	7.9	0.0
	All		6.8	0.0
Intersect.			5.9	



HCM Analysis Summary

Mary Opt 2 Phase 1 Alt 2035 | Airport Road/Main Street | Area Type: Non CBD
R Marvin | 10/12/2011 | Analysis Duration: 15 mins.
PM Design Hour | Case: Airport Main Mary Op2 Phase 1 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	2918	10	70	1714	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 150.0 Sec | Lost Time Per Cycle: 20.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP		R						
WB		LTP							
NB			LTP	TP					
SB				TP	LTR				
Green	39.0	6.0	20.0	56.0	6.0				0
Yellow / All Red	3.5 / 1.5	3.5 / 1.5	3.0 / 0.0	3.5 / 1.5	3.5 / 1.5				

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	* L	460	0.292	0.260	L	1.122	135.1	F	99.3	F
	LT	462	0.225	0.260	LT	0.866	68.1	E		
	R	639	0.054	0.413	R	0.131	27.3	C		
WB										
	* LT	74	0.040	0.040	LT	1.000	176.6	F	177.5	F
	R	64	0.039	0.040	R	0.984	178.5	F		
NB										
	L	236	0.137	0.133	L	1.025	123.7	F	85.2	F
	* TR	2677	0.607	0.527	TR	1.152	82.2	F		
SB										
	* L	72	0.041	0.040	L	1.028	184.0	F	34.9	C
	TR	2219	0.427	0.447	TR	0.955	29.7	C		

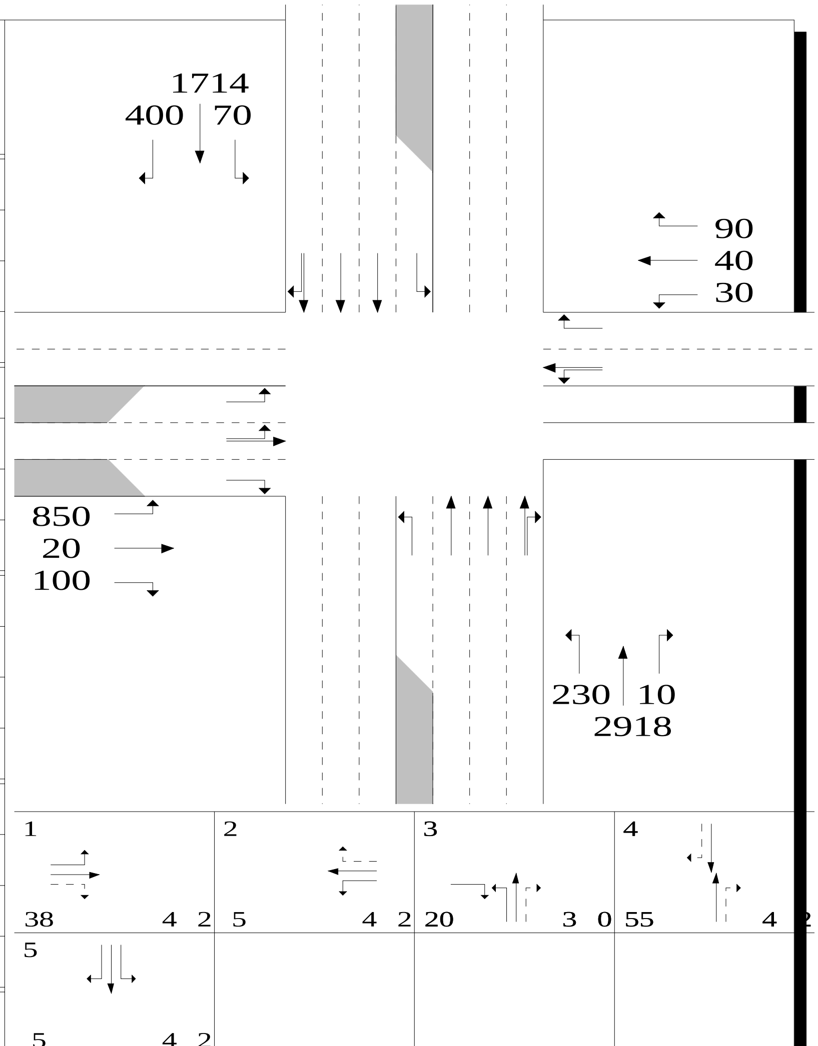
Intersection: Delay = 72.6 sec/veh Int. LOS=E X_c= 1.13 * Critical Lane Group Σ(v/s)Crit= 0.98

NETSIM Summary Results

Mary Opt 2 Phase 1 Alt 2035
R Marvin
PM Design Hour

Airport Road/Main Street
10/12/2011
Case: Airport Main Mary Op2 Phase 1 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	18 / 19	4.0	0.0
	LT	17 / 19	5.3	0.0
	R	1 / 2	17.9	0.0
	All		5.0	0.0
WB	LT	3 / 3	5.1	0.0
	R	3 / 4	9.5	0.0
	All		7.4	0.0
NB	L	13 / 16	2.9	0.0
	TR	25 / 30	7.0	12.9
	All		6.4	12.9
SB	L	4 / 6	7.2	0.0
	TR	11 / 18	10.0	0.0
	All		9.8	0.0
Intersect.			6.9	



HCM Analysis Summary

Mary Option 2 Alt 2035 Phase 1 | 1st Ave N/ | Area Type: Non CBD
R Marvin | 10/12/2011 | Analysis Duration: 15 mins.
PM design Hour | Case: US 87 MAIN FIRST Mary Op2 2035 PM Phase 1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	890	0	0	0	850	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			250			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 130.0 Sec | Lost Time Per Cycle: 15.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		52.0		26.0		37.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

Capacity Analysis Results										Approach:	
App		Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB											
	*	L	2060	0.368	0.400	L	0.920	28.7	C	29.4	C
		T	745	0.339	0.400	T	0.848	31.2	C		
WB											
	*	T	708	0.181	0.200	T	0.907	65.9	E	49.0	D
		R	812	0.434	0.523	R	0.830	33.0	C		
SB											
	*	L	958	0.266	0.285	L	0.934	50.3	D	28.3	C
		R	2015	0.253	0.723	R	0.350	0.5	A		

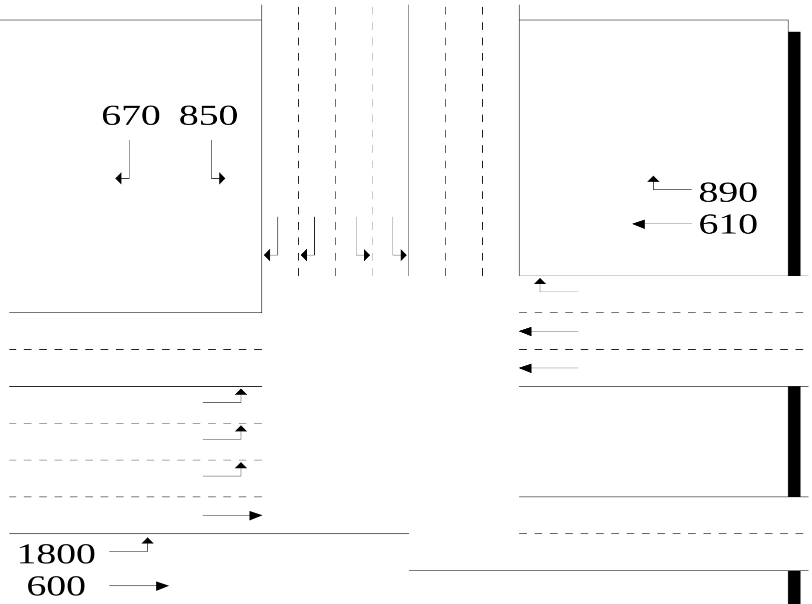
Intersection: Delay = 33.8 sec/veh | Int. LOS=C | X_c= 0.92 | * Critical Lane Group | Σ(v/s)Crit= 0.82

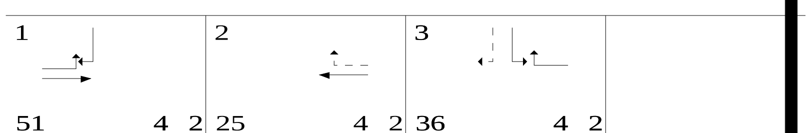
NETSIM Summary Results

Mary Option 2 Alt 2035 Phase 1
R Marvin
PM design Hour

1st Ave N/
10/12/2011
Case: US 87 MAIN FIRST Mary Op2 2035 PM Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	18 / 27	4.5	3.0
	T	12 / 17	6.8	0.2
	All		4.9	3.0
WB	T	11 / 13	5.7	0.0
	R	22 / 28	5.4	3.4
	All		5.5	3.4
	All		6.7	0.0
SB	L	16 / 18	4.1	0.0
	R	1 / 1	22.3	0.0
Intersect.			5.5	





HCM Analysis Summary

Mary Opt 2 2035 Phase 1	Old US 87/I90 EB Off Ramp	Area Type: Non CBD
R Marvin	10/13/2011	Analysis Duration: 15 mins.
PM Design Hour	Case: EB Ramps US 87 Op2 2035 PM Phase 1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	495	460	0	0	620	20	622	5	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)		0			5			100			0	
Peds/Hour		5			0			0			5	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated Operational Analysis Cycle Length: 120.0 Sec Lost Time Per Cycle: 9.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT		LT														
WB				TR														
NB						LTP												
SB																		
Green		32.0		25.0		49.0												0
Yellow	All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB	* Lper	61	0.307	0.250					50.5	D
	* Lpro	463	0.267	0.267	L	1.027	81.3	F		
	T	1817	0.140	0.508	T	0.275	17.2	B		
WB										
	TR	735	0.196	0.208	TR	0.939	68.0	E	68.0	E
NB										
	* L	699	0.395	0.408	L	0.967	60.6	E	50.4	D
	TR	648	0.174	0.408	TR	0.427	25.6	C		

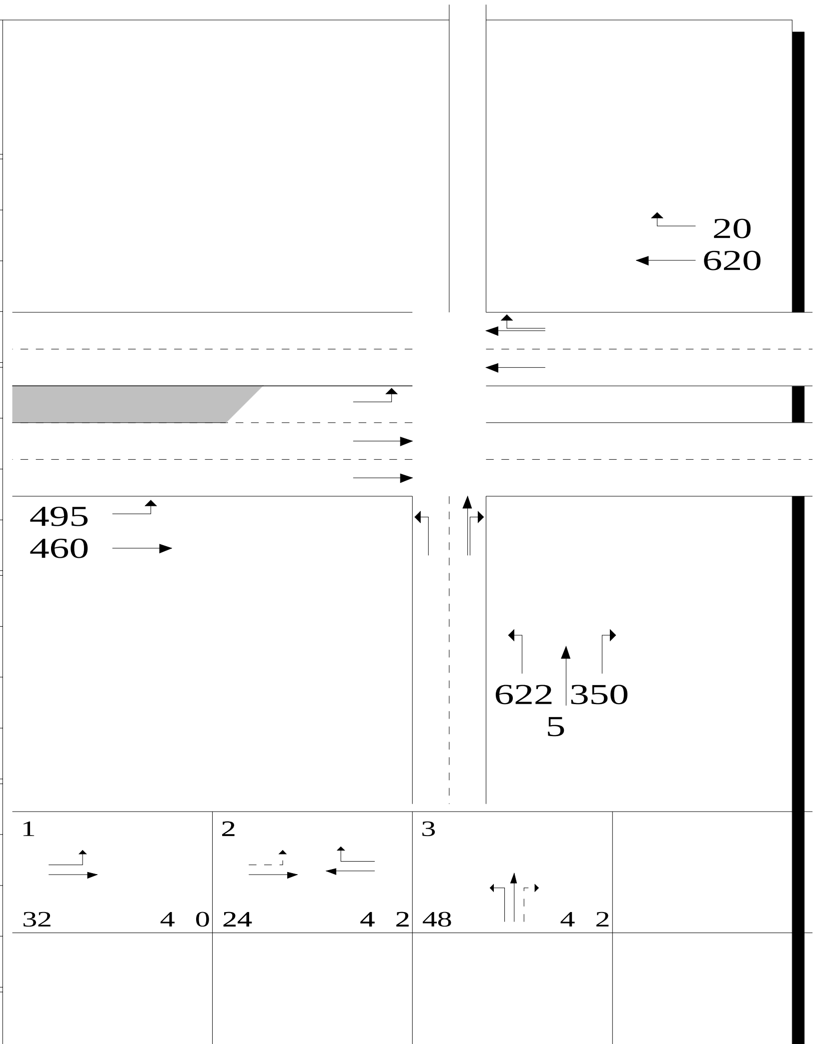
Intersection: Delay = 55.0 sec/veh Int. LOS=D X_c= 1.05 * Critical Lane Group Σ(v/s)Crit= 0.97

NETSIM Summary Results

Mary Opt 2 2035 Phase 1
R Marvin
PM Design Hour

Old US 87/I90 EB Off Ramp
10/13/2011
Case: EB Ramps US 87 Op2 2035 PM Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	26 / 29	2.7	53.8
	T	6 / 11	6.6	14.8
	All		4.7	53.8
WB	TR	9 / 11	6.8	0.0
	All		6.8	0.0
NB	L	17 / 24	6.2	0.8
	TR	4 / 8	15.0	0.0
	All		7.9	0.8
Intersect.			6.1	



HCM Analysis Summary

Mary Op2 Alt 2035 Phase 1 | Old US 87/I90 WB On Ramp | Area Type: Non CBD
R Marvin | 10/13/2011 | Analysis Duration: 15 mins.
PM Design Hour | Case: WB Ramps US 87 Mary OP2 2035 PM Phase 1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	926	422	220	1020	0	0	0	0	20	1	328
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)	150			0			0			100		
Peds/Hour	0			5			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 80.0 Sec | Lost Time Per Cycle: 14.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB			TR														
WB	LT		LT														
NB																	
SB					LTR												
Green	10.0		36.0		20.0												0
Yellow / All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1494	0.392	0.450	TR	0.872	30.9	C	30.9	C
WB	Lper	94	0.087	0.512					16.5	B
	* Lpro	223	0.125	0.125	L	0.754	33.4	C		
	T	2149	0.323	0.625	T	0.516	12.9	B		
SB										
	* LTR	395	0.172	0.250	LTR	0.686	31.2	C	31.2	C

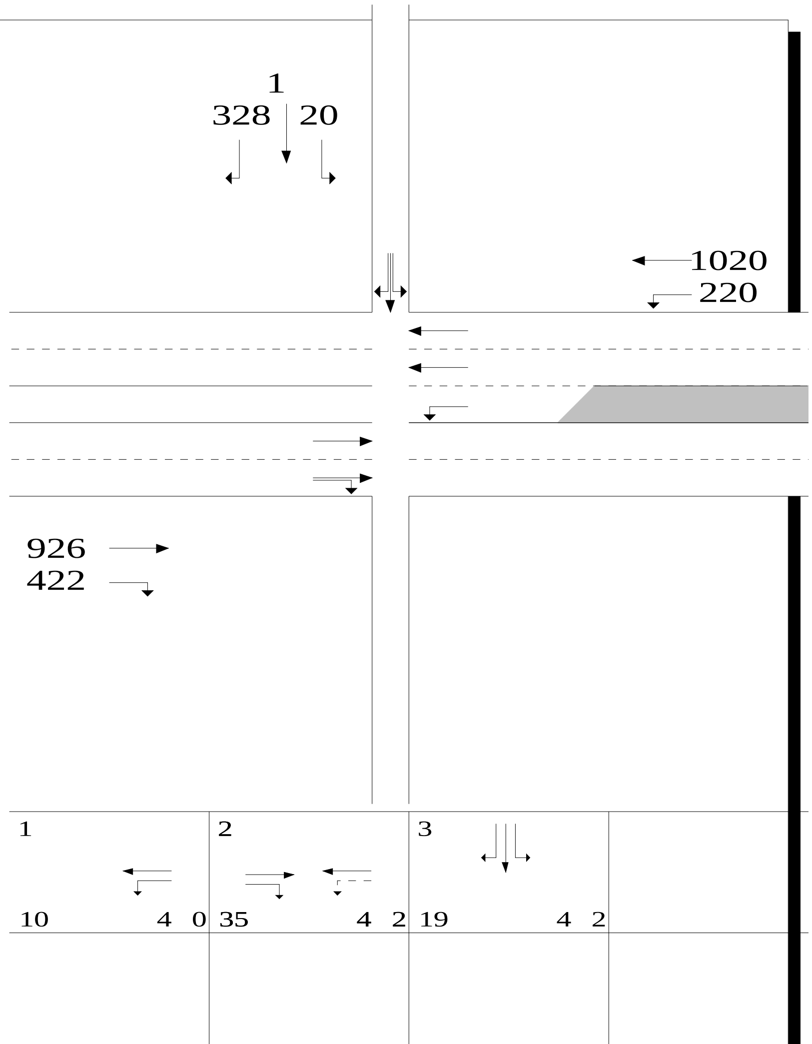
Intersection: Delay = 24.3 sec/veh | Int. LOS=C | X_c= 0.83 | * Critical Lane Group | Σ(v/s)Crit= 0.69

NETSIM Summary Results

Mary Op2 Alt 2035 Phase 1
R Marvin
PM Design Hour

Old US 87/I90 WB On Ramp
10/13/2011
Case: WB Ramps US 87 Mary OP2 2035 PM Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 13	11.9	0.0
	All		11.9	0.0
WB	L	5 / 6	4.6	0.0
	T	4 / 5	18.2	0.0
	All		14.5	0.0
	All		13.4	0.0
SB	LTR	4 / 7	13.4	0.0
Intersect.			13.0	



HCM Analysis Summary

Five Mile Alt 2035 Phase 2 | Wicks Lane/Main Street | Area Type: Non CBD
R Marvin | 8/15/13 | Analysis Duration: 15 mins.
PM | Case: Wicks Main Five Mile 2035 PM

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	TR	12.0						
WB	3	2	L	12.0	LT	12.0	TR	12.0						
NB	5	3	L	12.0	L	12.0	T	12.0	T	12.0	TR	12.0		
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	258	450	162	520	390	80	403	1450	380	140	920	287
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
% Heavy Vehicles	0	0	0	0	0	0	0	2	1	0	2	0
Lane Groups	L	TR		L	LTR		L	TR		L	TR	
Arrival Type	5	5		3	3		5	5		4	4	
RTOR Vol (vph)	80			30			100			100		
Peds/Hour	0			5			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 130.0 Sec | Lost Time Per Cycle: 18.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB								LTR										
WB						LTP												
NB		L		TP														
SB		L		TP														
Green		19.0		43.0		25.0		25.0										0
Yellow	All Red	3.0	0.0	3.5	1.5	3.5	1.5	3.5	1.5									

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	347	0.155	0.192	L	0.807	60.2	E	57.0	E
	* TR	678	0.164	0.192	TR	0.853	55.5	E		
WB										
	* L	347	0.223	0.192	L	1.159	151.2	F	104.0	F
	LTR	676	0.182	0.192	LTR	0.948	74.3	E		
NB										
	* L	512	0.125	0.146	L	0.855	64.6	E	95.5	F
	* TR	1640	0.379	0.331	TR	1.146	102.7	F		
SB										
	L	264	0.084	0.146	L	0.576	60.6	E	42.2	D
	TR	1638	0.243	0.331	TR	0.734	39.9	D		

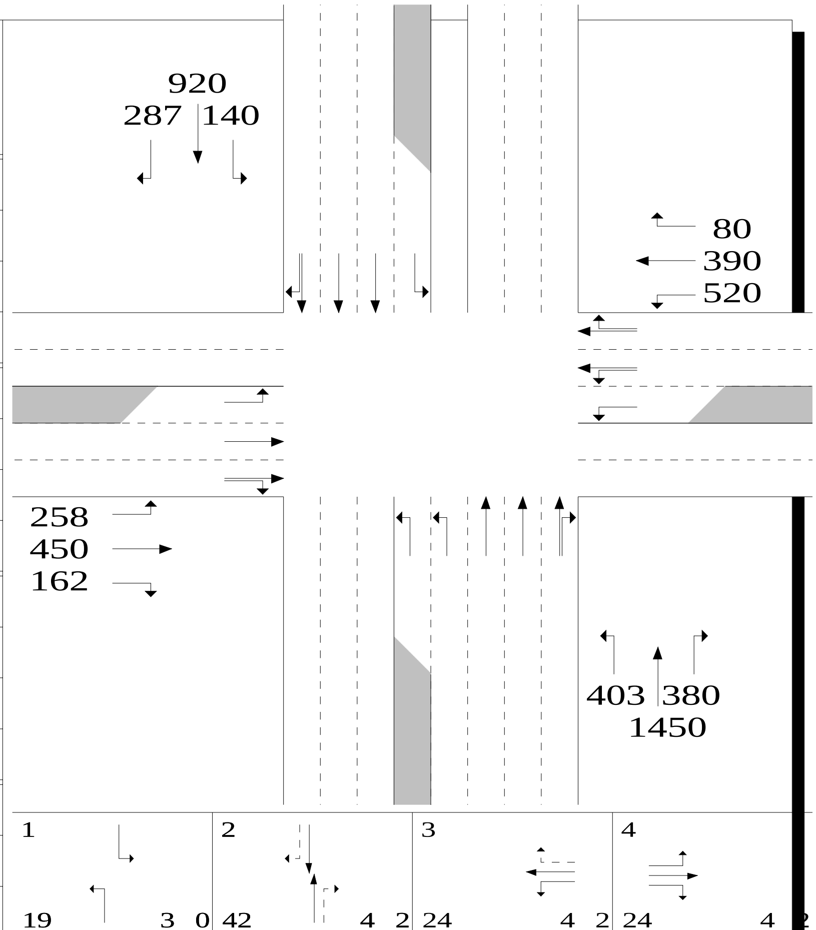
Intersection: Delay = 78.2 sec/veh | Int. LOS=E | X_c = 1.03 | * Critical Lane Group | Σ(v/s)Crit= 0.89

NETSIM Summary Results

Five Mile Alt 2035 Phase 2
R Marvin
PM

Wicks Lane/Main Street
8/15/13
Case: Wicks Main Five Mile 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	10 / 14	3.9	0.1
	TR	3 / 6	11.7	0.0
	All		7.8	0.1
WB	L	12 / 14	3.7	0.0
	LTR	12 / 13	5.9	0.0
	All		5.1	0.0
NB	L	8 / 9	3.9	0.0
	TR	13 / 28	5.2	4.2
	All		4.9	4.2
SB	L	9 / 11	3.3	0.0
	TR	9 / 13	7.3	0.0
	All		6.5	0.0
Intersect.			5.7	



HCM Analysis Summary

Five Mile Alt 2035 Phase 1	Airport Road/Main Street	Area Type: Non CBD
R Marvin	8/15/13	Analysis Duration: 15 mins.
PM Design Hour	Case: Airport Main Five Mile 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	2	2	LT	12.0	R	12.0								
NB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
SB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	850	20	100	30	40	90	230	3053	10	70	1822	400
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
% Heavy Vehicles	2	0	4	1	1	1	2	2	0	0	2	1
Lane Groups	L	LT	R		LT	R	L	TR		L	TR	
Arrival Type	3	3	3		3	3	5	5		5	5	
RTOR Vol (vph)	20			30			0			100		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 150.0 Sec | Lost Time Per Cycle: 20.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LTP		R						
WB		LTP							
NB			LTP	TP					
SB				TP	LTR				
Green	39.0	6.0	17.0	59.0	6.0				0
Yellow / All Red	3.5 / 1.5	3.5 / 1.5	3.0 / 0.0	3.5 / 1.5	3.5 / 1.5				

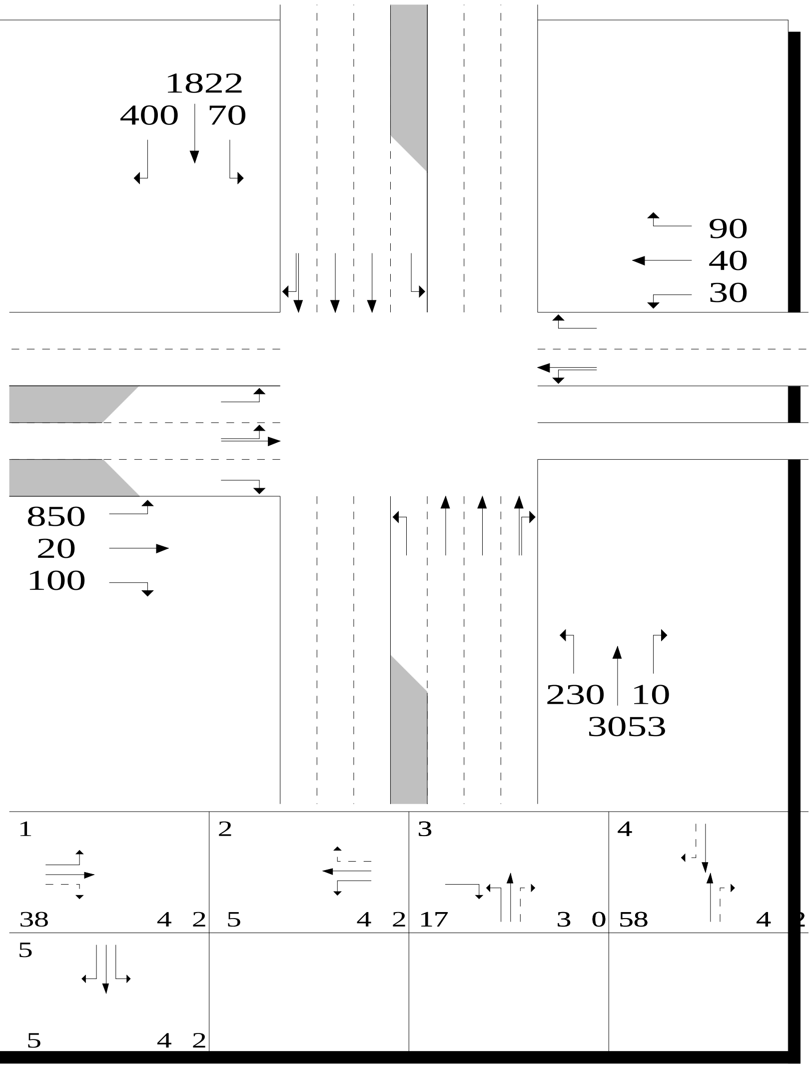
Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	460	0.292	0.260	L	1.122	135.1	F	99.4	F
	LT	462	0.225	0.260	LT	0.866	68.1	E		
	R	608	0.054	0.393	R	0.138	29.2	C		
WB										
	* LT	74	0.040	0.040	LT	1.000	176.6	F	177.5	F
	R	64	0.039	0.040	R	0.984	178.5	F		
NB										
	L	201	0.137	0.113	L	1.204	190.1	F	111.0	F
	* TR	2677	0.634	0.527	TR	1.205	105.1	F		
SB										
	* L	72	0.041	0.040	L	1.028	184.0	F	32.8	C
	TR	2322	0.449	0.467	TR	0.962	27.8	C		

Intersection: Delay = 84.5 sec/veh   Int. LOS=F X_c= 1.16   * Critical Lane Group Σ(v/s)Crit= 1.01

NETSIM Summary Results

Five Mile Alt 2035 Phase 1	Airport Road/Main Street
R Marvin	8/15/13
PM Design Hour	Case: Airport Main Five Mile 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	17 / 18	4.3	0.0
	LT	16 / 17	5.8	0.0
	R	1 / 2	17.9	0.0
	All		5.4	0.0
WB	LT	3 / 3	5.1	0.0
	R	3 / 4	9.4	0.0
	All		7.4	0.0
NB	L	17 / 20	1.7	0.0
	TR	28 / 30	6.0	28.3
	All		5.2	28.3
SB	L	6 / 9	2.8	0.0
	TR	11 / 17	10.5	0.0
	All		9.6	0.0
Intersect.			6.3	



HCM Analysis Summary

Mary Five Mile Alt 2035 Phase 1	1st Ave N/	Area Type: Non CBD
R Marvin	8/15/13	Analysis Duration: 15 mins.
PM design Hour	Case: US 87 MAIN FIRST Five Mile 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	4	2	L	12.0	L	12.0	L	12.0	T	12.0				
WB	3	2	T	12.0	T	12.0	R	12.0						
NB	0	3												
SB	4	0	L	12.0	L	12.0	R	12.0	R	12.0				

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	1800	600	0	0	610	1006	0	0	0	974	0	670
PHF	0.95	0.95	0.90	0.90	0.95	0.95	0.90	0.90	0.90	0.95	0.90	0.95
% Heavy Vehicles	2	2	2	2	2	4	2	2	2	4	2	2
Lane Groups	L	T			T	R				L		R
Arrival Type	5	5			3	3				5		5
RTOR Vol (vph)	0			250			0			0		
Peds/Hour	5			0			0			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 140.0 Sec   Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LT																
WB				TP		R												
NB																		
SB		R				L P												
Green		54.0		28.0		43.0												0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* L	1986	0.368	0.386	L	0.954	36.2	D	36.6	D
	T	719	0.339	0.386	T	0.879	37.6	D		
WB										
	T	708	0.181	0.200	T	0.907	69.8	E	58.1	E
	* R	843	0.513	0.543	R	0.944	48.6	D		
SB										
	L	1034	0.304	0.307	L	0.991	60.0	E	35.7	D
	R	2031	0.253	0.729	R	0.347	0.5	A		

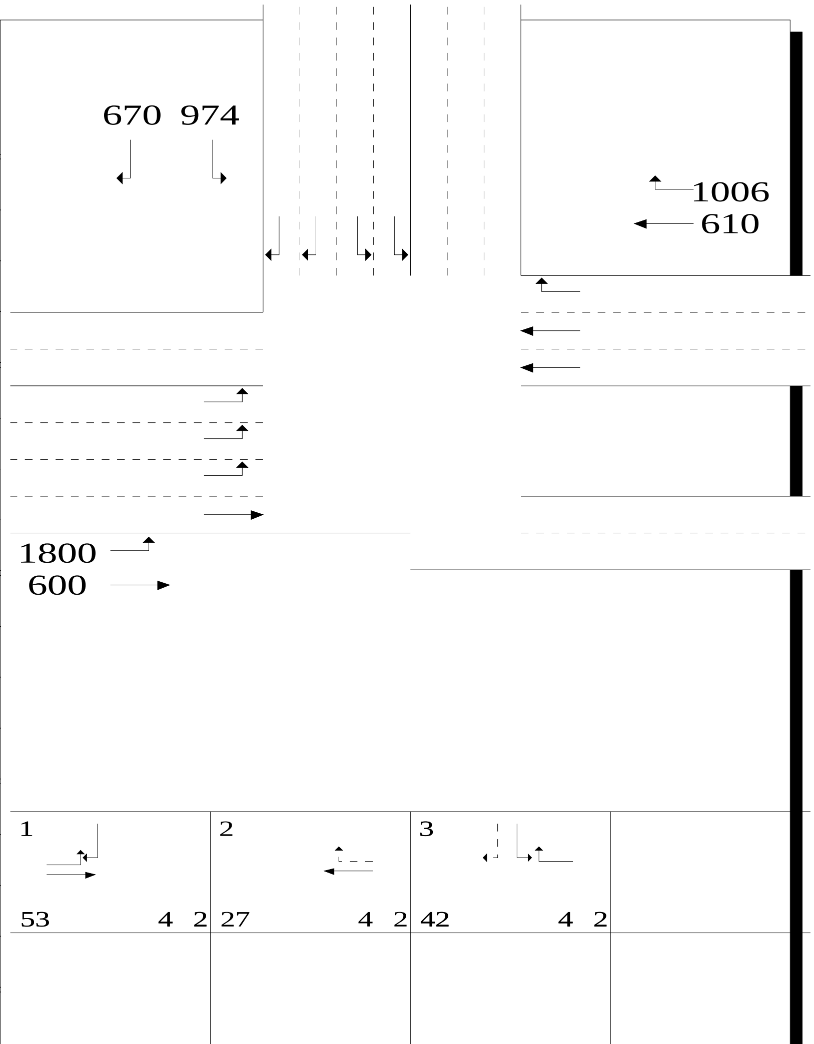
Intersection: Delay = 41.8 sec/veh   Int. LOS=D X_c= 0.95   * Critical Lane Group Σ(v/s)Crit= 0.88

NETSIM Summary Results

Mary Five Mile Alt 2035 Phase 1
R Marvin
PM design Hour

1st Ave N/
8/15/13
Case: US 87 MAIN FIRST Five Mile 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	21 / 29	4.3	8.7
	T	13 / 21	6.5	0.0
	All		4.7	8.7
WB	T	11 / 13	5.9	0.0
	R	28 / 30	4.2	24.6
	All		4.8	24.6
	All		5.9	0.0
SB	L	19 / 21	3.7	0.0
	R	1 / 2	22.6	0.0
Intersect.			5.0	



HCM Analysis Summary

Five Mile Alt 2035
R Marvin
PM Design Hour Phase 1

Old US 87/I90 EB Off Ramp
8/15/13
Case: EB RAMPS US 87 Five Mile Alt 2035 PM

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	2	L	12.0	T	12.0	T	12.0						
WB	2	2	T	12.0	TR	12.0								
NB	2	1	L	12.0	TR	12.0								
SB	0	0												

Geometry: Movements Serviced by Lane and Lane Widths (feet)

Data	East L	East T	East R	West L	West T	West R	North L	North T	North R	South L	South T	South R
Movement Volume (vph)	480	530	0	0	690	20	660	5	350	0	0	0
PHF	0.92	0.92	0.90	0.90	0.92	0.92	0.92	0.92	0.92	0.90	0.90	0.90
% Heavy Vehicles	4	1	2	2	2	2	5	0	2	2	2	2
Lane Groups	L	T			TR		L	TR				
Arrival Type	3	3			3		3	3				
RTOR Vol (vph)	0			5			100			0		
Peds/Hour	5			0			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 120.0 Sec   Lost Time Per Cycle: 9.0 Sec

Phase:	1	2	3	4	5	6	7	8	Ped Only
EB	LT	LT							
WB		TR							
NB			LTP						
SB									
Green	32.0	28.0	46.0						0
Yellow / All Red	4.0 / 0.0	3.5 / 1.5	3.5 / 1.5						

Capacity Analysis Results / Approach:

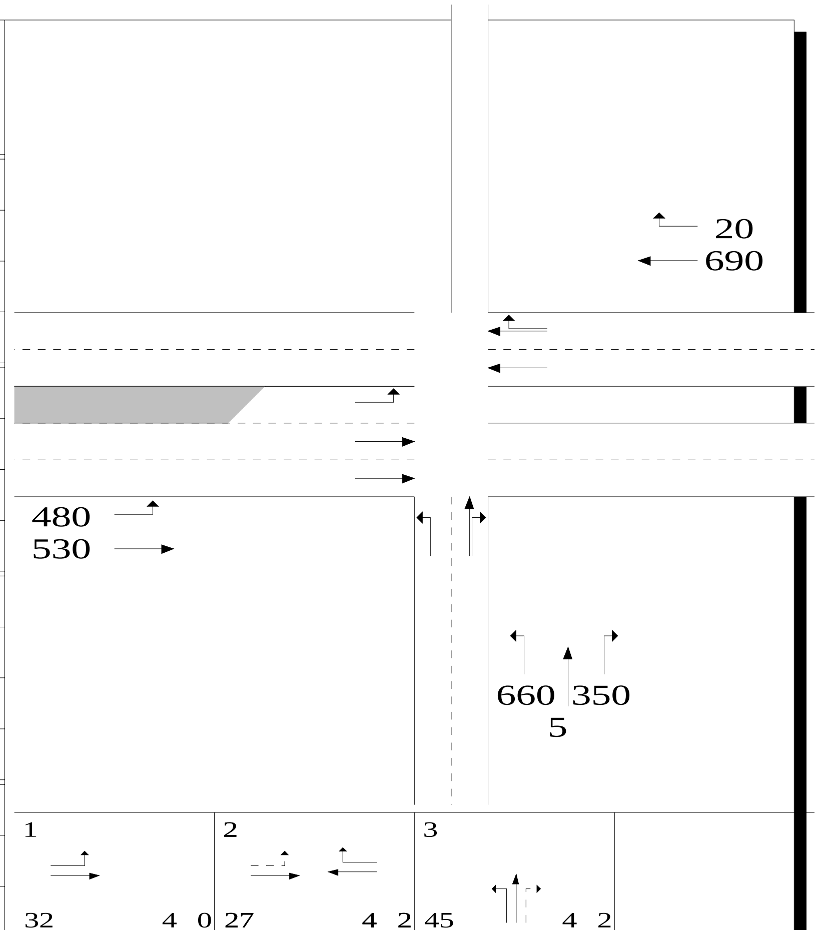
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach Delay (sec/veh)	Approach LOS
EB	* Lper	61	0.267	0.275					43.4	D
	* Lpro	463	0.267	0.267	L	0.996	73.7	E		
	T	1906	0.161	0.533	T	0.302	16.0	B		
WB										
	TR	823	0.217	0.233	TR	0.931	63.5	E	63.5	E
NB										
	* L	656	0.419	0.383	L	1.093	100.2	F	80.0	F
	TR	609	0.174	0.383	TR	0.455	27.8	C		

Intersection: Delay = 61.5 sec/veh   Int. LOS=E X_c= 1.03   * Critical Lane Group Σ(v/s)Crit= 0.95

NETSIM Summary Results

Five Mile Alt 2035	Old US 87/I90 EB Off Ramp
R Marvin	8/15/13
PM Design Hour Phase 1	Case: EB RAMPS US 87 Five Mile Alt 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	26 / 29	2.3	49.6
	T	5 / 8	8.3	7.3
	All		5.2	49.6
WB	TR	10 / 12	7.0	0.0
	All		7.0	0.0
NB	L	25 / 29	4.1	23.6
	TR	5 / 10	14.1	0.0
	All		5.4	23.6
Intersect.			5.7	



HCM Analysis Summary

Five Mile Alt 2035 Phase 1	Old US 87/I90 WB On Ramp	Area Type: Non CBD
R Marvin	8/15/13	Analysis Duration: 15 mins.
PM Design Hour	Case: WB RAMPS US 87 Five Mile 2035 PM	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	2	T	12.0	TR	12.0								
WB	3	2	L	12.0	T	12.0	T	12.0						
NB	0	0												
SB	1	1	LTR	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	990	460	220	1130	0	0	0	0	20	1	320
PHF	0.90	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.92	0.92	0.92
% Heavy Vehicles	2	5	5	1	5	2	2	2	2	1	0	5
Lane Groups		TR		L	T						LTR	
Arrival Type		2		2	2						3	
RTOR Vol (vph)		150			0			0			100	
Peds/Hour		0			5			0			0	
% Grade		0			0			0			0	
Buses/Hour		0			0			0			0	
Parkers/Hour (Left|Right)	---		---	---		---	---		---	---		---

Signal Settings: Actuated | Operational Analysis | Cycle Length: 80.0 Sec | Lost Time Per Cycle: 14.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB				TR														
WB		LT		LT														
NB																		
SB						LTR												
Green		10.0		37.0		19.0												0
Yellow	All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* TR	1533	0.426	0.463	TR	0.922	34.7	C	34.7	C
WB	Lper	94	0.089	0.525					16.5	B
	* Lpro	223	0.125	0.125	L	0.754	34.3	C		
	T	2192	0.357	0.637	T	0.560	13.1	B		
SB										
	* LTR	375	0.166	0.237	LTR	0.699	32.7	C	32.7	C

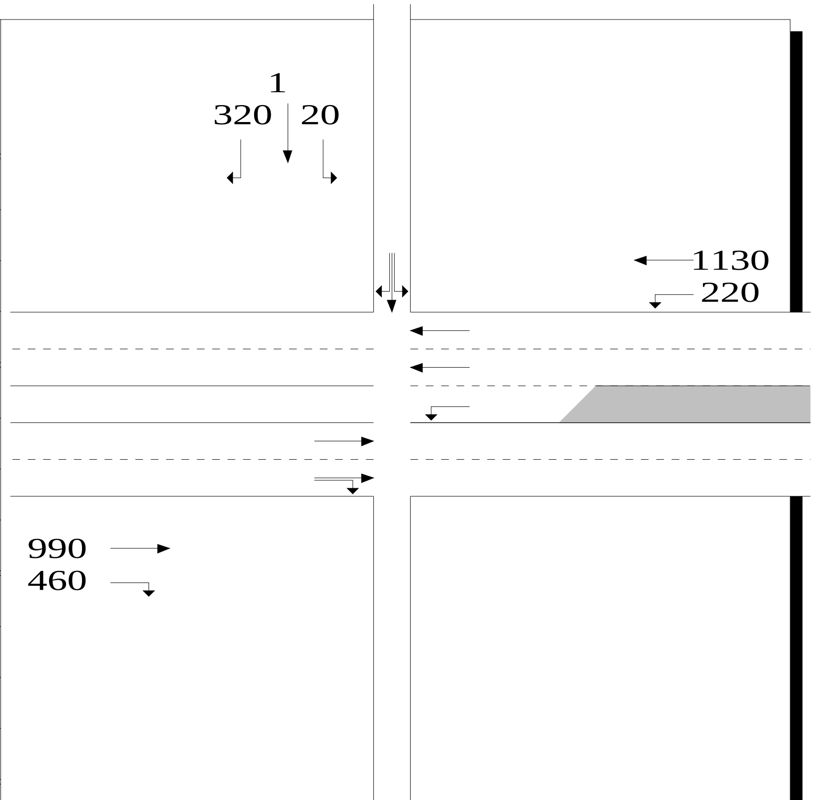
Intersection: Delay = 26.1 sec/veh | Int. LOS=C | X_c= 0.87 | * Critical Lane Group | Σ(v/s)Crit= 0.72

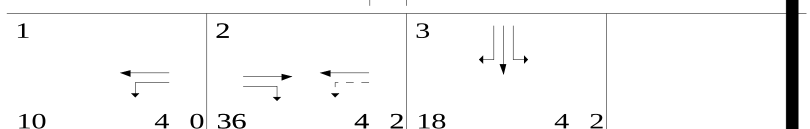
NETSIM Summary Results

Five Mile Alt 2035 Phase 1
R Marvin
PM Design Hour

Old US 87/I90 WB On Ramp
8/15/13
Case: WB RAMPS US 87 Five Mile 2035 PM

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	TR	10 / 14	12.5	0.0
	All		12.5	0.0
WB	L	5 / 7	4.8	0.0
	T	6 / 7	17.5	0.0
	All		14.3	0.0
	All		12.0	0.0
SB	LTR	4 / 7	12.0	0.0
Intersect.			13.1	





APPENDIX C

Phase 1

Alignments Intersections Capacity

HCM Analysis Summary

Mary Op 2 Phase 1 Signals | I90 EB Off Ramp/Johnson Lane | Area Type: Non CBD
R Marvin | 06/08/2013 | Analysis Duration: 15 mins.
2035 PM | Case: I90 EB Ramp Johnson MAry Op 2 Phase 1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	1	L	12.0	LT	12.0	R	12.0						
WB	0	0												
NB	3	2	T	12.0	T	12.0	R	12.0						
SB	2	2	L	12.0	T	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	480	1	675	0	0	0	0	730	230	269	528	0
PHF	0.95	0.95	0.95	0.90	0.90	0.90	0.90	0.95	0.95	0.95	0.95	0.90
% Heavy Vehicles	4	0	8	2	2	2	2	4	8	8	4	2
Lane Groups	L	LT	R					T	R	L	T	
Arrival Type	3	3	3					3	3	3	3	
RTOR Vol (vph)	300			0			80			0		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 90.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB					LTR												
WB																	
NB			TP														
SB	LT		LT														
Green	15.0		30.0		35.0												0
Yellow | All Red	0.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	675	0.145	0.389	L	0.373	19.8	B	22.3	C
	LT	677	0.146	0.389	LT	0.375	19.8	B		
	* R	581	0.264	0.389	R	0.680	25.5	C		
NB										
	* T	1157	0.221	0.333	T	0.664	26.8	C	26.1	C
	R	495	0.106	0.333	R	0.319	22.5	C		
SB	Lper	124	0.013	0.389					17.5	B
	* Lpro	279	0.167	0.167	L	0.702	18.3	B		
	T	914	0.304	0.500	T	0.608	17.0	B		

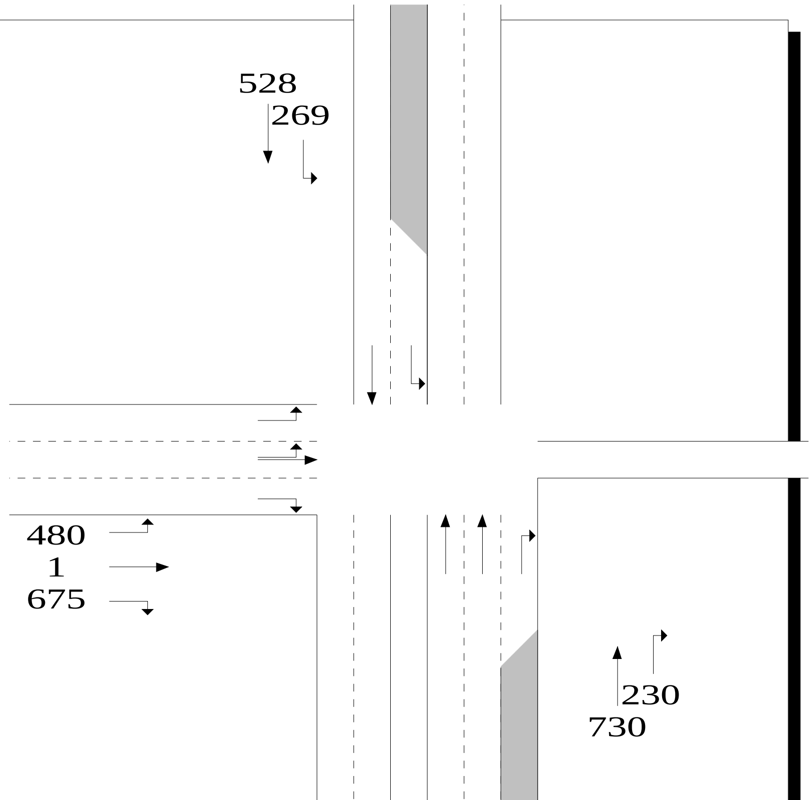
Intersection: Delay = 22.1 sec/veh | Int. LOS=C | X_c= 0.73 | * Critical Lane Group | Σ(v/s)Crit= 0.65

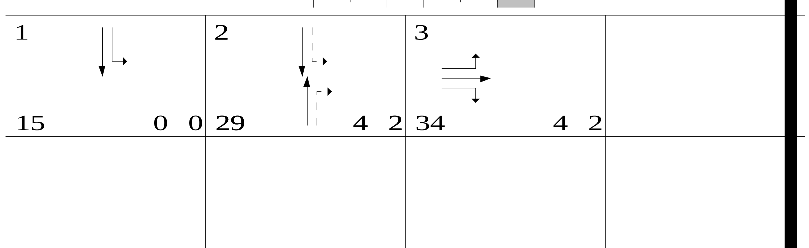
NETSIM Summary Results

Mary Op 2 Phase 1 Signals
R Marvin
2035 PM

I90 EB Off Ramp/Johnson Lane
06/08/2013
Case: I90 EB Ramp Johnson MAry Op 2 Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	5 / 6	10.7	0.0
	LT	3 / 4	14.6	0.0
	R	3 / 5	18.5	0.0
	All		15.2	0.0
	All		11.1	0.0
NB	T	8 / 9	10.7	0.0
	R	2 / 4	16.3	0.0
	All		10.4	0.0
SB	L	8 / 10	4.1	0.0
	T	7 / 8	16.1	0.0
Intersect.			12.2	





HCM Analysis Summary

Mary Op 2 Phase 1 Signals | I90 WB Off Ramp/Johnson | Area Type: Non CBD
R Marvin | 06/08/2013 | Analysis Duration: 15 mins.
2035 PM | Case: I90 WB Ramp Johnson Mary Op2 Phase 1

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	0	0												
WB	2	1	LT	12.0	R	12.0								
NB	2	1	L	12.0	T	12.0								
SB	1	1	T	12.0										

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	0	0	175	1	188	260	930	0	0	622	0
PHF	0.90	0.90	0.90	0.95	0.95	0.95	0.95	0.95	0.90	0.90	0.95	0.90
% Heavy Vehicles	2	2	2	8	0	8	6	4	2	2	4	2
Lane Groups					LT	R	L	T			T	
Arrival Type					3	3	3	3			3	
RTOR Vol (vph)	0			50			0			0		
Peds/Hour	5			0			5			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated | Operational Analysis | Cycle Length: 90.0 Sec | Lost Time Per Cycle: 10.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB																	
WB					LTP												
NB	LT		LT														
SB			T														
Green	15.0		40.0		25.0												0
Yellow / All Red	0.0	0.0	3.5	1.5	3.5	1.5											

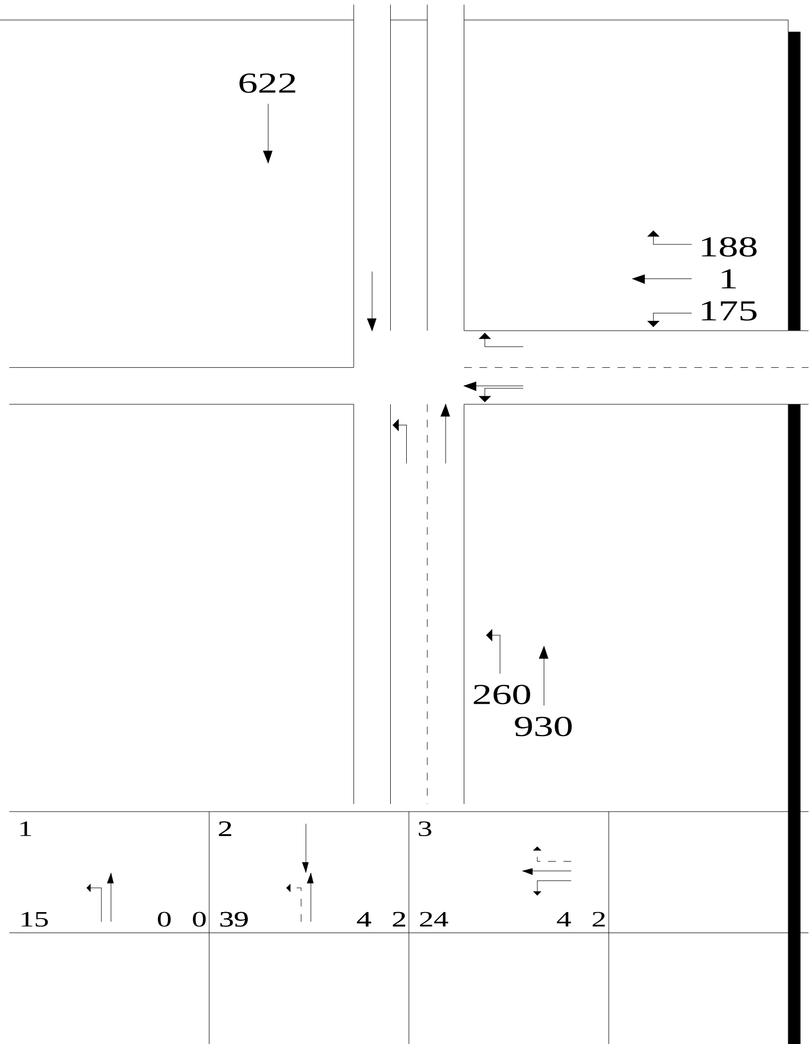
	Capacity Analysis Results								Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
WB										
	* LT	461	0.111	0.278	LT	0.401	26.6	C	26.4	C
	R	415	0.097	0.278	R	0.349	26.2	C		
NB	Lper	188	0.000	0.500					22.5	C
	Lpro	284	0.161	0.167	L	0.581	15.5	B		
	* T	1116	0.536	0.611	T	0.877	24.5	C		
SB										
	T	812	0.359	0.444	T	0.807	30.1	C	30.1	C

Intersection: Delay = 25.3 sec/veh | Int. LOS=C | X_c= 0.73 | * Critical Lane Group | Σ(v/s)Crit= 0.65

NETSIM Summary Results

Mary Op 2 Phase 1 Signals	I90 WB Off Ramp/Johnson
R Marvin	06/08/2013
2035 PM	Case: I90 WB Ramp Johnson Mary Op2 Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
	All		10.5	0.0
WB	LT	3 / 5	10.4	0.0
	R	3 / 5	10.7	0.0
	All		13.0	0.0
NB	L	5 / 5	10.3	0.0
	T	12 / 14	13.9	0.0
	All		10.3	0.0
SB	T	10 / 11	10.3	0.0
Intersect.			11.7	



HCM Analysis Summary

Mary Op 2 Phase 1 Signals	N Frontage/Johnson	Area Type: Non CBD
R Marvin	06/08/2013	Analysis Duration: 15 mins.
2035 PM	Case: Johnson N Frontage Mary Op 2 Phase 1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	2	1	L	12.0	TR	12.0								
WB	2	1	L	12.0	TR	12.0								
NB	3	1	L	12.0	T	12.0	R	12.0						
SB	3	2	L	12.0	T	12.0	TR	12.0						

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	150	25	210	25	20	25	195	893	30	5	675	100
PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
% Heavy Vehicles	1	0	8	1	1	1	8	2	1	1	2	2
Lane Groups	L	TR		L	TR		L	T	R	L	TR	
Arrival Type	3	3		3	3		3	3	3	3	3	
RTOR Vol (vph)	100			5			5			20		
Peds/Hour	0			5			5			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 90.0 Sec   Lost Time Per Cycle: 10.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB		LTP																
NB				LTP		TP												
SB						LTP												
Green		20.0		20.0		37.0												0
Yellow	All Red	3.5	1.5	3.0	0.0	3.5	1.5											

App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Approach: Delay (sec/veh)	Approach: LOS
EB										
	* L	301	0.123	0.222	L	0.555	32.4	C	31.5	C
	TR	346	0.096	0.222	TR	0.434	30.4	C		
WB										
	L	258	0.024	0.222	L	0.109	28.0	C	28.0	C
	TR	384	0.025	0.222	TR	0.115	28.0	C		
NB										
	L	371	0.130	0.222	L	0.585	32.9	C	18.8	B
	* T	1242	0.532	0.667	T	0.799	16.1	B		
	R	1062	0.018	0.667	R	0.026	5.1	A		
SB										
	L	178	0.014	0.411	L	0.034	16.2	B	22.3	C
	TR	1432	0.241	0.411	TR	0.586	22.3	C		

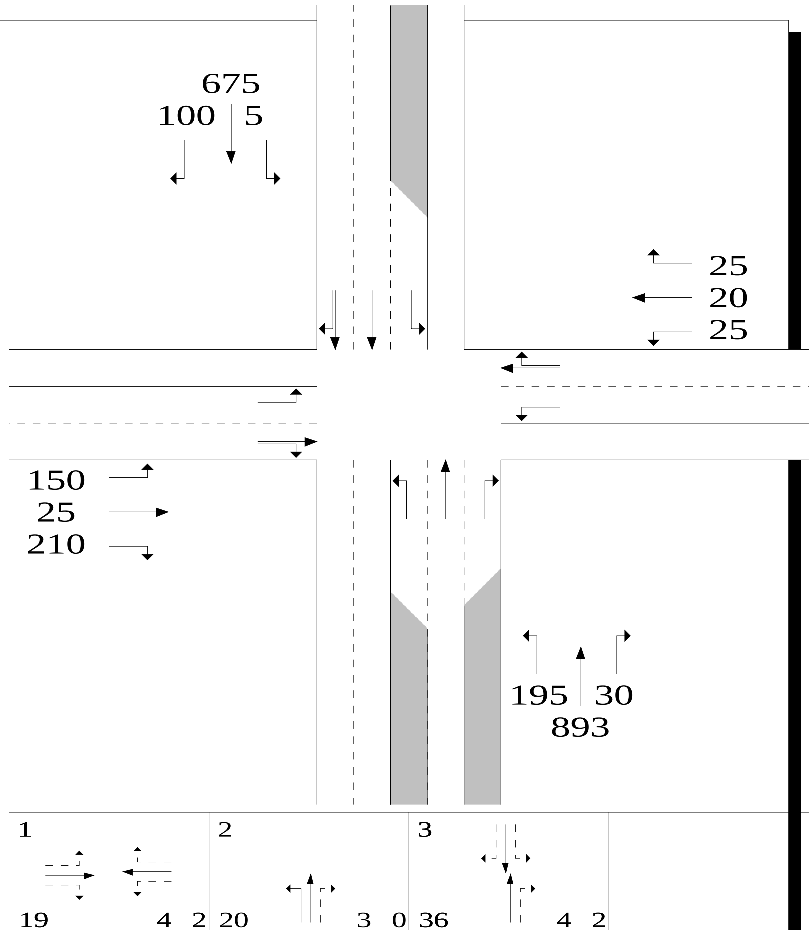
Intersection: Delay = 21.9 sec/veh   Int. LOS=C X_c= 0.74   * Critical Lane Group Σ(v/s)Crit= 0.66

NETSIM Summary Results

Mary Op 2 Phase 1 Signals
R Marvin
2035 PM

N Frontage/Johnson
06/08/2013
Case: Johnson N Frontage Mary Op 2 Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	4 / 6	9.4	0.0
	TR	3 / 6	16.3	0.0
	All		12.1	0.0
WB	L	1 / 2	8.3	0.0
	TR	1 / 2	11.5	0.0
	All		10.2	0.0
NB	L	6 / 7	4.8	0.0
	T	9 / 12	15.5	0.0
	R	1 / 1	17.6	0.0
	All		12.7	0.0
SB	L	1 / 2	8.1	0.0
	TR	6 / 9	12.5	0.0
	All		12.3	0.0
Intersect.			12.4	



TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*6/12/13*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary Opt 2 & Johnson N Phase 1*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Option 2* North/South Street: *Johnson Lane N*

Intersection Orientation: *East-West* Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	10	974			690	5
Peak-Hour Factor, PHF	0.95	0.95	1.00	1.00	0.95	0.95
Hourly Flow Rate, HFR (veh/h)	10	1025	0	0	726	5
Percent Heavy Vehicles	4	--	--	0	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	1	0	0	1	0
Configuration	L	T				TR
Upstream Signal		0			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				0		30
Peak-Hour Factor, PHF	1.00	1.00	1.00	0.60	1.00	0.60
Hourly Flow Rate, HFR (veh/h)	0	0	0	0	0	49
Percent Heavy Vehicles	0	0	0	5	0	5
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	0	0	0	0	0
Configuration					LR	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L						LR	
v (veh/h)	10						49	
C (m) (veh/h)	864						418	
v/c	0.01						0.12	
95% queue length	0.04						0.39	
Control Delay (s/veh)	9.2						14.8	
LOS	A						B	
Approach Delay (s/veh)	--	--				14.8		
Approach LOS	--	--				B		

 HCS+™ Version 5.6 Generated: 6/12/2013 11:48 AM

TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*6/12/13*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*Mary Op2 & Coulson Rd Phase 1*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *Mary Option 1*	North/South Street: *Coulson Road*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	55	919			610	5
Peak-Hour Factor, PHF	0.95	0.95	1.00	1.00	0.95	0.95
Hourly Flow Rate, HFR (veh/h)	57	967	0	0	642	5
Percent Heavy Vehicles	4	--	--	0	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	1	0	0	1	0
Configuration	L	T				TR
Upstream Signal		0			0	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)				5		80
Peak-Hour Factor, PHF	1.00	1.00	1.00	0.70	1.00	0.70
Hourly Flow Rate, HFR (veh/h)	0	0	0	7	0	114
Percent Heavy Vehicles	0	0	0	5	0	5
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	0	0	0	0	0
Configuration					LR	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L						LR	
v (veh/h)	57						121	
C (m) (veh/h)	929						377	
v/c	0.06						0.32	
95% queue length	0.20						1.36	
Control Delay (s/veh)	9.1						19.0	
LOS	A						C	
Approach Delay (s/veh)	--	--				19.0		
Approach LOS	--	--				C		

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MOVEMENT SUMMARY

Site: Mary Alignment Option 1
Intersection with Five Mile adn Mary Street

Mary Alignment Option 1 Phase 1
Intersection of Mary Alignment with Mary Street & Five Mile Road
Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate per veh	Average Speed mph
South: Mary Street NB											
3	L	5	0.0	0.140	16.8	LOS B	0.7	17.4	0.67	0.94	28.5
8	T	54	0.0	0.140	8.6	LOS A	0.7	17.4	0.67	0.72	31.5
18	R	22	0.0	0.140	10.2	LOS B	0.7	17.4	0.67	0.77	31.2
Approach		82	0.0	0.140	9.6	LOS A	0.7	17.4	0.67	0.75	31.2
East: Mary Alignment WB											
1	L	22	0.0	0.749	13.2	LOS B	10.9	279.8	0.55	0.72	30.3
6	T	745	4.0	0.749	5.1	LOS A	10.9	279.8	0.55	0.42	32.3
16	R	243	2.0	0.749	6.6	LOS A	10.9	279.8	0.55	0.49	32.0
Approach		1010	3.4	0.749	5.6	LOS A	10.9	279.8	0.55	0.44	32.2
North: Five Mile Road SB											
7	L	180	2.0	0.363	19.3	LOS B	2.4	60.9	0.86	0.95	26.5
4	T	11	0.0	0.363	11.0	LOS B	2.4	60.9	0.86	0.88	28.7
14	R	5	1.0	0.363	12.6	LOS B	2.4	60.9	0.86	0.90	28.5
Approach		197	1.9	0.363	18.6	LOS B	2.4	60.9	0.86	0.94	26.7
West: Mary Alignment EB											
5	L	5	1.0	0.488	14.2	LOS B	3.8	99.1	0.61	0.86	30.1
2	T	477	4.0	0.488	6.1	LOS A	3.8	99.1	0.61	0.53	32.1
12	R	5	0.0	0.488	7.5	LOS A	3.8	99.1	0.61	0.63	31.9
Approach		488	3.9	0.488	6.2	LOS A	3.8	99.1	0.61	0.54	32.0
All Vehicles		1776	3.2	0.749	7.4	LOS A	10.9	279.8	0.61	0.54	31.3

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Vehicle movement LOS values are based on average delay per movement
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

MOVEMENT SUMMARY

Site: Mary Alignment Option 2 Intersection with Five Mile & Mary Street

Mary Alignment Option 2 Phase 1
Intersection of Mary Alignment with Mary Street & Five Mile Road
Roundabout

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate per veh	Average Speed mph
South: Mary Street NB											
3	L	5	0.0	0.118	16.6	LOS B	0.7	17.1	0.71	0.88	28.6
8	T	54	0.0	0.118	8.6	LOS A	0.7	17.1	0.71	0.69	31.3
18	R	22	0.0	0.118	9.8	LOS A	0.7	17.1	0.71	0.73	31.3
Approach		82	0.0	0.118	9.4	LOS A	0.7	17.1	0.71	0.72	31.1
East: Mary Alignment WB											
1	L	22	0.0	0.719	13.1	LOS B	9.8	251.2	0.51	0.73	30.2
6	T	723	4.0	0.719	5.2	LOS A	9.8	251.2	0.51	0.41	32.4
16	R	243	2.0	0.719	6.4	LOS A	9.8	251.2	0.51	0.48	32.2
Approach		988	3.4	0.719	5.6	LOS A	9.8	251.2	0.51	0.44	32.3
North: Five Mile Road SB											
7	L	180	2.0	0.333	18.6	LOS B	2.2	55.4	0.84	0.92	26.9
4	T	11	0.0	0.333	10.5	LOS B	2.2	55.4	0.84	0.85	29.2
14	R	5	1.0	0.333	11.8	LOS B	2.2	55.4	0.84	0.86	29.0
Approach		197	1.9	0.333	18.0	LOS B	2.2	55.4	0.84	0.91	27.1
West: Mary Alignment EB											
5	L	5	1.0	0.463	14.0	LOS B	3.6	91.8	0.59	0.85	30.1
2	T	466	4.0	0.463	6.1	LOS A	3.6	91.8	0.59	0.53	32.1
12	R	5	0.0	0.463	7.3	LOS A	3.6	91.8	0.59	0.61	32.0
Approach		477	3.9	0.463	6.2	LOS A	3.6	91.8	0.59	0.54	32.1
All Vehicles		1743	3.2	0.719	7.4	LOS A	9.8	251.2	0.58	0.53	31.4

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Vehicle movement LOS values are based on average delay per movement
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

MOVEMENT SUMMARY

Site: Mary Alignment Bitteroot Alt B
2035 PM

Mary Street Op1 Alignment Bitteroot Phase 1
Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate per veh	Average Speed mph
South: Bitteroot NB											
3	L	22	0.0	0.285	11.0	LOS B	1.7	43.1	0.63	0.89	24.9
8	T	120	0.0	0.285	3.7	LOS A	1.7	43.1	0.63	0.49	26.2
18	R	98	0.0	0.285	5.4	LOS A	1.7	43.1	0.63	0.61	26.2
Approach		239	0.0	0.285	5.1	LOS A	1.7	43.1	0.63	0.58	26.1
East: Mary Alignment WB											
1	L	112	0.0	0.646	14.2	LOS B	6.4	163.0	0.65	0.78	29.9
6	T	502	4.0	0.646	6.1	LOS A	6.4	163.0	0.65	0.54	31.6
16	R	54	0.0	0.646	7.5	LOS A	6.4	163.0	0.65	0.61	31.5
Approach		668	3.0	0.646	7.6	LOS A	6.4	163.0	0.65	0.59	31.3
North: Bitteroot SB											
7	L	43	1.0	0.203	12.7	LOS B	1.2	31.3	0.75	0.89	24.1
4	T	54	0.0	0.203	5.4	LOS A	1.2	31.3	0.75	0.69	25.4
14	R	33	0.0	0.203	7.1	LOS A	1.2	31.3	0.75	0.74	25.6
Approach		130	0.3	0.203	8.3	LOS A	1.2	31.3	0.75	0.77	25.0
West: Mary Alignment EB											
5	L	11	0.0	0.382	14.0	LOS B	2.5	64.4	0.52	0.88	30.0
2	T	352	4.0	0.382	5.9	LOS A	2.5	64.4	0.52	0.52	32.6
12	R	11	0.0	0.382	7.4	LOS A	2.5	64.4	0.52	0.61	32.3
Approach		374	3.8	0.382	6.2	LOS A	2.5	64.4	0.52	0.53	32.5
All Vehicles		1412	2.5	0.646	6.8	LOS A	6.4	163.0	0.62	0.59	30.0

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Vehicle movement LOS values are based on average delay per movement
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	R Marvin	Intersection	Mary St & Bitteroot Phase 1
Agency/Co.	Marvin Associates	Jurisdiction	MDT
Date Performed	10/8/2011	Analysis Year	Year 2035
Analysis Time Period	Design Hour PM		

Project Description Billings Bypass

East/West Street: Mary Street	North/South Street: Bitteroot
Intersection Orientation: North-South	Study Period (hrs): 0.25

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	30	175	25	5	113	50
Peak-Hour Factor, PHF	0.70	0.70	0.70	0.70	0.70	0.70
Hourly Flow Rate, HFR (veh/h)	42	250	35	7	161	71
Percent Heavy Vehicles	0	--	--	0	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration	LTR			LTR		
Upstream Signal		0			0	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	40	30	40	10	15	15
Peak-Hour Factor, PHF	0.70	0.70	0.70	0.60	0.60	0.60
Hourly Flow Rate, HFR (veh/h)	57	42	57	16	24	24
Percent Heavy Vehicles	0	0	0	0	0	0
Percent Grade (%)	0			0		
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	LTR	LTR		LTR			LTR	
v (veh/h)	42	7		64			156	
C (m) (veh/h)	1348	1289		463			488	
v/c	0.03	0.01		0.14			0.32	
95% queue length	0.10	0.02		0.48			1.36	
Control Delay (s/veh)	7.8	7.8		14.0			15.8	
LOS	A	A		B			C	
Approach Delay (s/veh)	--	--	14.0			15.8		
Approach LOS	--	--	B			C		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin & Assoc*
Date Performed	*9/28/2011*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*Mary Align Op2 & Hawth Phase 1*
Jurisdiction	*City Billings*
Analysis Year	*2035*

Project Description *Billings Bypass EIS*

East/West Street: *Mary Align*

North/South Street: *Hawthorne*

Intersection Orientation: *East-West*

Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)		*404*	*5*	*50*	*602*	
Peak-Hour Factor, PHF	*1.00*	*0.90*	*0.90*	*0.90*	*0.90*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*0*	*448*	*5*	*55*	*668*	*0*
Percent Heavy Vehicles	*0*	--	--	*0*	--	--
Median Type	*Two Way Left Turn Lane*					
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*1*	*1*	*0*
Configuration			*TR*	*L*	*T*	
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*5*		*40*			
Peak-Hour Factor, PHF	*0.80*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*
Hourly Flow Rate, HFR (veh/h)	*6*	*0*	*49*	*0*	*0*	*0*
Percent Heavy Vehicles	*0*	*0*	*0*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*0*	*0*	*0*	*0*	*0*
Configuration		*LR*				

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration		*L*		*LR*				
v (veh/h)		*55*		*55*				
C (m) (veh/h)		*1118*		*557*				
v/c		*0.05*		*0.10*				
95% queue length		*0.16*		*0.33*				
Control Delay (s/veh)		*8.4*		*12.2*				
LOS		*A*		*B*				
Approach Delay (s/veh)	--	--	*12.2*					
Approach LOS	--	--	*B*					

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*10/3/2011*
Analysis Time Period	*Design Hour PM*

Site Information

Intersection	*HWY 312 & 5 Mile Alt Phase 1*
Jurisdiction	*MDT*
Analysis Year	*2035*

Project Description *Billings Bypass*

East/West Street: *HWY 312*	North/South Street: *Five Mile Road*
Intersection Orientation: *East-West*	Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Eastbound			Westbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*0*	*470*	*20*	*156*	*310*	*0*
Peak-Hour Factor, PHF	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*0*	*522*	*22*	*173*	*344*	*0*
Percent Heavy Vehicles	*0*	--	--	*3*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*2*	*0*	*1*	*2*	*0*
Configuration	*L*	*T*	*TR*	*L*	*T*	*TR*
Upstream Signal		*0*			*0*	

Minor Street	Northbound			Southbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*30*	*0*	*224*	*5*	*5*	*5*
Peak-Hour Factor, PHF	*0.90*	*1.00*	*0.90*	*0.60*	*0.60*	*0.60*
Hourly Flow Rate, HFR (veh/h)	*33*	*0*	*248*	*8*	*8*	*8*
Percent Heavy Vehicles	*3*	*0*	*3*	*0*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*1*	*0*	*1*	*0*
Configuration	*LT*		*R*		*LTR*	

Delay, Queue Length, and Level of Service

Approach	Eastbound	Westbound	Northbound			Southbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*	*LT*		*R*		*LTR*	
v (veh/h)	*0*	*173*	*33*		*248*		*24*	
C (m) (veh/h)	*1226*	*1014*	*148*		*762*		*190*	
v/c	*0.00*	*0.17*	*0.22*		*0.33*		*0.13*	
95% queue length	*0.00*	*0.61*	*0.81*		*1.42*		*0.43*	
Control Delay (s/veh)	*7.9*	*9.3*	*36.2*		*12.0*		*26.7*	
LOS	*A*	*A*	*E*		*B*		*D*	
Approach Delay (s/veh)	--	--	*14.8*			*26.7*		
Approach LOS	--	--	*B*			*D*		

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TWO-WAY STOP CONTROL SUMMARY

General Information

Analyst	*R Marvin*
Agency/Co.	*Marvin Associates*
Date Performed	*7/1/2013*
Analysis Time Period	*Peak PM*

Site Information

Intersection	*Dover & Five Mile Phase 1*
Jurisdiction	*MDT*
Analysis Year	*2035 Five Mile Rd Align*

Project Description

East/West Street: *Dover Road*
North/South Street: *Five Mile Road*
Intersection Orientation: *North-South*
Study Period (hrs): *0.25*

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume (veh/h)	*30*	*234*	*50*	*5*	*156*	*5*
Peak-Hour Factor, PHF	*0.92*	*0.92*	*0.92*	*0.90*	*0.90*	*0.90*
Hourly Flow Rate, HFR (veh/h)	*32*	*254*	*54*	*5*	*173*	*5*
Percent Heavy Vehicles	*1*	--	--	*1*	--	--
Median Type	*Undivided*					
RT Channelized			*0*			*0*
Lanes	*1*	*1*	*0*	*1*	*1*	*0*
Configuration	*L*		*TR*	*L*		*TR*
Upstream Signal		*0*			*0*	

Minor Street	Eastbound			Westbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume (veh/h)	*10*	*85*	*20*	*30*	*65*	*10*
Peak-Hour Factor, PHF	*0.85*	*0.85*	*0.85*	*0.80*	*0.80*	*0.80*
Hourly Flow Rate, HFR (veh/h)	*11*	*99*	*23*	*37*	*81*	*12*
Percent Heavy Vehicles	*0*	*2*	*0*	*2*	*0*	*0*
Percent Grade (%)	*0*			*0*		
Flared Approach		*N*			*N*	
Storage		*0*			*0*	
RT Channelized			*0*			*0*
Lanes	*0*	*1*	*0*	*0*	*1*	*0*
Configuration		*LTR*			*LTR*	

Delay, Queue Length, and Level of Service

Approach	Northbound	Southbound	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	*L*	*L*		*LTR*			*LTR*	
v (veh/h)	*32*	*5*		*130*			*133*	
C (m) (veh/h)	*1404*	*1258*		*418*			*459*	
v/c	*0.02*	*0.00*		*0.31*			*0.29*	
95% queue length	*0.07*	*0.01*		*1.31*			*1.19*	
Control Delay (s/veh)	*7.6*	*7.9*		*17.5*			*16.0*	
LOS	*A*	*A*		*C*			*C*	
Approach Delay (s/veh)	--	--	*17.5*			*16.0*		
Approach LOS	--	--	*C*			*C*		

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MOVEMENT SUMMARY

Site: Five Mile Road Alignment
Mary Street Intersection

Five Mile Road Alignment Phase 1
Mary Street Intersection Year 2035 PM Design Hour
Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate per veh	Average Speed mph
South East: Five Mile Align NWB											
3X	L	537	4.0	0.581	12.7	LOS B	6.0	154.8	0.26	0.70	29.8
8X	T	298	3.0	0.581	4.4	LOS A	6.0	154.8	0.26	0.32	33.7
Approach		835	3.6	0.581	9.7	LOS A	6.0	154.8	0.26	0.56	31.0
North West: Five Mile Align SEB											
4X	T	202	2.0	0.316	8.4	LOS A	1.9	47.9	0.70	0.74	31.5
14X	R	33	1.0	0.316	9.9	LOS A	1.9	47.9	0.70	0.78	31.5
Approach		235	1.9	0.316	8.6	LOS A	1.9	47.9	0.70	0.74	31.5
South West: Mary Street NEB											
5X	L	33	1.0	0.431	13.9	LOS B	2.7	68.5	0.51	0.80	29.6
12X	R	354	3.0	0.431	7.3	LOS A	2.7	68.5	0.51	0.60	31.7
Approach		387	2.8	0.431	7.9	LOS A	2.7	68.5	0.51	0.62	31.5
All Vehicles		1457	3.1	0.581	9.1	LOS A	6.0	154.8	0.40	0.61	31.2

Level of Service (LOS) Method: Delay (HCM 2000).
Roundabout LOS Method: Same as Signalised Intersections.
Vehicle movement LOS values are based on average delay per movement
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model used.

SIDRA INTERSECTION

HCM Analysis Summary

Mary Op2 Phase 1
R Marvin
2035 PM

Main Street/Bypass
06/14/2013
Case: Mary Align US 87 HWT 312 Phase 1

Area Type: Non CBD
Analysis Duration: 15 mins.

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	5	3	L	12.0	LT	12.0	T	12.0	T	12.0	R	12.0		
WB	4	3	L	12.0	T	12.0	T	12.0	TR	12.0				
NB	3	2	L	12.0	LT	12.0	TR	12.0						
SB	2	1	L	12.0	T	12.0								

Data	East			West			North			South		
	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	539	825	254	5	545	10	337	210	5	10	100	0
PHF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.90
% Heavy Vehicles	2	2	4	1	2	2	3	4	2	2	4	2
Lane Groups	L	LT	R	L	TR		L	LTR		L	T	
Arrival Type	3	3	3	3	3		3	3		3	3	
RTOR Vol (vph)	25			5			2			0		
Peds/Hour	5			5			5			0		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated   Operational Analysis   Cycle Length: 95.0 Sec   Lost Time Per Cycle: 20.0 Sec

Phase:		1		2		3		4		5		6		7		8		Ped Only
EB		LTP																
WB				LTR														
NB						LTP												
SB								LT										
Green		30.0		18.0		19.0		8.0										0
Yellow	All Red	3.5	1.5	3.5	1.5	3.5	1.5	3.5	1.5									

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	L	559	0.192	0.316	L	0.608	28.9	C	29.0	C
	* LT	1589	0.218	0.316	LT	0.689	29.5	C		
	R	487	0.156	0.316	R	0.495	26.6	C		
WB										
	L	339	0.003	0.189	L	0.015	31.3	C	35.9	D
	* TR	962	0.114	0.189	TR	0.602	36.0	D		
NB										
	* L	350	0.122	0.200	L	0.609	36.8	D	35.3	D
	LTR	687	0.107	0.200	LTR	0.533	34.4	C		
SB										
	L	149	0.006	0.084	L	0.074	40.2	D	50.9	D
	* T	154	0.057	0.084	T	0.682	52.0	D		

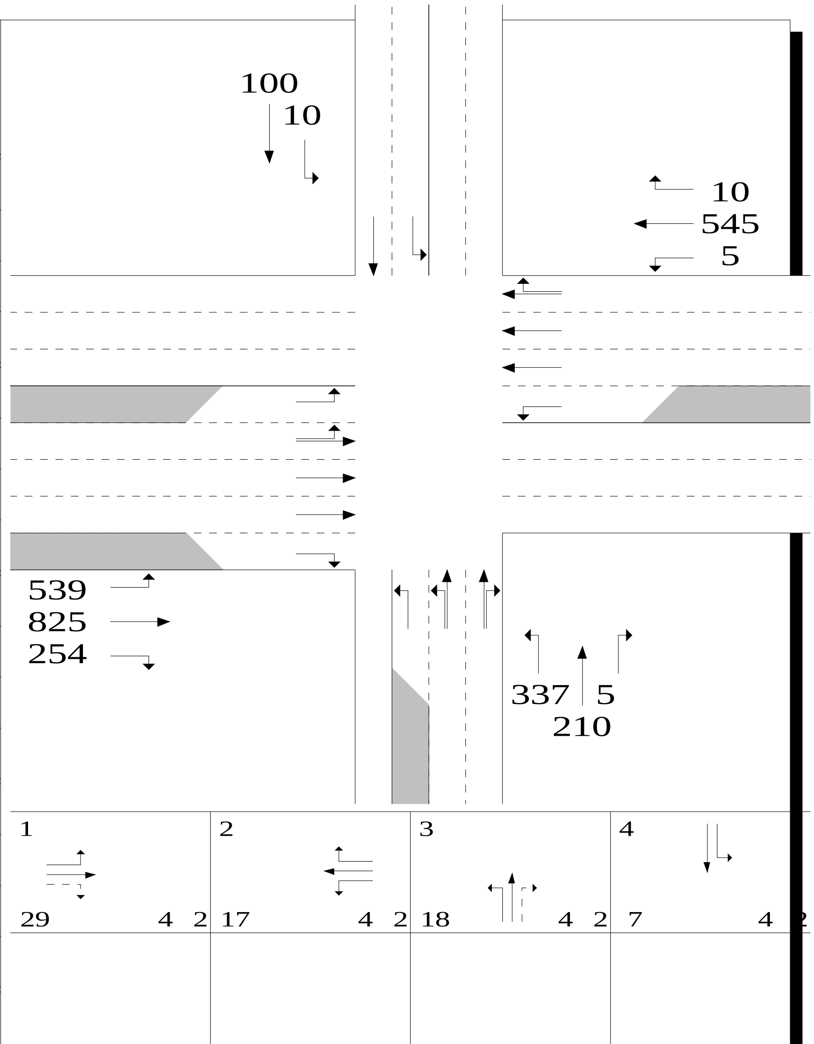
Intersection: Delay = 32.4 sec/veh   Int. LOS=C X_c= 0.65   * Critical Lane Group Σ(v/s)Crit= 0.51

NETSIM Summary Results

Mary Op2 Phase 1
R Marvin
2035 PM

Main Street/Bypass
06/14/2013
Case: Mary Align US 87 HWT 312 Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	L	8 / 10	5.0	0.0
	LT	8 / 9	10.4	0.0
	R	1 / 3	19.1	0.0
	All		9.6	0.0
WB	L	0 / 2	6.9	0.0
	TR	4 / 6	8.5	0.0
	All		8.5	0.0
NB	L	5 / 5	4.7	0.0
	LTR	4 / 5	10.6	0.0
	All		8.6	0.0
SB	L	0 / 2	8.8	0.0
	T	2 / 3	7.7	0.0
	All		7.8	0.0
Intersect.			9.1	



HCM Analysis Summary

Mary Op2 Phase 1	Main Street/Bench Blvd	Area Type: Non CBD
R Marvin	06/14/2013	Analysis Duration: 15 mins.
2035 PM	Case: Bench US 87 w Mary Align Phase 1	

Lanes			Geometry: Movements Serviced by Lane and Lane Widths (feet)											
	Approach	Outbound	Lane 1		Lane 2		Lane 3		Lane 4		Lane 5		Lane 6	
EB	3	3	T	12.0	T	12.0	T	12.0						
WB	3	3	L	12.0	T	12.0	T	12.0						
NB	2	1	L	12.0	R	12.0								
SB	2	1	T	12.0	R	12.0								

	East			West			North			South		
Data	L	T	R	L	T	R	L	T	R	L	T	R
Movement Volume (vph)	0	1189	0	245	637	0	105	0	420	0	75	315
PHF	0.90	0.95	0.90	0.95	0.95	0.90	0.95	0.90	0.95	0.90	0.95	0.95
% Heavy Vehicles	2	3	2	3	2	2	0	2	1	2	1	3
Lane Groups		T		L	T		L		R		T	R
Arrival Type		3		3	3		3		3		3	3
RTOR Vol (vph)	0			0			200			140		
Peds/Hour	5			5			0			5		
% Grade	0			0			0			0		
Buses/Hour	0			0			0			0		
Parkers/Hour (Left|Right)	---	---		---	---		---	---		---	---	

Signal Settings: Actuated Operational Analysis Cycle Length: 95.0 Sec Lost Time Per Cycle: 14.0 Sec

Phase:	1		2		3		4		5		6		7		8		Ped Only
EB			T														
WB	LT		LT														
NB					L R												
SB					TP												
Green	14.0		44.0		23.0												0
Yellow / All Red	4.0	0.0	3.5	1.5	3.5	1.5											

Capacity Analysis Results									Approach:	
App	Lane Group	Cap (vph)	v/s Ratio	g/C Ratio	Lane Group	v/c Ratio	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
EB										
	* T	2332	0.249	0.463	T	0.537	19.1	B	19.1	B
WB	Lper	129	0.000	0.516					11.0	B
	* Lpro	258	0.147	0.147	L	0.667	20.5	C		
	T	2310	0.190	0.653	T	0.290	7.4	A		
NB										
	L	323	0.083	0.242	L	0.344	30.0	C	32.5	C
	* R	387	0.145	0.242	R	0.599	33.7	C		
SB										
	T	455	0.042	0.242	T	0.174	28.5	C	30.5	C
	R	377	0.118	0.242	R	0.488	31.3	C		

Intersection: Delay = 19.1 sec/veh Int. LOS=B X_c= 0.63 * Critical Lane Group Σ(v/s)Crit= 0.54

NETSIM Summary Results

Mary Op2 Phase 1	Main Street/Bench Blvd
R Marvin	06/14/2013
2035 PM	Case: Bench US 87 w Mary Align Phase 1

App	Lane Group	Queues Per Lane Avg/Max (veh)	Average Speed (mph)	Spillback in Worst Lane (% of Peak Period)
EB	T	6 / 9	12.9	0.0
	All		12.9	0.0
WB	L	5 / 10	8.5	0.0
	T	3 / 5	20.4	0.0
	All		16.0	0.0
NB	L	2 / 6	10.8	0.0
	R	4 / 7	15.3	0.0
	All		13.9	0.0
SB	T	2 / 4	9.1	0.0
	R	1 / 2	23.6	0.0
	All		17.6	0.0
Intersect.			14.4