

APRIL 2016



# CASPER SIGNAL TIMING STUDY

FINAL REPORT





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# CHAPTER 1 - INTRODUCTION

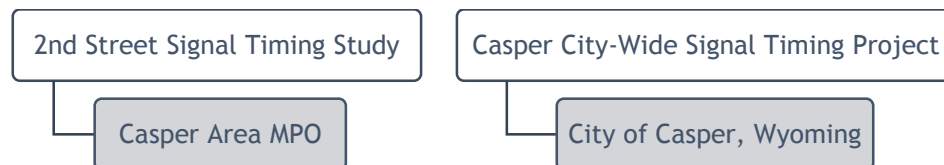
Very few engineering projects can have as significant impact on quality of life as signal timing and coordination. Signal timing impacts the time we spend traveling, the quality of the air we breathe, safety of roadway travel, costs of our trips and many more aspects of our daily lives. Signal retiming and coordination is as necessary as patching potholes, removing snow and restriping pavement lanes and markings.

Traffic signal retiming and coordination efforts have proven to be one of the most cost-effective ways to improve traffic flow and make streets safer. Studies around the country have shown the benefits of area-wide signal timing outweigh the costs forty to one.

According to the City of Casper and the Casper Area Metropolitan Planning Organization (Casper Area MPO), the overarching goal of the Casper Signal Timing Study is to develop an effective signal coordination strategy to reduce travel time and harmful auto emissions. The City of Casper and the Casper Area MPO also identified additional objectives to be addressed through the development of the Casper Signal Timing Study:

- » Determine the current Level of Service (LOS) and future LOS through signal optimization.
- » Implement the revised signal timing with the City of Casper Staff.
- » Monitor the revised signal timing and make appropriate adjustments.

The Casper Signal Timing Study is a combination of two signal timing projects, as listed below, that encompass all traffic signals owned and operated by the City of Casper:



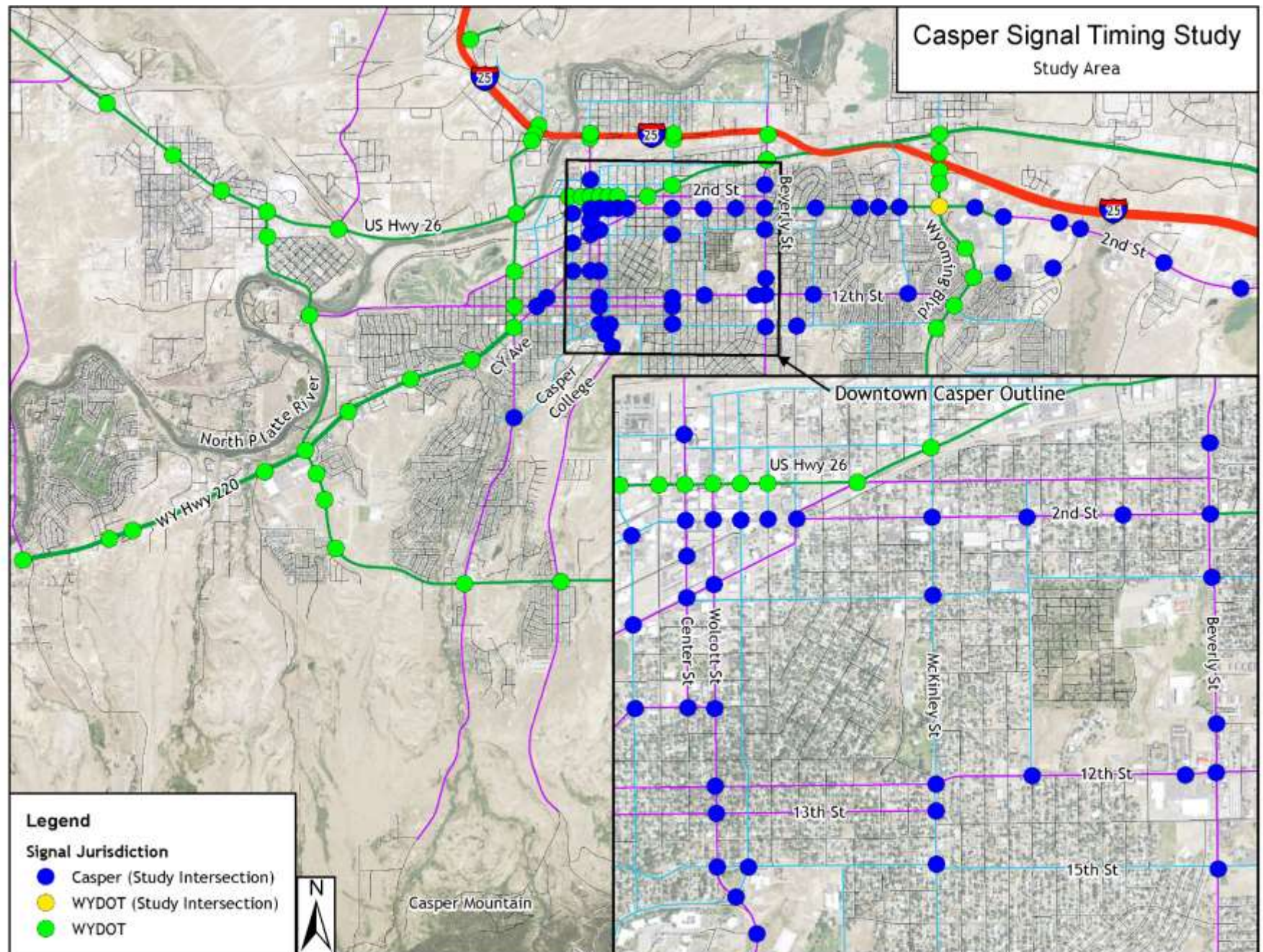
## Study Area

Traffic signals throughout the Casper metropolitan area are owned and operated by two jurisdictions: Wyoming Department of Transportation (WYDOT) and the City of Casper. WYDOT owns and operates signals on the state and National Highway System as well as those included with interstate interchanges. The City of Casper owns and operates the remaining traffic signals in the Casper metropolitan area.

As shown in **Figure 1**, this is not as straightforward as it seems, with various highways weaving throughout the Casper metropolitan area. One example is in downtown Casper, where US Highway 20/26 runs parallel to 2nd Street, the backbone of downtown Casper. The highway's route forces adjacent traffic signals on Center Street to alternate from City of Casper to WYDOT and then back to City of Casper. Another example is on the east side of Casper where Wyoming Boulevard/WY Highway 258 splits 2nd Street in half. Although the intersection of Wyoming Boulevard and 2nd Street is a WYDOT traffic signal, due to its importance within the 2nd Street corridor, it is included in the list of study intersections; however, its signal timing will not be adjusted as part of the Casper Signal Timing Study.



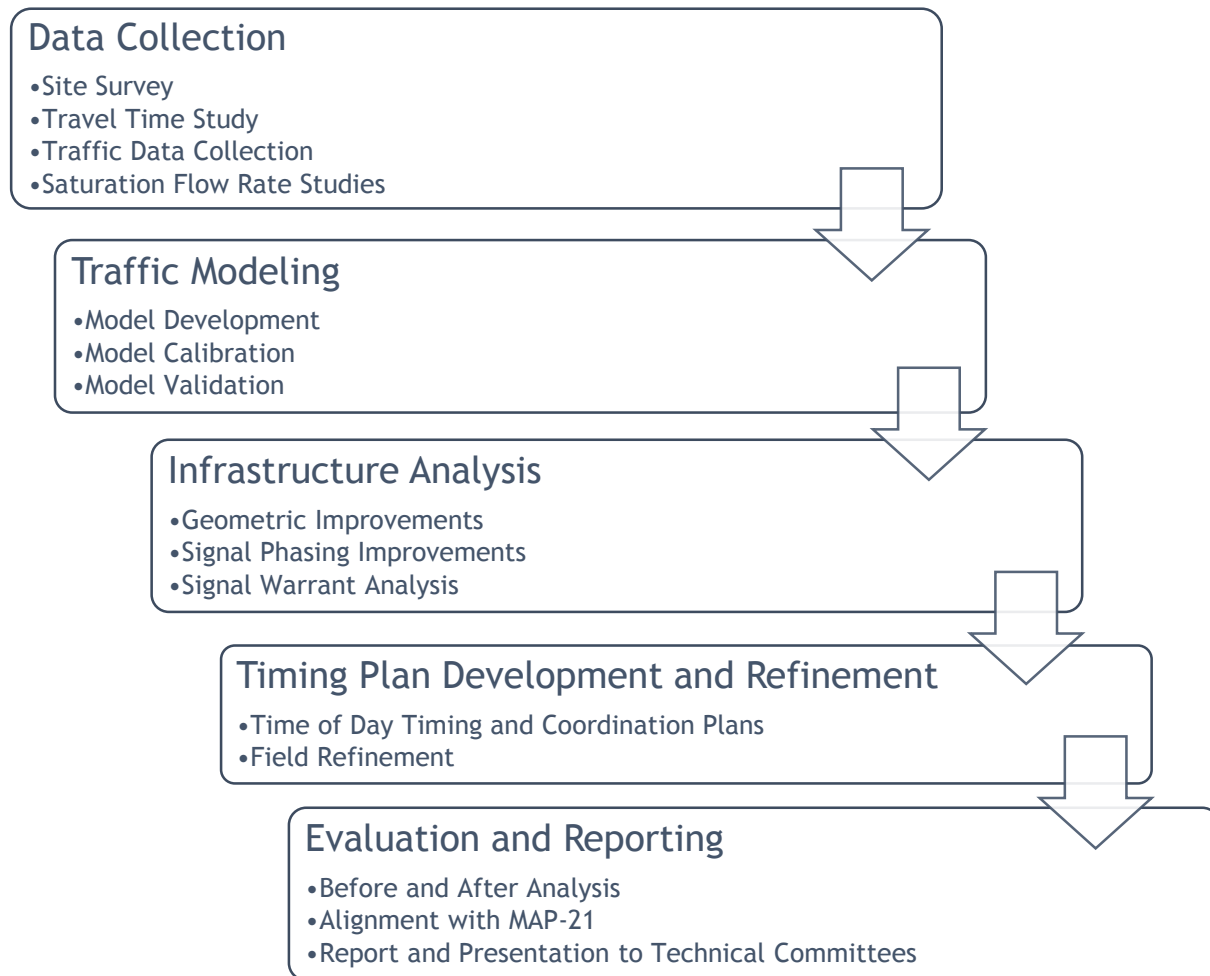
Figure 1 - Study Area



## Study Process

**Figure 2** illustrates the process for the Casper Signal Timing Study. Each step of the study process is summarized below. More information on each step of the process is available throughout the body of the report.

*Figure 2 - Study Process*



### **Data Collection**

Efficient and accurate data collection is the key to a successful signal timing study. With 55 intersections each requiring five to seven hours of data collection, travel time studies and calibration studies, traditional data collection techniques would take several hundred hours and exhaust the project's budget. A data collection plan was designed for efficiency, without sacrificing reliability, by first collecting daily traffic volumes on each corridor to identify the peak A.M., midday and P.M. hour of traffic. Then, processing data only for that peak hour. This allowed for a significant reduction to the amount of data collection hours needed per intersection.

## Traffic Modeling

Intersection traffic operations and signal timing is based on Synchro and SimTraffic model outputs. Synchro is a macroscopic traffic software program based on capacity analysis as specified in the *Highway Capacity Manual* (HCM). SimTraffic is a microscopic model based upon stochastic methodology. SimTraffic simulates and tracks vehicles within a network and records specific measures of effectiveness on a 0.1-second iterative basis. Both software models have unique features and limitations. As a result, the two models are used as complementary tools.

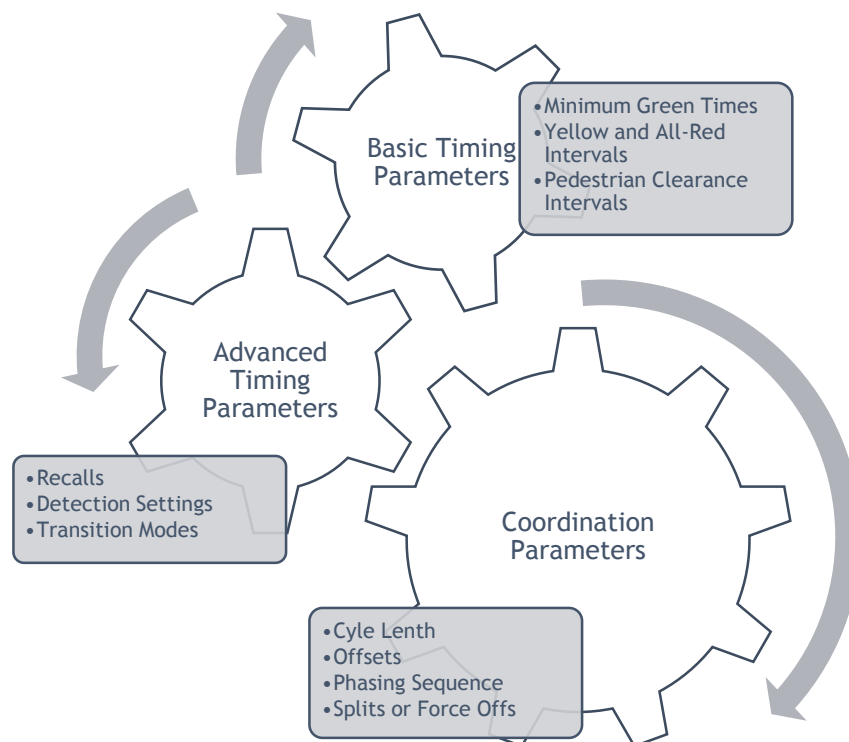
## Infrastructure Analysis

Using the calibrated models and collected field data, operational analysis was conducted and infrastructure improvements were evaluated and recommended. This analysis includes intersection capacity analysis as well as documentation of the arterial LOS for the entire corridor. The recommendations addressed any identified deficiency or improvement opportunity that cannot be corrected via signal timing and coordination improvements. Improvements were focused on intersection geometrics, signal phasing and equipment improvements.

## Timing Plan Development and Refinement

The final models developed from existing conditions were used to create optimized signal timing and coordinating strategies. The traffic signal optimization includes the parameters, shown in Figure 3. Upon the completion of the final timing plans and the preparation of the controller markups, the plans will be implemented and observed in the field. KLJ will work with City traffic personnel to implement new plans into the Centrac traffic control system and make field adjustments.

Figure 3 - Traffic Signal Optimization Parameters







## ***Evaluation and Reporting***

Once the new signal timing and coordination plans are implemented and refined in the field, travel time studies will be conducted to quantify benefits of the new timing plans. Also included in the evaluation and reporting section of this report is a summary of the data collection, final field adjusted timing plans with corresponding time space diagrams, before and after evaluation results and all other infrastructure recommendations. Finally, this report includes an evaluation of how the study achieves the seven national performance goals for the Federal Highway program.

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## CHAPTER 2 - EXISTING CONDITIONS

An evaluation of the existing conditions was completed in April and May 2015. Key components of the existing conditions include the collection of intersection and corridor traffic volume characteristics, existing signal timing parameters, development and calibration of the signal timing models and evaluation of the existing levels of service.

The following field studies were conducted in accordance with the 2010 ITE *Manual of Transportation Engineering Studies, 2nd Edition*. The locations of these studies are listed in **Table 1** and can be seen in **Figure 4**.



### Intersection Turning Movement Counts (TMC)

- Used to develop splits for signal timing plans.
- 55 intersection turning movement counts (TMC) were collected using a combination of video devices and hand-held count boards.
- The following datasets were obtained from turning movement counts
  - 15-minute turning movement counts per direction per approach
  - Pedestrian and bicycle counts
  - Peak Hour Factor (PHF)
  - Heavy Vehicle Factor (HVF)



### Average Daily Traffic Counts (ADT)

- Daily traffic counts were conducted at fourteen locations throughout the City of Casper by using a combination of road tubes and radar for the following purposes:
  - Used to determine daily and weekly traffic patterns to pinpoint specific time periods for the TMC data collection.
  - Provides an estimation of less critical off-peak periods without the time-intensive turning movement counts. These off-peak estimations were also used in the signal warrants analysis discussed in Chapter 3.
  - Finally, daily traffic counts were used to determine the optimal time to transition between time-of-day timing plans.



### Saturation Flow Rates

- The saturation flow rate can be defined as the number of vehicles that can pass through the signal given a constant green light, usually measured in vehicles per hour per lane (vphpl).
- Studies have shown that saturation flow rates may vary by 25 percent or greater depending on the study area's size and context. This highlights changes in driver behavior based upon contextual factors. Incorrect baseline information in the model will lead to poor timing and coordination plans.



### Corridor Travel Time Study

- Four travel time studies were conducted to:
  - Document existing corridor progression and delay before improvements
  - Help quantify project benefits after implementation



### Site Survey

- A site survey was conducted to record relevant geometric and traffic control data to input into traffic models. This data includes the number of lanes, lane width, lane assignment (e.g. exclusive left-turn, through only, shared through and right-turn, etc.), signal head identification, presence of turn bays, lengths of turn bays, lengths of pedestrian crosswalks and intersection width for all approach legs.



Figure 4 - Data Collection Locations

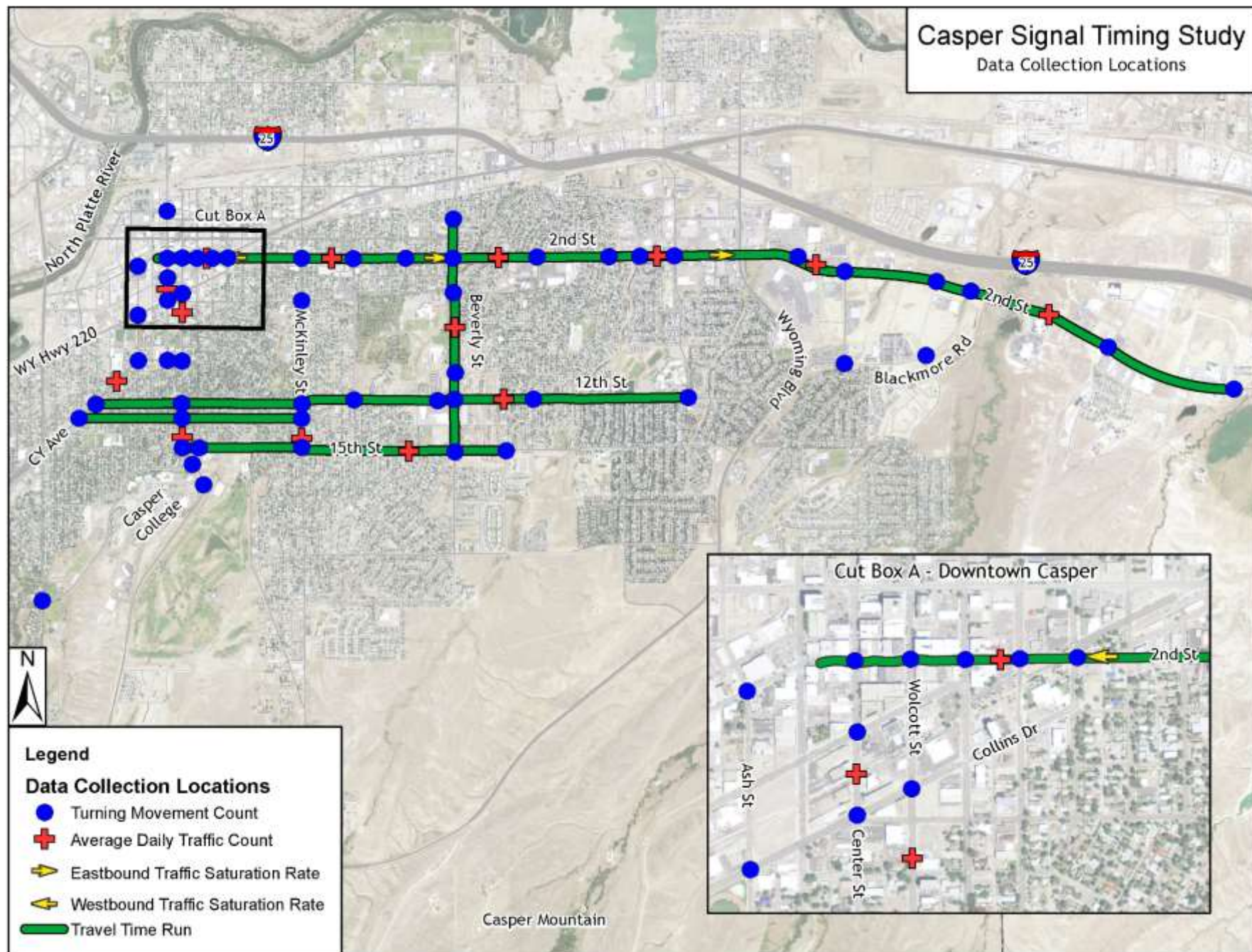


Table 1 - Data Collection Locations

Study Intersections	
2nd Street and Center Street	Center Street and 9th Street
2nd Street and Wolcott Street	Wolcott Street and 9th Street
2nd Street and Durbin Street	CY Avenue and 12th Street
2nd Street and Beech Street	CY Avenue and 13th Street
2nd Street and Kimball Street	Wolcott Street and 12th Street
2nd Street and McKinley Street	Wolcott Street and 13th Street
2nd Street and Conwell Street	Wolcott Street and 15th Street
2nd Street and Elk Street	Durbin Street and 15th Street
2nd Street and Beverly Street	Wolcott Street and Durbin Street
2nd Street and Country Club Road	Casper Mountain Road and Campus Drive
2nd Street and Sun Drive	Poplar Street and 25th Street/College Drive
2nd Street and Forest Drive	McKinley Street and 5th Street
2nd Street and Walsh Drive	McKinley Street and 12th Street
2nd Street and Wyoming Boulevard	McKinley Street and 13th Street
2nd Street and Eastridge Mall/Walmart	McKinley Street and 15th Street
2nd Street and Landmark Drive	Conwell Street and 12th Street
2nd Street and Newport Road	Beverly Street and A Street
2nd Street and Blackmore Road	Beverly Street and 4th Street
2nd Street and Coliseum Way	Beverly Street and 10th Street
2nd Street and Granite Peak Drive	Beverly Street and 12th Street
Ash Street and Yellowstone Highway	Beverly Street and 15th Street
Center Street and B Street	12th Street and Country Club Road
Center Street and Midwest Avenue	12th Street and Walsh Drive
Ash Street and Collins Drive	15th Street and Missouri Avenue
Center Street and Collins Drive	Blackmore Road and Landmark Drive
Wolcott Street and Collins Drive	Blackmore Road and Newport Road
Ash Street and 9th Street	12th Street Midblock Pedestrian Crossing

Daily Traffic Count Locations
2nd Street west of Beech Street
2nd Street west of Conwell Street
2nd Street east of Beverly Street
2nd Street east of Wyoming Boulevard
2nd Street west of Wyoming Boulevard
2nd Street east of Blackmore Road
Center Street south of 2nd Street
CY Avenue north of 12th Street
Wolcott Street south of Collins Drive
Wolcott Street north of 15th Street
McKinley Street north of 15th Street
Beverly Street north of 12th Street
12th Street east of Beverly Street
15th Street west of Beverly Street

Saturation Flow Rate Study Locations	
Intersection	Direction
2nd Street and Durbin Street	Eastbound
2nd Street and Kimball Street	Westbound
2nd Street and Beverly Street	Eastbound
2nd Street and Wyoming Boulevard	Eastbound

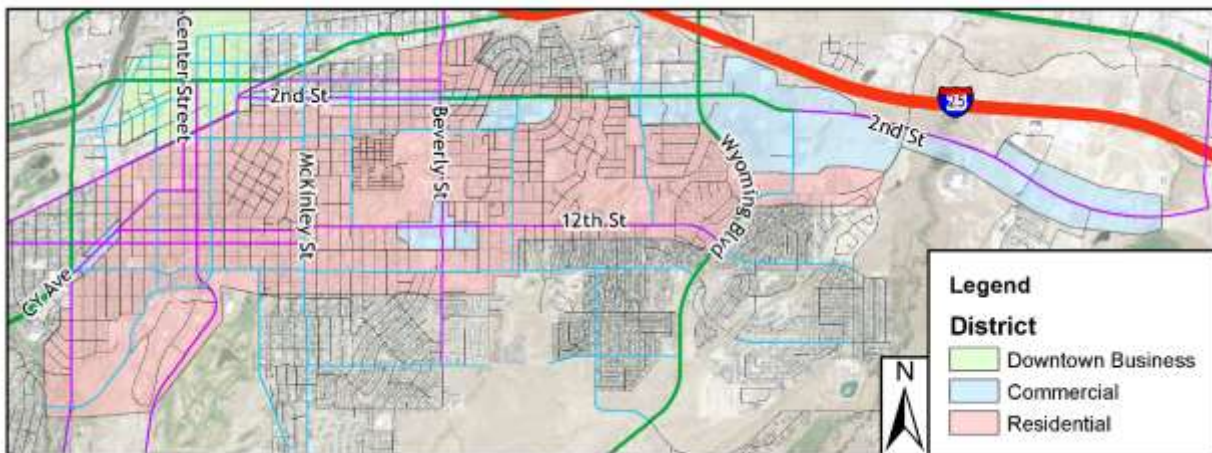
Travel Time Study Corridors
2nd Street from Center Street to Granite Peak Drive
Beverly Street from A Street to 15th Street
12th Street/13th Street from CY Avenue to Walsh Drive
15th Street from Wolcott Street to Missouri Avenue



## Traffic Volumes

The traffic volumes and patterns throughout the study area of Casper vary greatly throughout the course of a typical day, as some areas have large peak hour directional splits (e.g., Beverly Street and 15th Street) while others are more balanced throughout the day (e.g., 2nd Street). Based on observations of the study area and analysis of the ADT information, three main districts became prevalent as seen in **Figure 5**, each with different roadway and traffic characteristics. The locations of the average daily traffic counts, with respective heavy vehicle factor and 85th percentile speed, can be seen in **Figure 12** on page 14.

*Figure 5 - Study Area Districts*



### ***Downtown Business District***

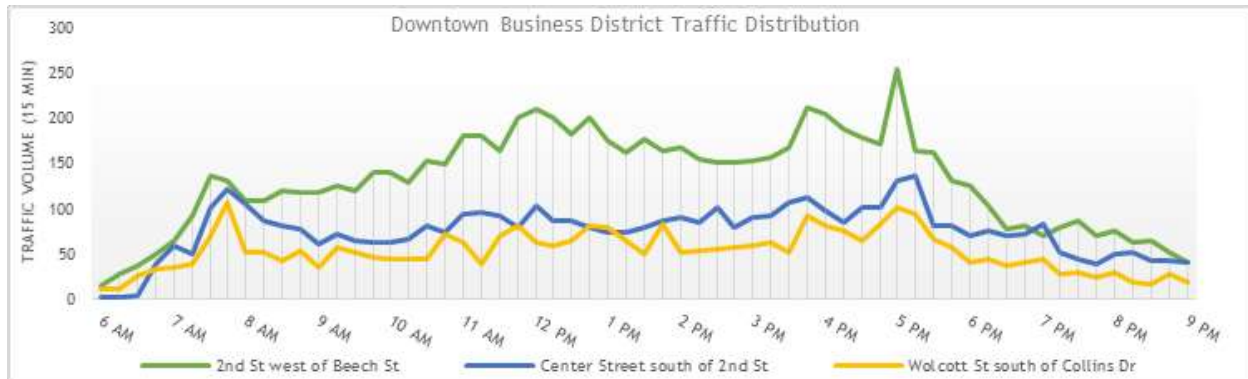
Downtown Casper features a unique roadway configuration as 2nd Street from David Street to Durbin Street weaves itself through the heart of Casper, as shown in **Figure 6**.

*Figure 6 - 2nd Street Weaving through Downtown Casper*



Traffic in this district can be characterized as low-speed with high traffic volumes during the typical 8:00 to 5:00 workday and low volumes during the off-peak periods. **Figure 7** displays a typical traffic distribution for the downtown business district.

*Figure 7 - Downtown Business District Traffic Distribution*



As shown in **Table 2**, the 85th percentile speeds for the downtown business district are 35 to 40 percent greater than the posted speed limit of 20 miles per hour (mph) for downtown Casper. Similar to the traffic volumes, traffic speeds in the downtown district are constant throughout the typical workday of 8:00 to 5:00. There is, however, a slight uptick of 1-2 mph in travel speed during the evening when downtown Casper becomes less congested.

*Table 2 - Downtown Business District 85th Percentile Speeds*

Downtown Business District Speed Analysis			
Location	Posted Speed (mph)	85th Percentile Speed (mph)	Percent above Posted
2nd Street west of Beech Street	20	28	40%
Center Street south of 2nd Street	20	28	40%
Wolcott Street south of Collins Drive	20	27	35%

The Downtown District also experiences strong pedestrian activity through a typical day, particularly during the noon lunch hour, as shown in **Figure 8**. The combination of ample parking off 2nd Street, limited on-street parking along 2nd Street and concentrated business activities support much of the pedestrian activity.

*Figure 8 - Downtown Casper Pedestrian Traffic*



## SIGNAL TIMING IMPLICATIONS

Pedestrian recall will be included in the downtown traffic signals due to the high pedestrian volumes. Pedestrian recall increases the green time given to side streets, which are generally low volume. Only short cycles (60 to 90 seconds) were considered for the downtown district. Short signal cycles reduce overall pedestrian wait times as well as side street delay, resulting in improved pedestrian crossing compliance and decreased congestion on surrounding streets.

As shown in **Figure 7**, the downtown business district, especially off 2nd Street, tends to have a constant flow of traffic volume throughout the day. Diminishing the need for numerous signal timing plan transitions, this subject will be discussed in detail in Chapter 5 - Timing Methods and Assumptions.

*Figure 9 - Street view of Downtown Casper*



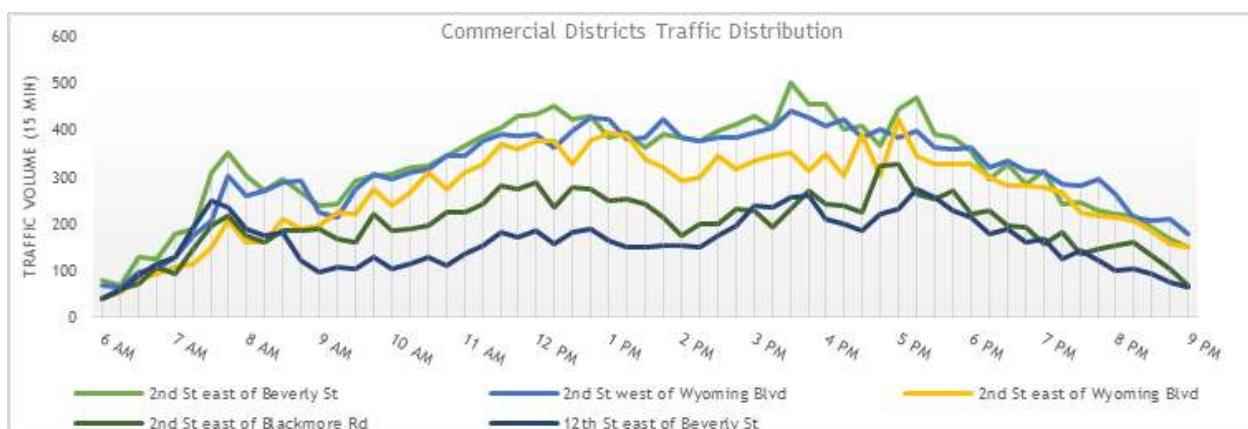
## Commercial Districts

Within the study area, the following three commercial/general business corridors occur outside the downtown business district:

- » 2nd Street from Kimball Street to Granite Peak Drive
- » 12th Street near the intersection of Beverly Street
- » CY Avenue near the intersections of 12th Street and 13th Street

The entire 2nd Street commercial corridor regularly sees ADTs surpass 20,000 vehicles with the intersection of 2nd Street and Wyoming Boulevard thought to be one of the busiest intersections in the entire state of Wyoming. Traffic distributions collected at or near the commercial districts can be seen in **Figure 10**.

*Figure 10 - Commercial Districts Traffic Distribution*



Besides the heavily congested stretch between Wyoming Boulevard and Eastridge Mall/Walmart, it was noticed that the 85th percentile speeds for 2nd Street from McKinley Street out to Granite Peak Drive were consistently 10 mph over the posted speed limit. Contradicting assumptions, it was found that traffic speeds increased by 1-2 mph during the A.M., midday and P.M. peak traffic hours and decreased



by 1-2 mph during the off-peak time periods, compared to the daily 85th percentile speeds. The 85th percentile speeds for the six commercial corridor data collection locations are shown in **Table 3**.

*Table 3 - Commercial District 85th Percentile Speeds*

Commercial District Speed Analysis			
Location	Posted Speed (mph)	85th Percentile Speed (mph)	Percent above Posted
2nd Street east of McKinley Street	30	41	37%
2nd Street east of Beverly Street	30	38	27%
2nd Street west of Wyoming Boulevard	30	42	40%
2nd Street east of Wyoming Boulevard	30	31	3%
2nd Street east of Blackmore Road	40	49	23%
12th Street east of Beverly Street	30	34	13%

Unlike the Downtown District, these business districts experience minimal pedestrian activity. This is due to heavy traffic on the mainline, lack of mixed land use, frequent access points and ample parking. These factors often negate the advantages or desire to walk between locations.

### **SIGNAL TIMING IMPLICATIONS**

For the commercial districts, longer cycle lengths were pursued with the goal of pushing more traffic through the intersection. The side streets along these corridors will be set as “No Recall”, meaning that the phase could be skipped if there are no vehicles queueing at the intersection. Additionally, pedestrian phases are not included in side street split allocation as most intersections experience a 99:1 vehicle to pedestrian ratio on the side streets. This does not imply that pedestrian movements cannot be serviced from the side streets; when they do, the intersection will temporarily fall out of coordination. The controller will take several cycles to regain coordination. The benefit of this operation is that side streets can operate under green times that match demand, resulting in improved operations. It is important to note that mainline pedestrian phases can be serviced due to long green times without affecting coordination.

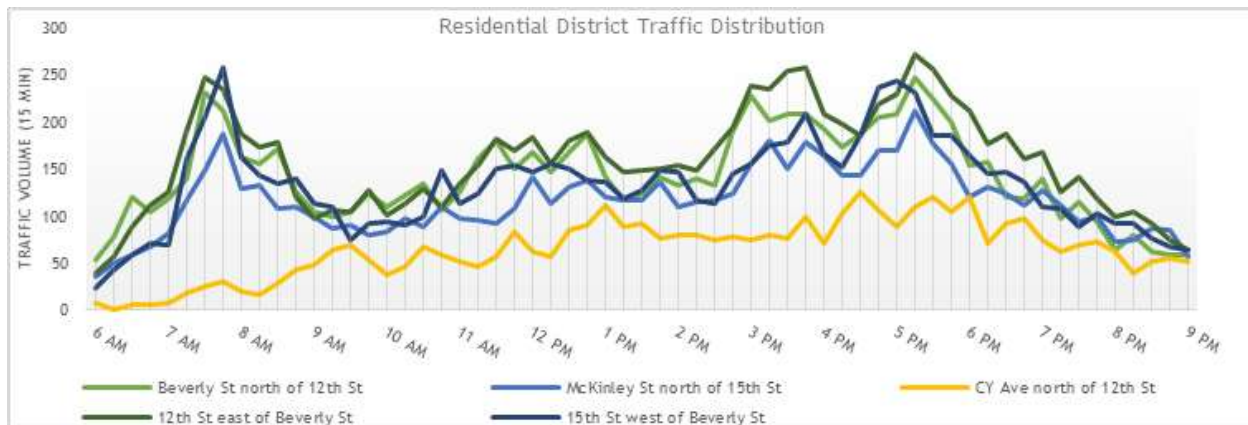
Similar to the downtown business district, but with far greater traffic volume, the commercial districts tend to have a low variance in volume throughout the day as seen in **Figure 10**, lessening the need for many signal-timing plans.

### ***Residential District***

The majority of the traffic signals within the Casper signal timing study area occur in places that could be classified as residential neighborhoods. Traffic along these corridors, whether on an arterial (e.g., Wolcott Street and 12th Street) or a collector (e.g., McKinley Street and 15th Street), tends to be concentrated in the A.M and P.M. peak hours, during the typical workday commute. Numerous Natrona County schools are also within residential districts of the study area, which leads to an additional traffic spike between 3:15 P.M. and 3:45 P.M., when most schools end class for the day.

In general, traffic through the residential districts have moderate speed with high peak-hour and low off-peak traffic. Traffic distributions collected throughout the residential district can be seen in **Figure 11**.

*Figure 11 - Residential District Traffic Distribution*



As a whole, the 85th percentile speeds for the residential district closely represent the posted limit of 30 mph. As can be seen in **Table 4**, residential district 85th percentile traffic speeds vary only between 28 mph along CY Avenue and 35 mph along 15th Street. Through the analysis of the speed study, it was found that traffic speeds often increased during the non-peak hours and decreased during the peak hours, when traffic is more congested.

*Table 4 - Residential District 85th Percentile Speeds*

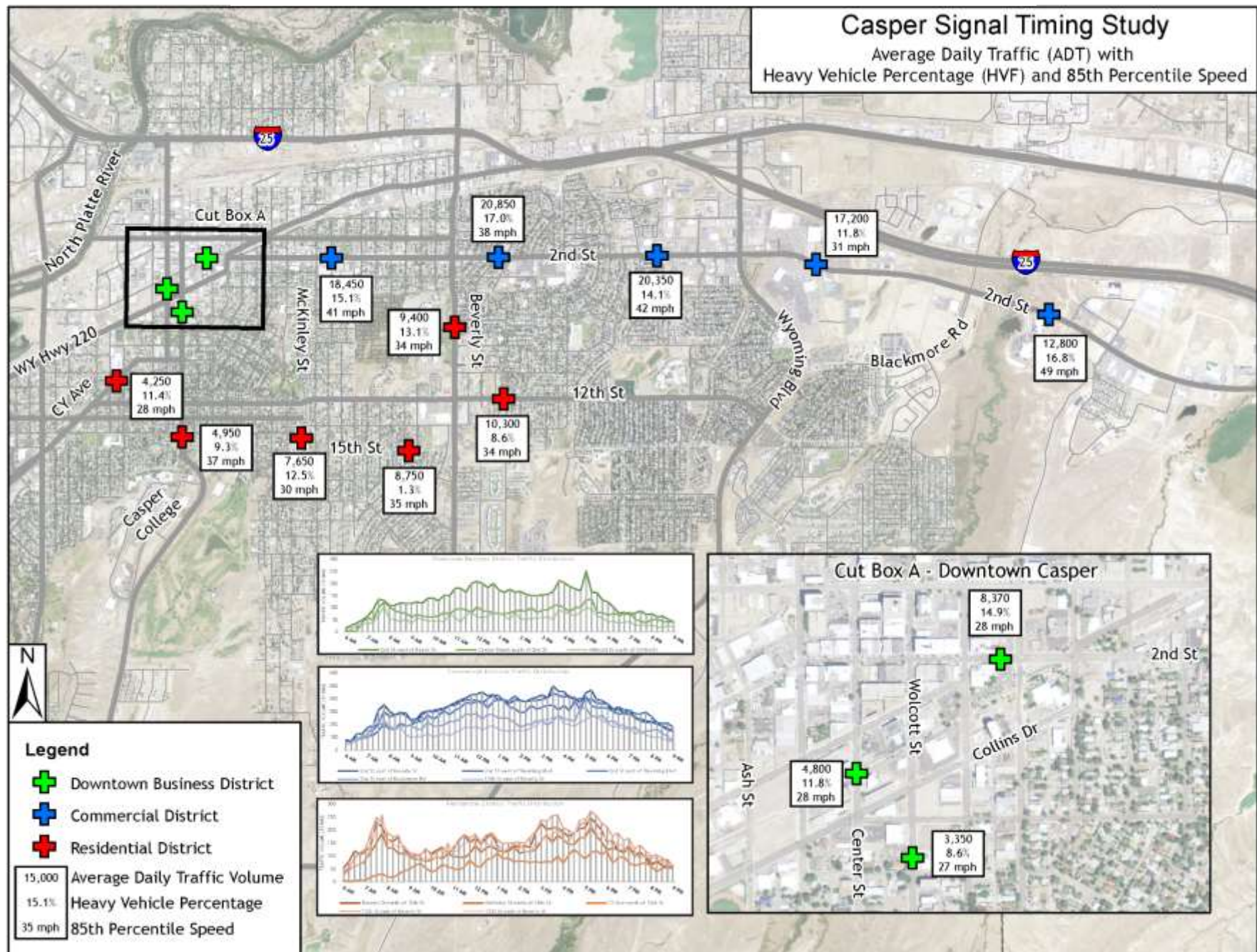
Residential District Speed Analysis			
Location	Posted Speed (mph)	85th Percentile Speed (mph)	Percent above Posted
Beverly Street north of 12th Street	30	34	13%
McKinley Street north of 15th Street	30	30	0%
CY Avenue north of 12th Street	30	28	-7%
12th Street east of Beverly Street	30	34	13%
15th Street west of Beverly Street	30	35	17%

## **SIGNAL TIMING IMPLICATIONS**

Medium cycle lengths were sought to balance a need to move traffic with the needs of pedestrians traveling to schools and other local generators. Pedestrian clearance timings incorporated into splits are either site specific, depending on adjacent land uses (e.g., schools) or pedestrian and bicycle volumes.

Timing plans for the residential district will include A.M., midday and P.M. plans. An evaluation of a special P.M. school-related timing plan is discussed in Chapter 5 of this report.

Figure 12 - Study Area Average Daily Traffic





## Travel Time Study

The initial travel time study was conducted in April 2015 to document the corridor's progression and delay. Another travel time study will be completed after the signal timing improvements have been implemented to help quantify the signal timing study's benefits. The four travel time study corridors are listed below along with their timings (**Table 5**) and speeds (**Table 6**).

*Table 5 - Casper Travel Time Study Time Characteristics*

Corridor	Direction	Free Flow		A.M. Peak Hour						P.M. Peak Hour					
				Average			Longest Observed			Average			Longest Observed		
		Min	Sec	Min	Sec	Efficiency	Min	Sec	Efficiency	Min	Sec	Efficiency	Min	Sec	Efficiency
2nd Street - Center Street to Granite Peak Drive	WB	9	50	12	40	129%	14	36	149%	13	14	135%	14	18	146%
	EB			13	29	138%	14	10	144%	12	51	131%	13	7	134%
Beverly Street - A Street to 15th Street	NB	2	17	3	49	167%	4	51	213%	4	11	185%	5	31	242%
	SB			4	19	190%	4	59	219%	3	11	140%	3	45	164%
12th Street & 13th Street - CY Avenue to Walsh Drive	WB	5	44	7	13	126%	7	46	135%	7	0	122%	7	10	125%
	EB			6	21	111%	6	36	115%	7	4	123%	7	51	137%
15th Street - Wolcott Street to Missouri Avenue	WB	3	10	5	9	163%	5	30	174%	4	28	142%	4	36	146%
	EB			4	43	149%	4	59	158%	4	31	143%	5	11	164%

\*Efficiency = Observed / Free

*Table 6 - Casper Travel Time Study Speed Characteristics*

Corridor	Direction	Posted	A.M. Peak Hour				P.M. Peak Hour			
			Average		Slowest Observed		Average		Slowest Observed	
		mph	mph	performance	mph	performance	mph	performance	mph	performance
2nd Street - Center Street to Granite Peak Drive	WB	20/30/40	25.1	129%	21.7	149%	24.0	135%	22.2	146%
	EB		23.5	138%	22.4	144%	24.7	131%	24.2	134%
Beverly Street - A Street to 15th Street	NB	30	18.0	167%	14.1	213%	16.2	185%	12.4	242%
	SB		15.8	190%	13.7	219%	21.5	140%	18.3	164%
12th Street & 13th Street - CY Avenue to Walsh Drive	WB	30	23.9	126%	22.2	135%	24.6	122%	24.0	125%
	EB		27.1	111%	26.1	115%	24.4	123%	21.9	137%
15th Street - Wolcott Street to Missouri Avenue	WB	30	18.4	163%	17.2	174%	21.2	142%	20.6	146%
	EB		20.1	149%	19.0	158%	21.0	143%	18.3	164%

\*Performance = Actual / Posted



## ***2nd Street Travel Time Study***

The entire 5.3-mile stretch of 2nd Street produced fairly consistent travel time runs near 13 minutes, approximately 30 percent greater than free flow conditions. Small segments of the corridor experience high variations between travel time runs due to the lack of existing coordination throughout the 2nd Street corridor.

During the P.M. peak, 2nd Street between Walsh Drive and the Mall/Walmart approaches experience a significant reduction in travel speed. The posted speed in this segment is 30 miles per hour but the average speed during the travel time runs was only 17.2 miles per hour, more than a 40 percent reduction in travel speed. Two factors are contributing to this delay. First, this is a heavily traveled area with the Eastridge Mall and Walmart being major destination centers, and secondly, the lack of coordination with the WYDOT traffic signal at the intersection of 2nd Street and Wyoming Boulevard produces stop-and-go traffic conditions.

## ***Beverly Street Travel Time Study***

As can be seen in **Table 5**, the average Beverly Street observed travel time runs were significantly higher than expected versus the ideal scenario of free flow traffic conditions. Based on the existing timing plans and the conducted travel time runs, the average travel time for the Beverly Street corridor is 70 percent longer than under free flow conditions. The worst observed travel time run was 90 percent higher than free flow (meaning that during peak hours, the Beverly Street corridor may take twice as long to travel when compared to the free flow conditions).

## ***12th Street and 13th Street Travel Time Study***

The 12th Street/13th Street corridor from Walsh Drive to CY Avenue has two subareas with distinct traffic flow characteristics. From McKinley Street to Walsh Drive, traffic is bidirectional on 12th Street. However, west of McKinley Street to CY Avenue, 12th Street converts into a two-lane westbound-only road and 13th Street in that same stretch transforms into a two-lane eastbound-only road.

Overall, the travel time runs for the 12th Street and 13th Street corridor were fairly consistent; the average observed run was only 1 minute and 9 seconds (17 percent higher) than the ideal scenario, with the worst observed runs averaged out to 1 minute and 35 seconds, an increase of only 22 percent of the ideal travel run.

## ***15th Street Travel Time Study***

The travel time runs for the 15th Street study area produced very consistent runs, although significantly greater (50 percent) than the free flow conditions, in the eastbound and westbound directions as well as in the morning and evening with an average run time of 4 minutes and 43 seconds.

## **Saturation Flow Rate Study**

As stated at the beginning of Chapter 2, saturation flow rate can be defined as the number of vehicles that pass through a traffic signal given a constant green light, typically measured in vehicles per hour per lane (vphpl). Studies have shown that saturation flow rates may vary by 25 percent or greater depending on the study area's size and context, often highlighting changes in driver behavior upon contextual factors. Saturation flow rates were collected throughout the study area to ensure proper baseline information, resulting in improved timing and coordination plans.

Saturation flow rate studies were completed during both the A.M. and P.M. peak periods; their locations were chosen based upon volume to capacity ratios, and observation of longer queueing approaches. The results of the saturation flow rate studies are shown in **Table 7**.



Table 7 - Casper Saturation Flow Rate Study

Intersection	Movement	Saturation Flow Rate (vphpl)
2nd Street and Durbin Street	Eastbound	1,480
2nd Street and Kimball Street	Westbound	1,500
2nd Street and Beverly Street	Eastbound	1,565
2nd Street and Wyoming Boulevard	Eastbound	1,650
Mean Saturation Flow		1,565
Adjusted Saturation Flow Rate		1,700

The mean saturation flow rate, as collected throughout the Casper study area, was 1,565 vphpl. This is well below the national average of 1,750 vphpl for a city with the similar size as Casper, WY as per the *National Cooperative Highway Research Program (NCHRP) Report 599*. More data is needed to confirm the lower-than-normal saturation flow rate is consistent throughout the Casper study area.

As per *NCHRP Report 599*, the adjusted saturation flow rate range for an urban area is 1,700 to 1,900 vphpl. Since the collected saturation flow rate of 1,565 vphpl is still well below the recommended range, the adjusted saturation flow rate range floor of 1,700 vphpl will be used to calibrate the timing models.

## Operations

Peak hour traffic operations were evaluated at all study intersections using the Synchro software. Synchro implements analysis methods based on methods published in the *Highway Capacity Manual*. Traffic operations are described in terms of “level of service” (LOS), with levels of service ranging from LOS “A” to LOS “F”. LOS “A” indicates near free flow traffic operations with little delay, and LOS “F” indicates breakdown of traffic flow and high amounts of delay.

Analysis in this study will consider traffic operations at LOS “A”, “B” and “C” as acceptable, per WYDOT and City of Casper standards. LOS “D”, “E” and “F” will be considered deficient, with locations operating at these levels of service being candidates for improvements.

Level of service analysis was performed for both A.M. and P.M. peak hour traffic volumes under the existing signal timings that were obtained from the City of Casper. Approach LOS deficiencies were observed at 20 of 55 study intersections; however, only four intersections were observed to have operations resulting in overall intersection levels of service at LOS “D” or worse:

- » 2nd Street and Beverly Street - A.M. and P.M. peak hour intersection LOS “D”
- » 2nd Street and Walsh Drive - P.M. peak hour intersection LOS “D”
- » Center Street, 5th Street and Collins Drive - A.M. peak hour intersection LOS “F”
- » McKinley Street and 13th Street - A.M. peak hour intersection LOS “D”

An overview of locations with overall intersection operational deficiencies (intersection LOS “D” or worse) or approach operational deficiencies (approach LOS “D” or worse) can be seen in **Table 8**. Intersection and approach levels of service for all intersections can be seen in **Figure 13** through **Figure 18**. Locations with identified operational deficiencies were considered candidates for minor

geometric and/or signal phasing improvements, with analysis related to these locations and potential improvements being presented in **Chapter 4** of this report.

*Table 8 - Identified Peak Hour Operational Deficiencies*

Intersection	Time Period With Deficiency (LOS D or Worse)				
	Overall Intersection Deficiency	Approach Deficiency			
		EB	WB	NB	SB
2nd Street and Beech Street					P.M.
2nd Street and McKinley Street					P.M.
2nd Street and Beverly Street	A.M., P.M.	P.M.	A.M., P.M.	A.M., P.M.	
2nd Street and Sun Drive				A.M.	A.M., P.M.
2nd Street and Walsh Drive	P.M.	P.M.		P.M.	A.M., P.M.
2nd Street and Wyoming Boulevard	P.M.	P.M.			P.M.
2nd Street and Mall/WalMart					A.M., P.M.
Center Street and B Street		A.M.			
Center Street, 5th Street and Collins Drive	A.M.		A.M., P.M.	A.M.	A.M.
CY Avenue, Spruce Street and 12th Street			A.M., P.M.		A.M., P.M.
CY Avenue, Walnut Street and 13th Street		AM, P.M.			P.M.
Poplar Street and 25th Street/College Drive				A.M.	
McKinley Street and 5th Street			P.M.		
McKinley Street and 12th Street					P.M.
McKinley Street and 13th Street	A.M.	A.M.			
McKinley Street and 15th Street					P.M.
Beverly Street and 4th Street		P.M.			
Beverly Street and 12th Street		A.M.			
Beverly Street and 15th Street				A.M.	P.M.
12th Street and Country Club Road					P.M.
12th Street and Walsh Drive			A.M.		
Notes: Blank cells indicate no deficiencies; intersections with no deficiencies are not listed in this table. Green highlighted cells indicated those locations where deficiencies can be eliminated with signal timing optimization. Red highlighted cells indicate those intersections where deficiencies cannot be eliminated with signal timing optimization. Yellow highlighted cells indicated those intersections that cannot be fixed with signal timing optimization alone.					

As can be seen in **Table 8**, the preliminary signal timing optimization eliminates the majority of the existing traffic operational deficiencies. The following chapters will help refine the preliminary timing plans. However, this analysis helps identify deficiencies resulting from existing signal timing and those indicating an underlying capacity deficiency that cannot be fixed with signal timing alone.



Figure 13 - A.M. Traffic Operations Sheet 1

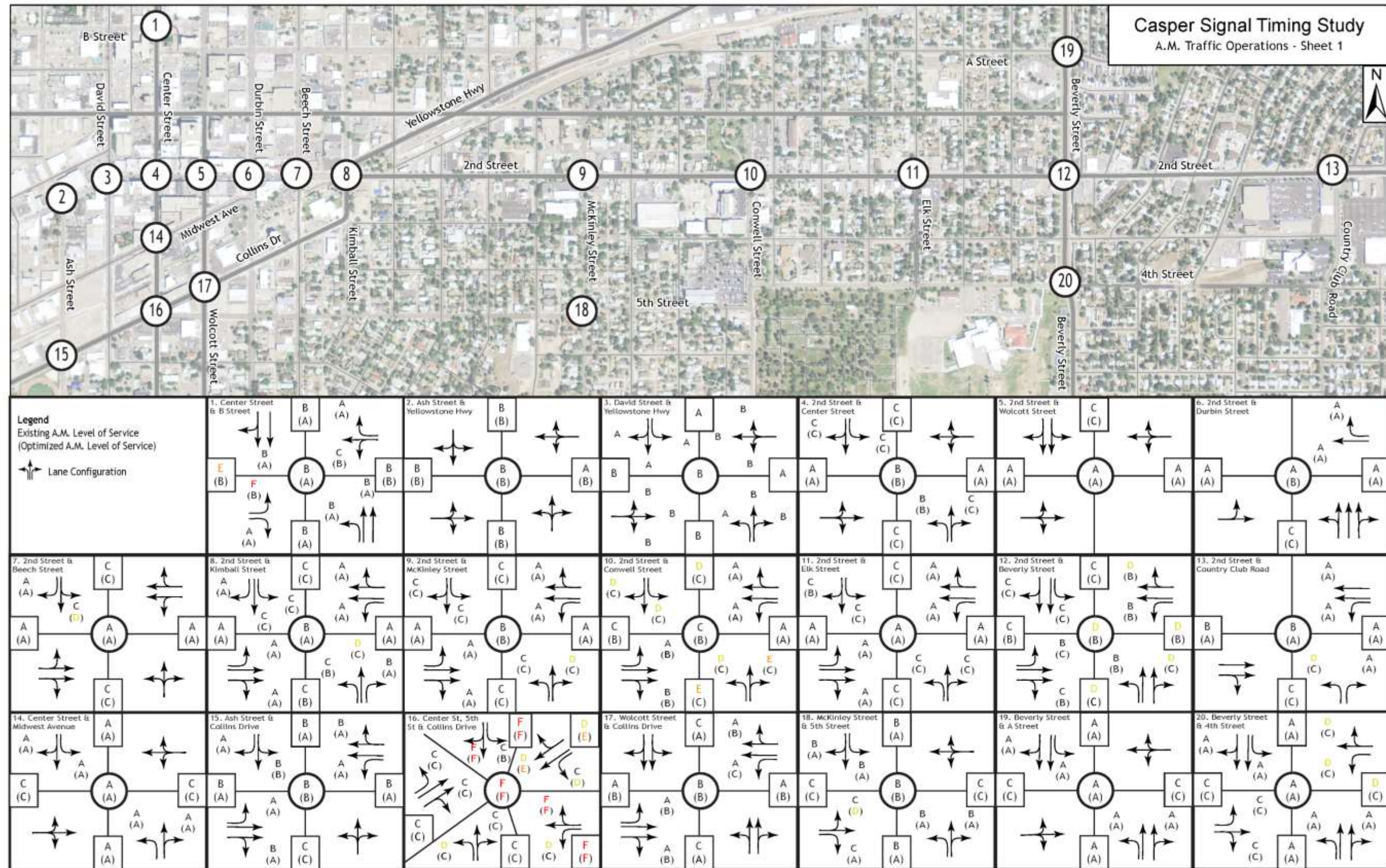




Figure 14 - A.M. Traffic Operations Sheet 2

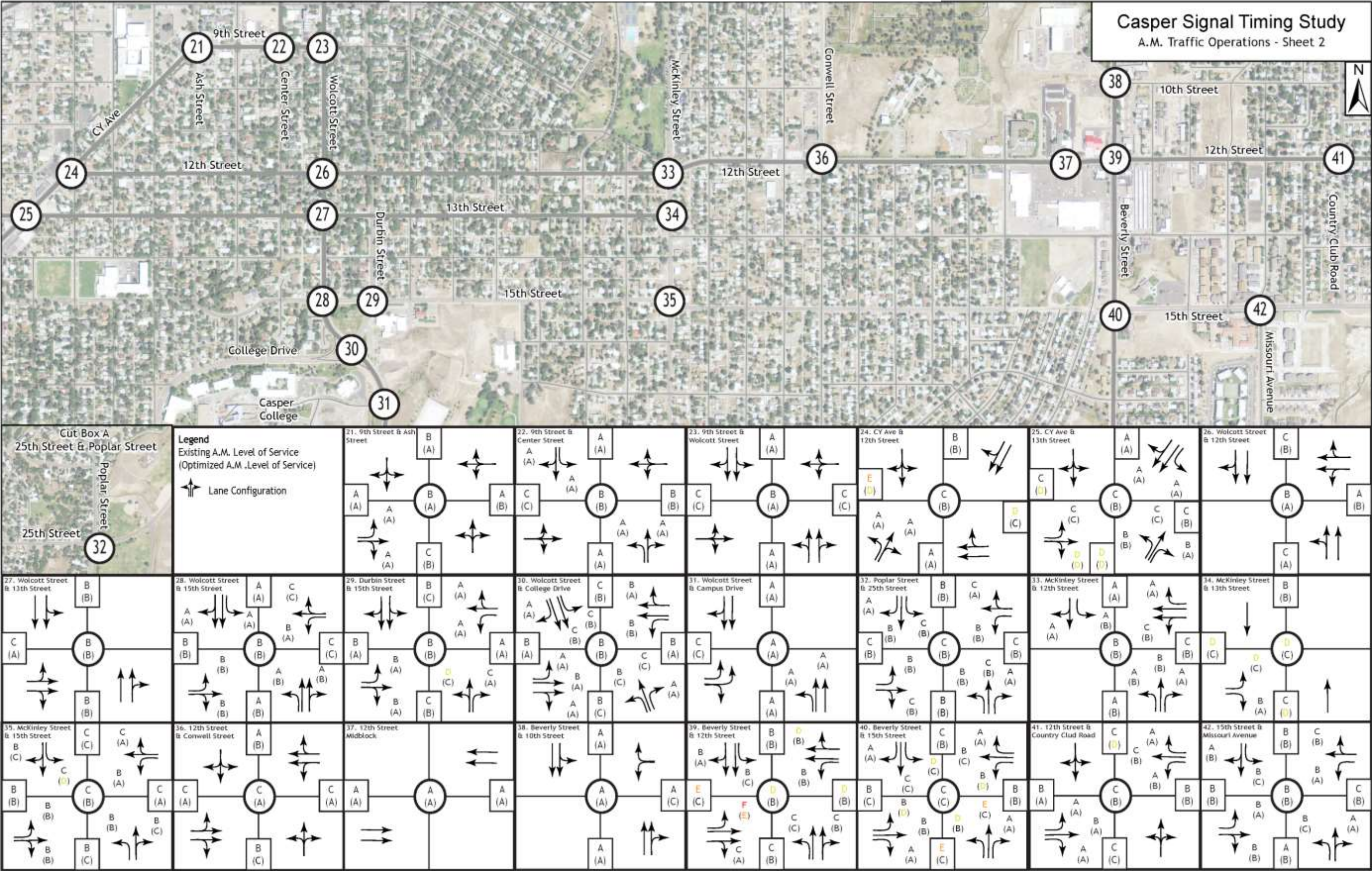




Figure 15 - A.M. Traffic Operations Sheet 3

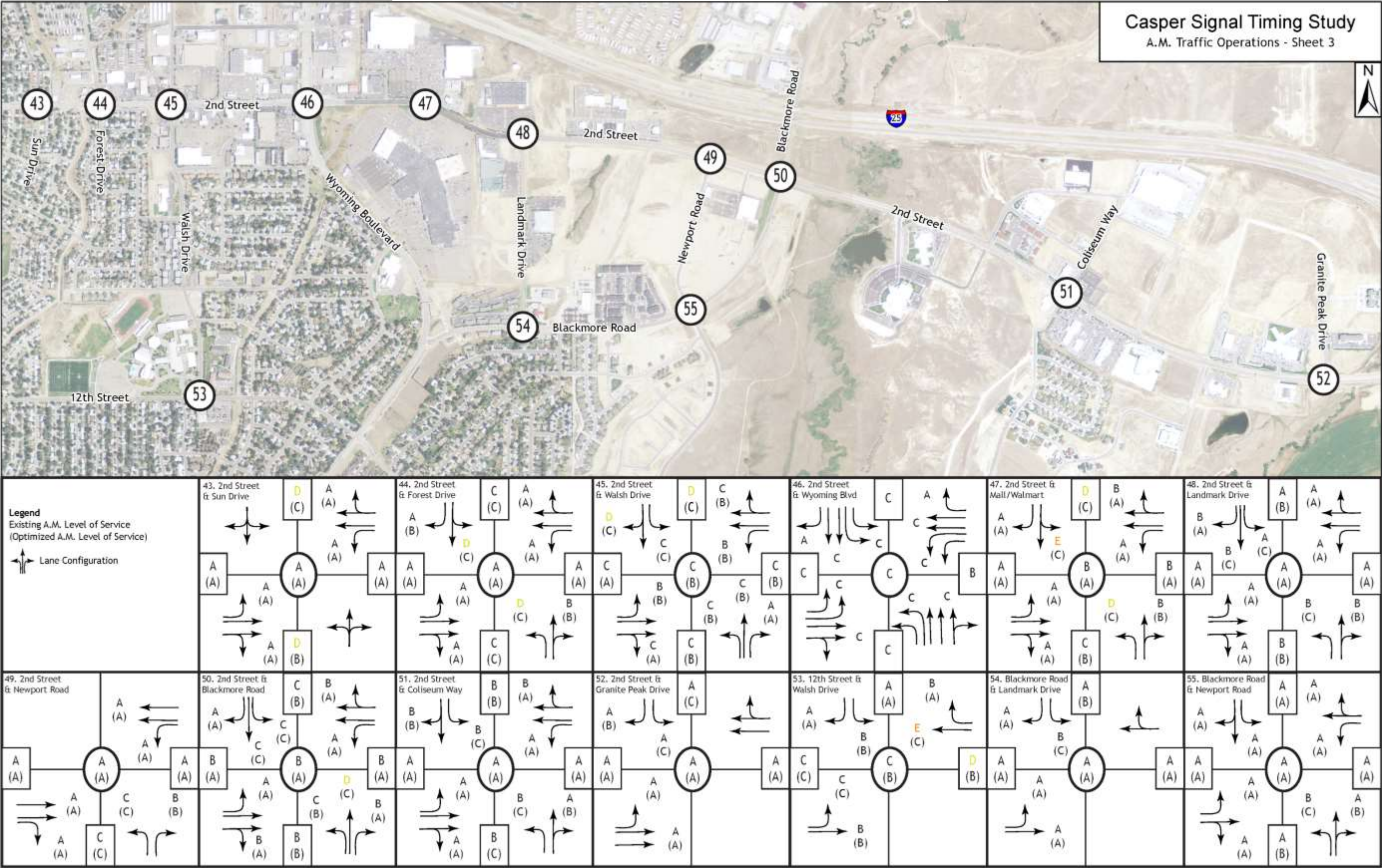




Figure 16 - P.M. Traffic Operations Sheet 1

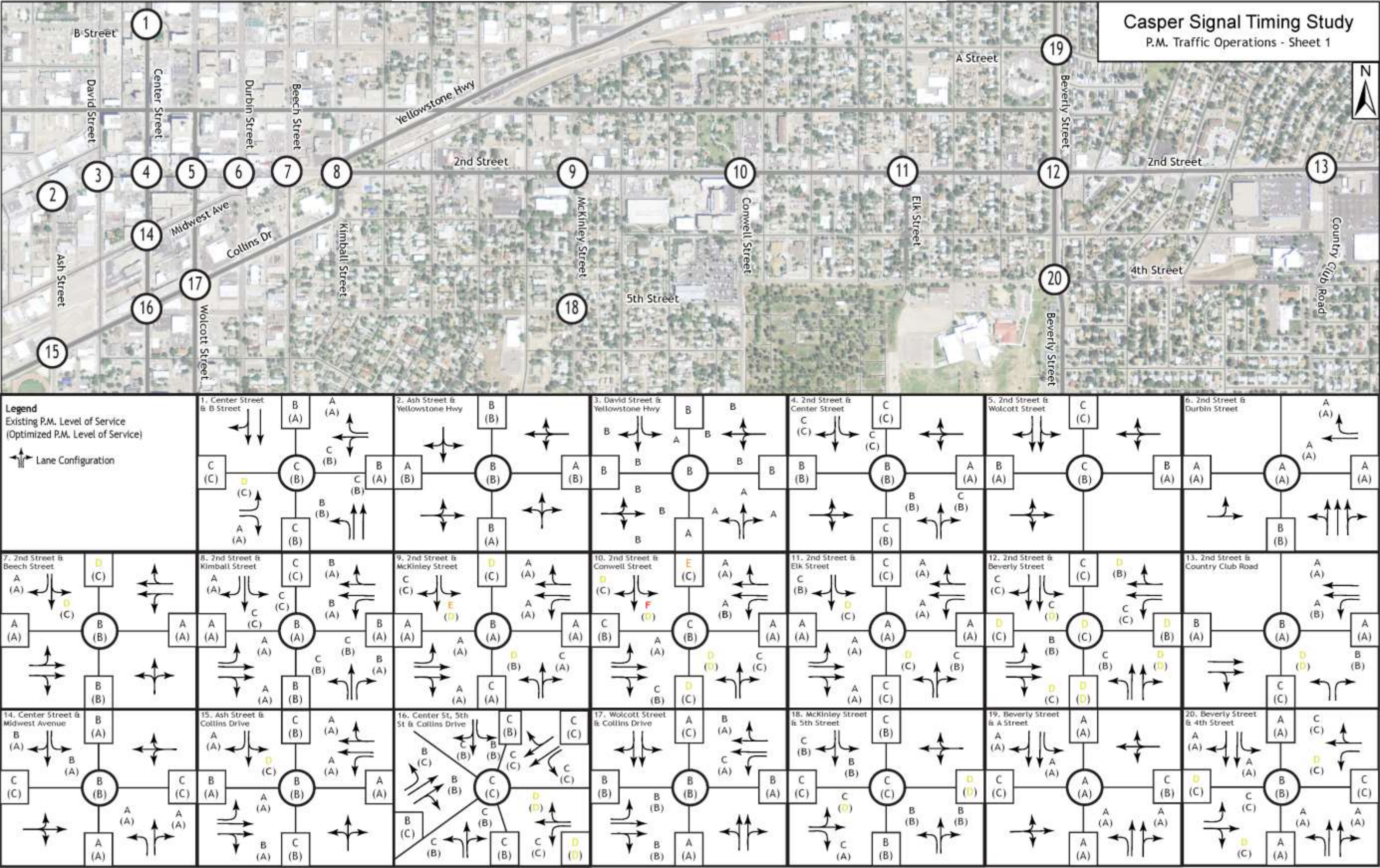




Figure 17 - P.M. Traffic Operations Sheet 2

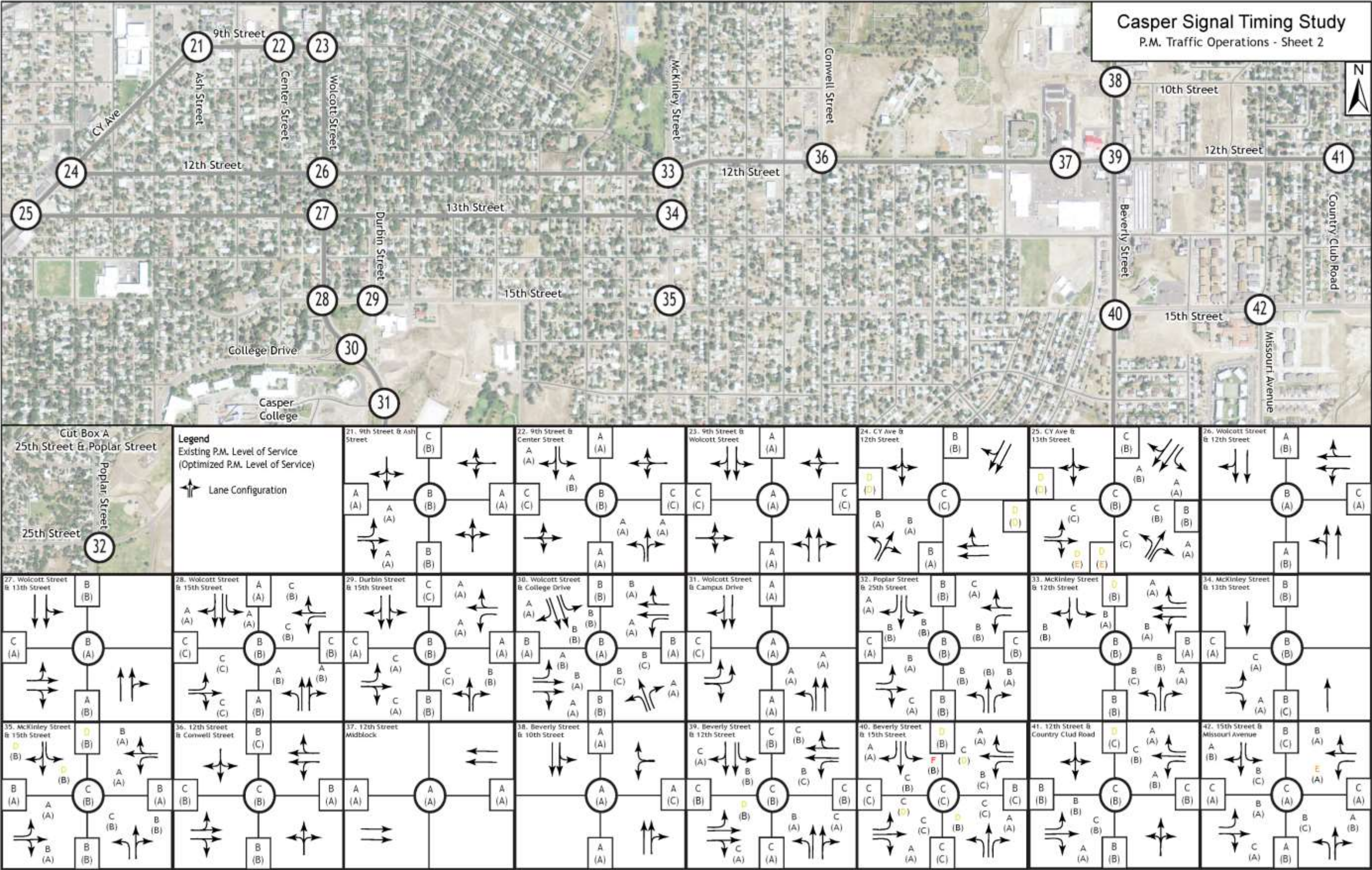
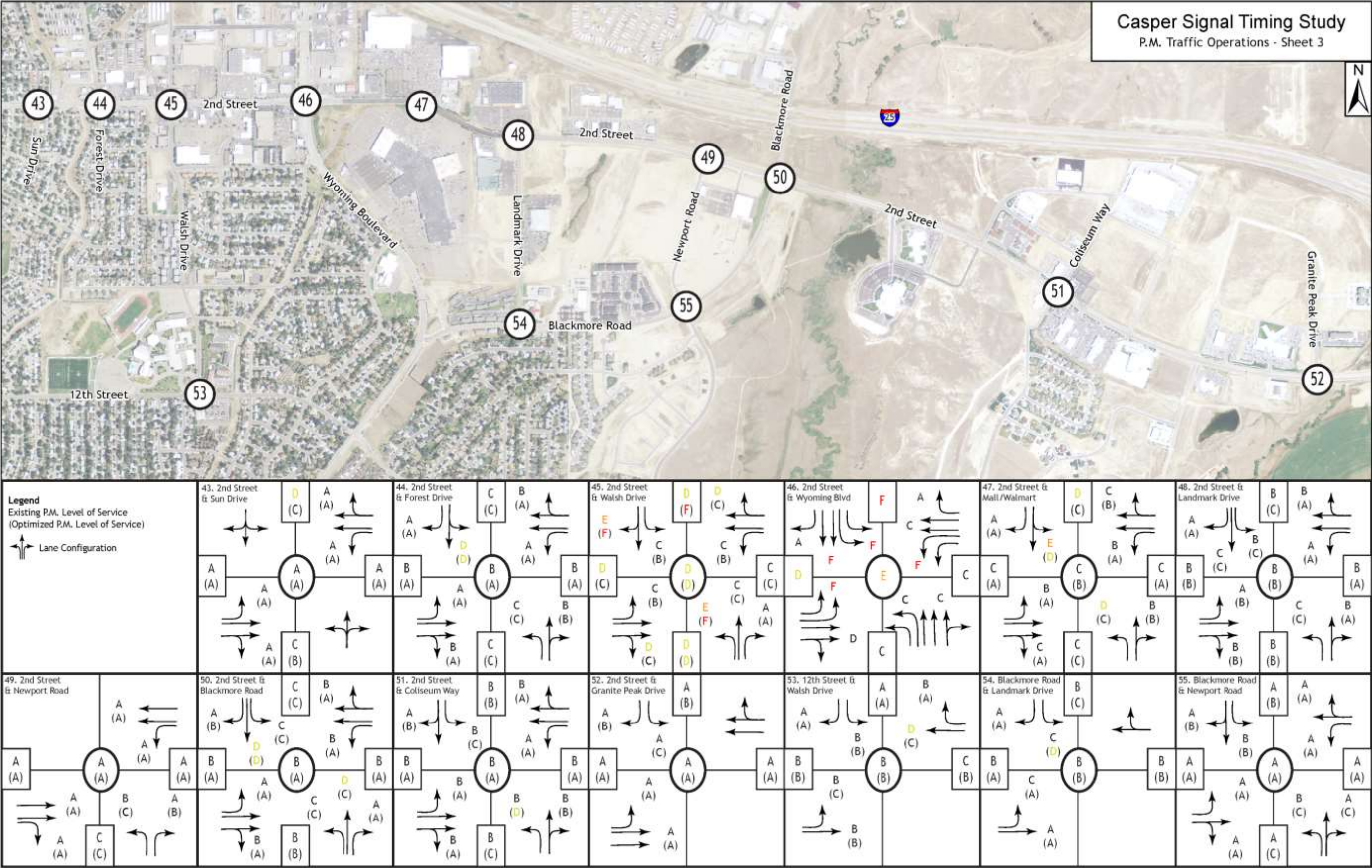




Figure 18 - P.M. Traffic Operations Sheet 3





### ***Existing Network-Wide Delay***

Peak hour network-wide delay was estimated under existing signal timings at all study intersections, then compared to network-wide delays that could be expected if signal timings were optimized at all study intersections. Results from each of these analyses can be seen in **Table 5**.

Note that optimized signal timings used in this analysis are preliminary in nature and are intended to be used for illustrative purposes, and therefore are subject to further refinement throughout the course of this study. Optimized signal timings do not consider any additional improvements (e.g., geometric improvements or left-turn phasing revisions).

*Table 5 - Network-Wide Delay under Existing and Optimized Signal Timings*

Condition	Hours of Delay	
	A.M. Peak	P.M. Peak
Existing	314	394
Optimized	195.1	268.6
Improvement	118.9	125.4
Percent Improvement	38%	32%

### **MONETARY VALUE OF DELAY SAVINGS**

Based on the assumptions described below, it is assumed that the yearly monetary value of delay savings associated with signal timing optimization is approximately \$10.4 million per year (2015 dollars).

#### **Assumptions:**

- » Delay values and associated monetary value of travel-time savings based only on 2015 traffic volumes
- » Value of passenger car travel time = \$12.30 per person-hour
  - Assume 1.55 people per vehicle, based on data in *NCHRP Report 716*
- » Value of truck travel time = \$25.40 per person-hour
  - Assume 1 person per truck
- » Monetary values of travel time based on information from US DOT's *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis* (2014)
- » City-wide truck traffic percentage estimated using weighted average across all locations where daily traffic data was collected
- » Peak hour delays extrapolated throughout entire day based on hourly to daily volume ratios published in *NCHRP Report 716*



## EMISSIONS BENEFITS

Improved traffic flow throughout Casper offers the benefit of reducing citywide automobile emissions. Synchro traffic models for the A.M. and P.M. peak hours were used to estimate emissions reductions that could be expected after signal timing optimization.

Synchro is capable of estimating network-wide emissions for the following pollutants:

- » Carbon Monoxide (CO)
- » Nitrogen Oxide (NO<sub>x</sub>)
- » Volatile Organic Compounds (VOC)

**Table 6** below shows A.M. and P.M. peak hour emissions (network-wide hourly emissions, in kilograms) before and after signal timing optimization.

*Table 6 - Peak Hour Vehicle Emissions*

Emission (kg)	A.M. Existing	A.M. Optimized	A.M. Improvement		P.M. Existing	P.M. Optimized	P.M. Improvement	
			kg	% Change			kg	% Change
CO	67.2	60.0	7.2	10.7%	89.1	79.8	9.3	10.4%
NO <sub>x</sub>	13.1	11.7	1.4	10.5%	17.3	15.5	1.8	10.6%
VOC	15.6	13.9	1.7	10.7%	20.7	18.5	2.2	10.4%

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## CHAPTER 3 - SIGNAL WARRANT ANALYSIS

Unwarranted traffic signals can lead to disobedience of signals, rerouting of unwanted traffic onto other roadways, elevated crash levels and excessive delays. The presence of unwarranted signals in a coordinated signal system can hinder corridor progression, creating traffic flow issues at adjacent signalized intersections. According to data from the Crash Modification Factors Clearinghouse, removal of unwarranted traffic signals may result in a 24 percent decrease in all crashes, an 18 percent decrease in vehicle and pedestrian crashes, a 24 percent decrease in angle, left-turn and right-turn crashes and a 29 percent decrease in rear-end crashes. Typical maintenance and operations costs range from \$2,500 to \$8,000 per signal annually. These financial burdens add to the reasons for installing signalization only at fully warranted intersections.

### Methodology

The 2009 Manual for Uniform Traffic Control Devices (MUTCD) provides nine warrants for the installation of traffic control signals:

- » Warrant 1: Eight-Hour Vehicular Volume
  - Certain volume threshold exceeded for eight hours of the day.
- » Warrant 2: Four-Hour Vehicular Volume
  - Certain volume threshold exceeded for four hours of the day. This hourly volume threshold is higher than that used for the eight-hour warrant.
- » Warrant 3: Peak Hour
  - Certain volume threshold exceeded for one hour of the day. The peak hour warrant is typically reserved for locations with atypical peaking characteristics where high traffic volumes are discharged over a short period of time. Examples include large office buildings, manufacturing plants and industrial complexes.
- » Warrant 4: Pedestrian Volume
  - Certain pedestrian volume threshold exceeded for four hours of the day.
- » Warrant 5: School Crossing (**warrant not analyzed in this study**)
  - Inadequate number of crossing gaps for schoolchildren without signalization (**collection of gap data beyond the scope of this study**).
- » Warrant 6: Coordinated Signal System
  - Signal installation benefits corridor progression on coordinated corridors.
- » Warrant 7: Crash Experience (**warrant not analyzed in this study**)
  - Crash history supports installation of signal (**this warrant is based on crash history under unsignalized conditions, therefore it does not apply**).
- » Warrant 8: Roadway Network (**warrant not analyzed in this study**)
  - Intended for intersections on major routes.
    - Significant existing traffic and Warrants 1, 2 or 3 are met or expected to be met within five years (**detailed traffic projections are beyond the scope of this study**).
    - Significant weekend traffic (**weekend traffic data collection is beyond the scope of this study for majority of intersections**).
- » Warrant 9: Intersection Near a Grade Crossing (**warrant does not apply to any study intersection**)
  - The intersection's proximity to an at-grade railroad crossing supports signal installation for safety purposes.

### ***Warrant Analysis Assumptions***

For warrants requiring more than peak hour turning movement data, average daily traffic data collected near each study intersection was used to extrapolate peak hour turning movements into hourly turning movements for all hours between 6:00 A.M. and 8:00 P.M.

Minor approach right turns were considered in all warrant analyses. Typically, warrant analysis omits minor approach right turns since these movements can generally turn right without traffic signal protection with little impediment. However, for a conservative analysis, these movements were maintained when identifying unwarranted signals. This will be considered in later analysis to identify optimal signal removal candidates.

### ***Removal Candidate Analysis***

There were 24 signalized intersections (excluding dedicated pedestrian signals) which failed to meet any of the nine traffic control signal warrants, as can be seen in **Figure 22**. In other words, nearly half of all signals in Casper are unwarranted. However, even though a signal is not warranted, does not mean it is not valuable and should be removed. Under certain circumstances, a traffic signal operates and assigns right-of-way safely and more efficiently than any other traffic control device. To identify signals that are providing little value and are good candidates for removal, further analysis was performed using a signal justification point system. Within this signal justification point system, six criteria were evaluated, with points added based on conditions that justify maintaining the signal and points deducted based on conditions that justify removing the signal.

### **TRAFFIC VOLUME JUSTIFICATION ANALYSIS**

Examining only the 8-Hour Warrant, intersections were scored based upon the number of hours meeting the minimum hourly volume threshold. This analysis is intended to identify locations where providing alternating right-of-way is beneficial since warrants are close to being met.

- » -1 Point: Five to seven hours met of 8-Hour Warrant
- » -2 Points: Three to four hours met of 8-Hour Warrant
- » -3 Points: Two or less hours met of 8-Hour Warrant

*Figure 19 - Example of Low Traffic Volumes at 2nd Street and Granite Peak Drive*



## TRAFFIC GROWTH JUSTIFICATION

Using the City of Casper's travel demand model, projected 2040 traffic volumes were analyzed to determine if signal warrants are expected to be met in the future. To accomplish this, information in the *WYDOT Traffic Studies Manual* that presents minimum ADT thresholds that are expected to result in signal warrants being met was used.

- » +1 Point: 8-Hour Warrant met if 70 percent factor is applied
- » +2 Points: Both conditions of 8-Hour warrant met if 80 percent factor is applied
- » +3 Points: 8-Hour warrant met without application of volume reduction factors

*Figure 20 - East Casper Growth from 2002 to 2015*



## TRAFFIC OPERATIONS JUSTIFICATION

Candidates for signal removal were analyzed to determine whether signal removal would introduce level of service deficiencies. Signal replacement options were evaluated using the following thresholds: two-way stop control (TWSC) was applied to intersections if the mainline entering volume is 60 percent or more of overall entering volume or all-way stop control (AWSC) if the mainline entering volume is less than 60 percent of overall entering volume.

- » +1 Point: Approach LOS D for worst approach under TWSC or AWSC
- » +2 Points: Approach LOS E for worst approach under TWSC or AWSC
- » +3 Points: Approach LOS F for worst approach under TWSC or AWSC

Prior to making a final decision regarding signal removal, intersection operations under revised traffic control should be studied in greater detail as part of a separate study. For example, a potential alternative to AWSC is roundabout control. This study analysis is cursory to highlight potential issues with signal removal.

## PEDESTRIAN ACTIVITY JUSTIFICATION

Pedestrians can benefit from traffic signals, especially when there are high pedestrian volumes and high vehicular volumes. Pedestrian impacts were investigated for each signal removal candidate intersection using the following system:

- » +1 Point: 25 to 50 pedestrians crossing the major roadway during the peak hour
- » +2 Points: 50 or more pedestrians crossing the major roadway during the peak hour



- » +3 Points: One or more hours met for the Four-Hour Pedestrian Volume Warrant
  - In cities with a population and climate similar to Casper, this warrant is often difficult to meet outside of high pedestrian areas such as central business districts and college campuses

## CONTEXT JUSTIFICATION

Signalization can mitigate safety issues at intersections where visibility between intersection approaches is an issue. This condition is present at complex intersection geometries (e.g., intersections with more than four approaches) and at intersections with physical obstructions present such as buildings, utility boxes, vegetation or signs. Signal removal candidate intersections were analyzed for such conditions using the following scoring system:

- » +3 Points: Complex intersections with five or more legs
- » +3 Points: Sight distance restrictions - evaluated using AASHTO intersection sight triangle method

*Figure 21 - Ash Street and Yellowstone Highway Limited Sight Distance*



## SIDE-STREET RIGHT-TURNING TRAFFIC DISTRIBUTION JUSTIFICATION

The benefit of traffic control signals is diminished when minor approach volumes have a high proportion of right-turning vehicles. This is due to the general ability for right-turning vehicles to turn right on a red signal indication, therefore making the minor approaches operate under de-facto two-way stop control. The following scoring system was used:

- » -1 Point: 40 to 55 percent of minor approach traffic is turning right
- » -2 Point: 55 to 70 percent of minor approach traffic is turning right
- » -3 Point: 70 percent or more of minor approach traffic is turning right

## ***Candidates for Removal***

KLJ applied the signal justification point system to the 24 intersections that did not meet one of the nine signal warrants. **Table 9** shows the scores for all 24 unwarranted signalized intersections.

Figure 22 - Traffic Signal Warrant Locations

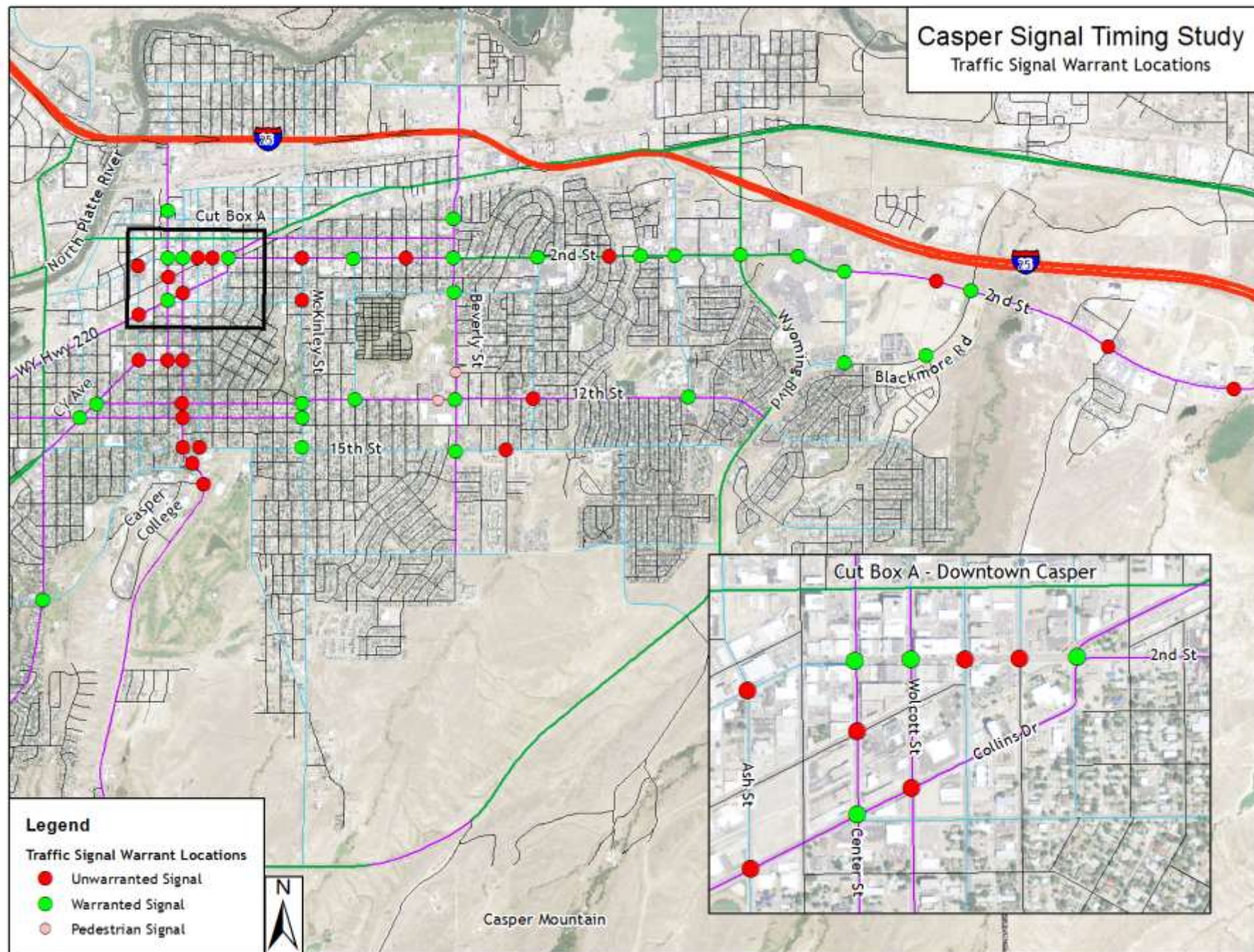






Table 9 - Candidates for Signal Removal

Unwarranted Signal Justification Score								
North/South	East/West	Traffic Volume	Traffic Growth	Traffic Operations	Pedestrian Activity	Context	Side-Street Right-Turns	Total
Granite Peak Drive	2nd Street	-3	0	0	0	0	-2	-5
Center Street	9th Street	-3	0	0	0	0	-1	-4
Casper Mountain Rd	Campus Drive	-3	0	0	0	0	0	-3
Wolcott Street	9th Street	-3	0	0	0	0	0	-3
Coliseum Way	2nd Street	-3	3	1	0	0	-3	-2
Durbin Street	15th Street	-2	3	0	0	0	-3	-2
Ash Street	9th Street	-3	0	0	0	3	-2	-2
Sun Drive	2nd Street	-3	0	3	0	0	-2	-2
Newport Road	2nd Street	-3	1	0	0	0	0	-2
Missouri Avenue	15th Street	-2	0	1	0	0	-1	-2
Country Club Road	12th Street	-3	0	3	0	0	-1	-1
Center Street	Midwest Avenue	-3	0	0	0	3	-1	-1
Elk Street	2nd Street	-3	0	3	0	0	-1	-1
Wolcott Street	Collins Drive	-3	3	0	0	0	0	0
Wolcott Street	College Drive	-2	3	0	0	0	-1	0
Ash Street	Yellowstone Hwy	-3	0	0	0	3	0	0
Durbin Street	2nd Street	-2	1	0	0	3	-1	1
Wolcott Street	15th Street	-3	1	0	0	3	0	1
Wolcott Street	13th Street	-3	2	0	0	3	0	2
McKinley Street	2nd Street	-2	3	3	0	0	0	4
Ash Street	Collins Drive	-1	3	3	0	0	-1	4
Wolcott Street	12th Street	-2	2	1	0	3	0	4
Beech Street	2nd Street	-1	0	3	0	3	-1	4
McKinley Street	5th Street	-2	0	3	0	3	0	4

**Traffic Volume Justification**

- 1 Point: 5-7 hours met of 8-Hour Warrant
- 2 Points: 3-4 hours met of 8-Hour Warrant
- 3 Points: Two or less hours met of 8-Hour Warrant

**Pedestrian Activity Justification**

- +1 Point: 25-50 Pedestrians Crossing the Mainline in the Peak Hour
- +2 Points: 50 or More Pedestrians Crossing the Mainline in the Peak Hour
- +3 Points: One or More Hours Met for Pedestrian Volume Warrant

**Traffic Growth Justification**

- +1 Point: Meets 8-Hour Warrant with 70% Factor Applied
- +2 Points: Meets Both Conditions of 8-Hour Warrant With 80% Factor Applied
- +3 Points: Meets 8-Hour Warrant without Volume Reduction Factors

**Context Justification**

- +3 Points: Complex Intersections (5 Legs or More)
- +3 Points: Sight Distance Restrictions

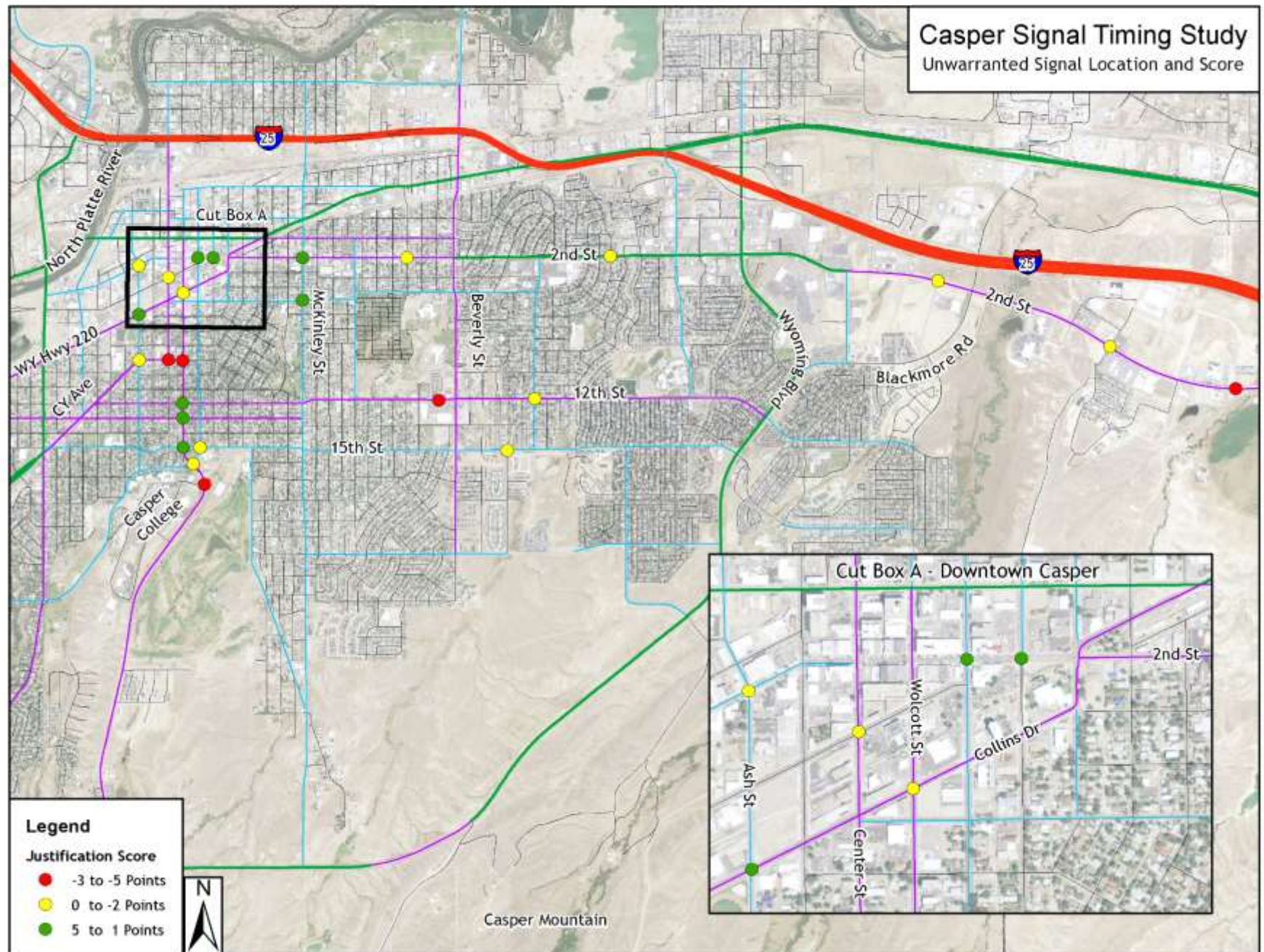
**Traffic Operation Justifications**

- +1 Point: Approach LOS D For worst approach under TWSC or AWSC
- +2 Points: Approach LOS E For worst approach under TWSC or AWSC
- +3 Points: Approach LOS F For worst approach under TWSC or AWSC

**Side-Street Right-Turning Traffic Distribution Justification**

- 1 Point = 40-55% Right-Turn Traffic for the Approach
- 2 Points = 55-70% Right-Turn Traffic for the Approach
- 3 Points = 70% or More Right-Turn Traffic for the Approach

Figure 23 - Unwarranted Signal Location and Justification







## Recommended Improvement Plan

Based on a review of the warrant analysis and subsequent “Removal Candidate Analysis,” the following recommendations should be considered.

### ***Develop Incremental Signal Removal Approach***

Signal removal can be very controversial, particularly in neighborhood settings. The public tends to associate traffic signals with increased safety and is generally unaware of the negative outcomes at unwarranted signals. It is recommended that an incremental approach be adopted toward signal removals, with the process being initiated at the locations where signal removal would offer the greatest benefit with the least impacts. Once removed, the City can perform before and after analysis to highlight the benefits. To fully appreciate crash reduction benefits, more than one year of after-condition crash data will need to be collected.

Once the City is equipped with the information needed to support the signal removal process, it can begin addressing additional locations where signals are not warranted. Transparent public involvement in the signal removal process is critical to garner public support in order to best avoid scenarios where political will, rather than empirical evidence, is used to support maintaining unwarranted signals. Public involvement steps are provided below under the “Next Steps” heading.

Based on the signal justification scores in **Table 9**, four intersections received scores of -3 or worse. These intersections are the highest priority candidates for signal removal. Below is more detailed analysis regarding these intersections and providing recommendations for next steps.

### ***Analysis of Highest Priority Signal Candidate Sites***

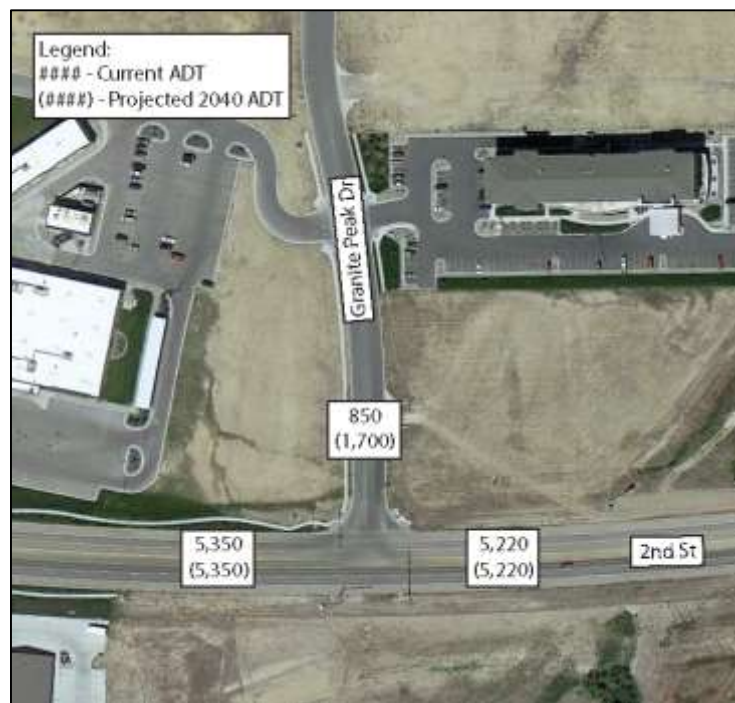
It is important to note that “Removal Candidate Analysis” is strictly a technical look at the intersections in isolation. This does not account for political constraints (e.g., signal near a school) or surrounding constraints (e.g., closely spaced upstream-signalized intersections). Incorporating these factors into the technical analysis, the four high priority signal removal sites are ranked below.

Note: All analysis below refers to 2015 traffic conditions unless otherwise noted.

## 2ND STREET AND GRANITE PEAK DRIVE

- » 0 hours meet the 8-Hour Traffic Volume Warrant.
- » Warrants not expected to be met by 2040.
- » Operates at LOS “A” throughout the day under TWSC on the minor southbound approach.
- » No more than two pedestrians per hour observed crossing the major roadway (2nd Street).
- » No major sight distance restrictions if signal is removed and replaced with TWSC.
- » Fifty percent of minor side-street movements are right-turns.

*Figure 24 - Existing and Projected 2040 ADT at 2nd Street and Granite Peak Drive*



From a technical standpoint, this intersection is a clear choice for signal removal. This intersection is not remotely close to meeting warrants and operates very effectively without a traffic signal. In fact, this intersection is currently in flash mode in the same functionality as TWSC. Even after reviewing future volumes, it is clear this signal likely will not meet warrants by 2040. The only challenge with this intersection is perception. This intersection was installed less than 5 years ago. Removal of this signal would acknowledge a mistake has been made and may produce some negative sentiment from the public about wasted funds.

**Recommendation:** After discussion with City staff, it was determined that this signal should not be removed at this time because it was recently installed and is operating as a TWSC due to flash mode operations and the new hospital has the potential to spur growth. However, this intersection should be monitored to determine if new development is generated and whether the signal system should be removed.

## CASPER MOUNTAIN ROAD AND CAMPUS ROAD

- » 0 hours meet the 8-Hour Traffic Volume Warrant.
- » Warrants not expected to be met by 2040.
- » Eastbound minor approach operates at LOS “B” or better throughout the day under TWSC control.
- » Zero pedestrians observed crossing the major roadway (Casper Mountain Road).
- » Fifteen percent of side-street movements are right-turns.

*Figure 25 - Existing and Projected 2040 ADT at Campus Drive and Casper Mountain Road*



It can be seen in **Figure 25** that significant traffic growth is expected on Casper Mountain Road; however, the low volumes on Campus Drive result in signal warrants not being met under projected 2040 volumes. There is a new YMCA planned for construction on the east side of the intersection that may increase the need for a traffic signal.

This intersection is an ideal signal removal location for the following reasons:

- » College Drive is not projected to see significant increases in the very low traffic volumes in the future. This is compounded by the fact that college traffic is disbursed throughout the day, resulting in limited conflicts between college traffic and typical commuter traffic.
- » When traffic is generated to and from the campus during peak commute hours, motorists can route to College Drive to access Wolcott Street.
- » Can easily and efficiently be replaced with TWSC on the proposed east and existing west approaches.





***Recommendation:*** It is recommended that this intersection be included in the first tier of signal removal candidate sites. Public involvement with Casper College and the YMCA will be particularly important with this intersection to ensure they are well-educated on the benefits of the improvement plan.

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## CENTER STREET AND 9TH STREET

- » 0 hours meet the 8-Hour Traffic Volume Warrant.
- » Warrants not expected to be met under 2040 traffic volumes.
- » Southbound minor approach operates at LOS “B” or better throughout the day under TWSC control.
- » No more than 24 pedestrians per hour observed to cross the major roadway (9th Street).
- » Thirty-one percent of minor side-street movements are right-turns.

*Figure 26 - Existing and Projected 2040 ADT at 9th Street and Center Street*



This intersection is directly adjacent to Park Elementary School and signal removal at this location may be controversial depending upon the traffic control device selected to replace the traffic signal. The peak pedestrian hour (based on available data) is the A.M. peak hour, where 14 pedestrians were observed to cross the major roadway. It is recommended that additional pedestrian data be collected prior to a final decision be made regarding signal removal. It is likely that pedestrian traffic volumes are concentrated to the few warm weather months during the school year.

Pertaining to traffic operations exclusively, TWSC operates better than a traffic signal or AWSC. It is recommended that Center Street be controlled for the following reasons:

- » Center Street has considerably lower traffic volumes than 9th Street surrounding the intersection.
- » Center Street south of 9th Street is classified a local road whereas the rest of the intersection approaches are collectors.
- » 9th Street has traffic signals 370 feet east and 740 feet west of Center Street.

Either real or perceived, safety is of the utmost importance when dealing with elementary school pedestrians as their cognitive abilities and roadway experience are lower than the typical pedestrian. There are, however, very low cost safety enhancements that can be implemented to facilitate safe pedestrian crossing if a particular approach is left uncontrolled. The figures below highlight the recommended improvement strategy for the intersection after traffic signals are removed. Details regarding the improvements are included below.

**Crossing Guards.** Crossing guards facilitate the safety of crossing pedestrians; an adult wearing a safety vest stops traffic, allowing pedestrians to cross the street. According to PEDSAFE, an online FHWA pedestrian safety tool, the use of well-trained adult crossing guards has been found to be one of the most effective measures for assisting children in crossing streets safely. Crossing guards would be implemented across the west approach of 9th Street where traffic is uncontrolled and pedestrian activity is expected.

*Figure 27 - Crossing Guards*



*Figure 28 - Curb Extension*



**Curb Extensions.** Curb extensions reduce pedestrian crossing exposure, improve pedestrian visibility and have the potential to reduce 85th percentile vehicle speeds by 2 to 4 percent (speed reduction data from Minnesota Department of Transportation). Curb extensions are only applicable on the north and south approaches where parking is present.

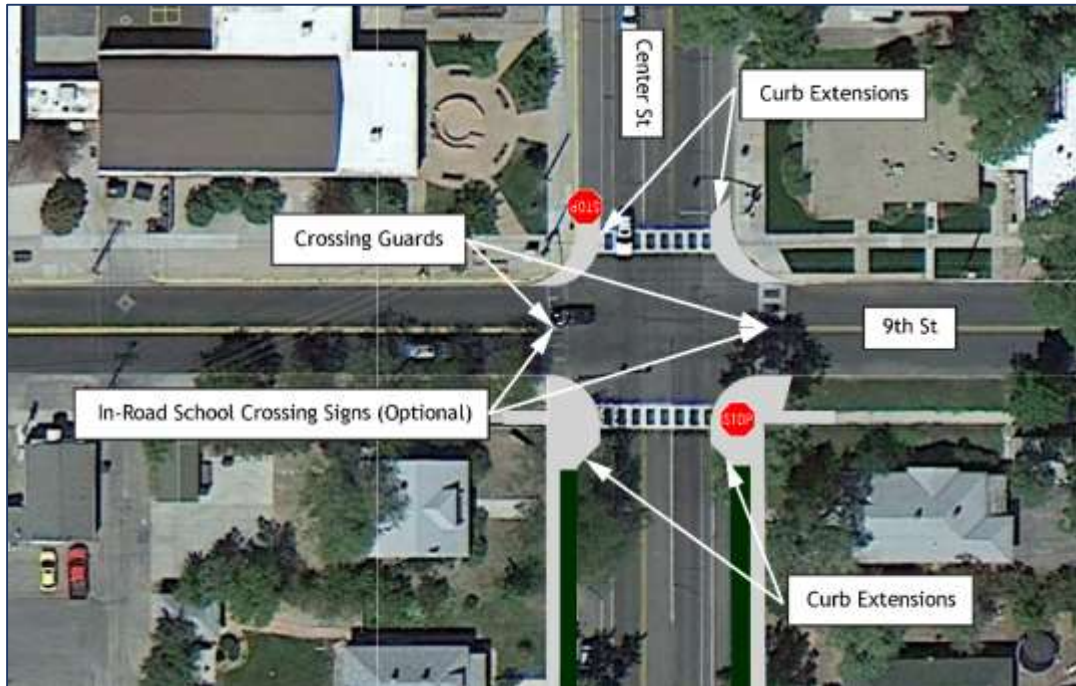
**In-Roadway Crossing Signs (Optional).** In-roadway signs can be placed between travel lanes to notify drivers that they must yield to pedestrians in the crosswalk. Such signs would be placed on 9th Street, between the travel lanes. Data indicates an 87 percent driver compliance rate when these signs are in place. In-roadway signs may need to be removed during winter months to avoid being struck by snowplows. This alternative is also optional, as crossing guards should assure safety to and from the school when peak traffic and pedestrian volumes coincide.

*Figure 29 - In-Roadway Crossing Sign*





*Figure 30 - 9th Street and Center Street Recommendations*

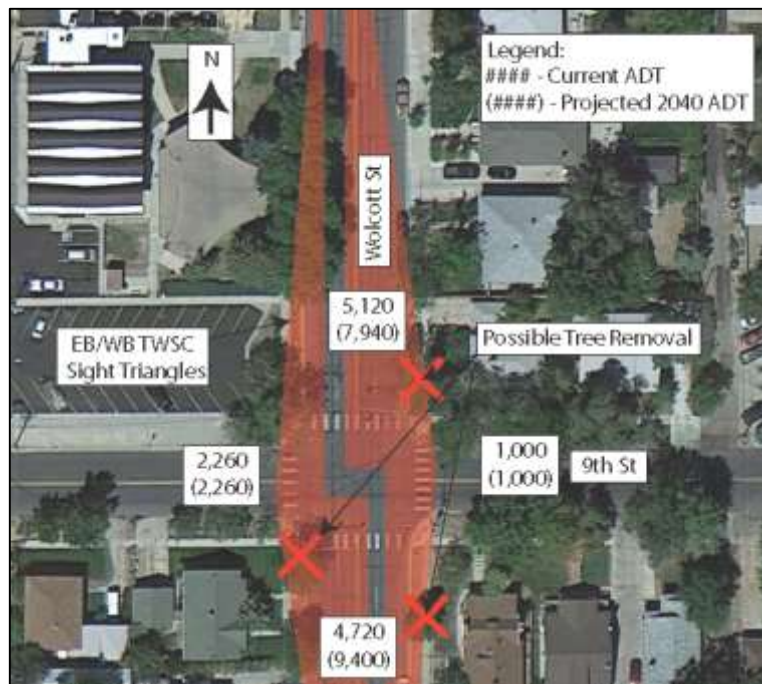


**Recommendation:** It is recommended that this intersection be included in the first tier of signal removal candidate sites. Public involvement with Park Elementary School and the surrounding neighborhood will be particularly important with this intersection to assure they are well-educated on the benefits of the improvement plan.

## WOLCOTT STREET AND 9TH STREET

- » 0 hours meet the 8-Hour Traffic Volume Warrant.
- » Warrants not expected to be met by 2040.
- » Eastbound and westbound minor approaches operate at LOS “C” or better throughout the day under TWSC control.
- » Sight distance issues due to the existing placement of trees.
- » No more than 16 pedestrians per hour observed crossing the major roadway (Wolcott Street).
- » Fifteen percent of minor side-street movements are right-turns.

*Figure 31 - Existing and Projected 2040 ADT at 9th Street and Wolcott Street*



**Recommendation:** It is recommended that this intersection be included in the first tier of signal removal candidate sites. Public involvement with the church will be critical to the success of this improvement strategy. Tree removal may seem trivial but can result in very negative responses from the surrounding neighborhood who value the aesthetic benefits of the trees. Trees, however, can be replaced with bushes and other landscaping that can provide aesthetic value to the intersection without being a sight distance obstruction.

*Figure 32 - Wolcott Street and 9th Street - Tree lined roadway*



## DURBIN STREET AND 15TH STREET

- » Three hours meet the 8-hour traffic volume warrant.
- » Travel demand model results indicate a signal may be warranted by 2040.
- » Northbound and southbound minor approaches operate at LOS “C” or better throughout the day under TWSC control.
- » Sight distance issues due to the existing placement of trees.
- » No more than eight pedestrians per hour observed crossing the major roadway (15th Street).
- » Forty-eight percent of minor side-street movements are right-turns.

*Figure 33 - Existing and Projected 2040 ADT at Durbin Street and 15th Street*







Although not within the lowest scoring subset of intersections, this location was in the next closest scoring cluster and was requested for further analysis. Initial analysis indicates that intersection operates effectively under AWSC; however, AWSC will impede progression on 15th Avenue to a greater extent than the traffic signal, particularly considering that a signal is in place just 400 feet west at Wolcott Street/15th Street and 440 feet south at Wolcott Street/Durbin Street. It is important to note that the two signals at Wolcott Street/15th Street and Wolcott Street/Durbin Street are also not warranted. Additionally, this intersection does not meet traffic volume to warrant an AWSC.

Converting to TWSC results in acceptable operations as well (LOS “C”). To promote efficient traffic flow on 15th Street (a primary coordinated corridor), it is recommended that TWSC be placed on the Durbin Street approaches. Queues on Durbin Street are not anticipated to approach the intersection of Wolcott Street and Durbin Street. The only challenge this presents is sight distance as trees on the northwest quadrant provide visibility issues. Removal of trees will be unfavorable to the adjacent property owner. This location is also a potential roundabout candidate location.

**Recommendation:** It is recommended that this intersection NOT be included in the first tier of signal removal candidate sites. This intersection should be studied in later phases when the intersections of Wolcott Street/15th Street and Durbin Street/Wolcott Street (both within 450 feet from this intersection) can be studied concurrently.

### **RECOMMENDED SECOND TIER OF SIGNAL REMOVAL**

The following seven intersections received signal justification scores of -2, indicating the existing signals offer little benefit and could likely be removed without issue.

- » 2nd Street and Coliseum Way
  - Travel demand model results indicate a signal may be warranted by 2040
- » 15th Street and Durbin Street
- » 9th Street and Ash Street
- » 2nd Street and Sun Drive
- » 2nd Street and Newport Road
- » 15th Street and Missouri Avenue
- » 12th Street and Country Club Road

It is recommended that these intersections be more closely studied to evaluate whether signal removal would indeed be beneficial. As part of further analysis, it will be important to consider adjacent signals (which are potentially unwarranted) and the impact that the removal of the signals listed above.



## ***Pedestrian Signals***

Pedestrian signals have different characteristics than traffic signals at full intersections and thus could not be fully studied with the Removal Candidate Analysis detailed above. There are currently two pedestrian specific signals in Casper, both upstream of the intersection of Beverly Street and 12th Street. Pedestrian signals differ from standard signals in that signal indications remain green other than when the pedestrian actuation occurs. This helps mitigate negative operational impacts from the unwarranted signal, but may actually increase the crash potential as motorists become accustomed to the green signal and can be surprised when the light actually turns red.

### **12TH STREET PEDESTRIAN SIGNAL**

The first pedestrian signal is at 12th Street, 600 feet west of Beverly Street signal. This crossing has even fewer pedestrians during the peak hours, seeing only 2 pedestrians combined between the A.M., P.M. and midday peak hours. This location is between two commercial uses located midblock. This midblock crossing provides minimal value. Removing the traffic signal would result in pedestrians walking 600 feet to the Beverly Street signal.

***Recommendation:*** Remove pedestrian signal with Tier 1 intersection removals. A pedestrian refuge island could be implemented on 12th Street within the unused two-way left-turn lane at this crossing. Studies have found that pedestrian refuge islands reduce vehicle-pedestrian crashes by 46 percent. Based on the low volumes of pedestrian activity, it is recommended that the crosswalk be completely removed and pedestrian traffic routed to the Beverly Street traffic signal.

### **BEVERLY STREET PEDESTRIAN SIGNAL**

The second pedestrian signal is at Beverly Street just south of Frontier Middle School and 615 feet north of the 12th Street signal. Based on available pedestrian data, it appears no more than 10 pedestrians per hour cross Beverly Street during the peak hours, all of which occur in the A.M. peak, where the A.M. school peak and commute peak overlap. It is likely that the most active pedestrian period is when school releases. As such, the pedestrian volume warrant requires 107 pedestrians per hour for 4 hours, a requirement this location will not meet. The School Crossing Warrant (Warrant 5) is generally only applied at elementary school crossings where the typical age of pedestrians is such that they do not have the same roadway experience as adults.

This signal only has signal indications for the northbound/southbound Beverly Street approaches, with stop control placed on the westbound 10th Street approach. FHWA discourages the use of half-signal due to potential driver confusion given the two different types of traffic control at the same intersection.

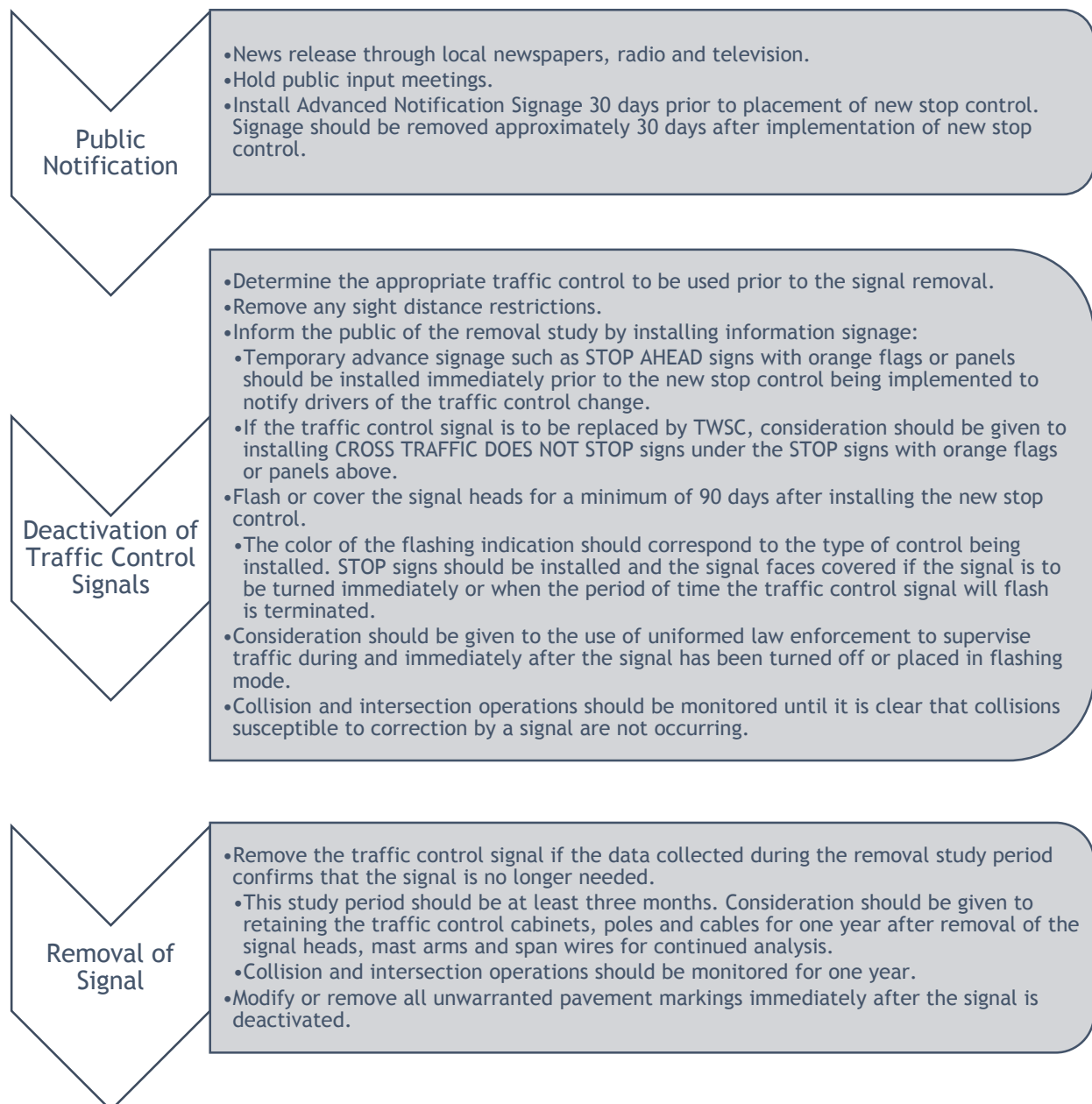
***Recommendation:*** Removal of this traffic signal will receive a tremendous amount of opposition due to the proximity to Frontier Middle School. For the time being, this signal should not be removed. If the 12th Street signal is successfully removed with positive results, it can be studied later to remove this signal.



## Next Steps for Signal Removal

Once a traffic signal is designated for removal, the *Guidelines for Activation, Modification or Removal of Traffic Control Signal*, produced by the Institute of Traffic Engineers, recommends the procedure shown in **Figure 34**. It is important to note that more traffic data should be collected prior to confirmation of signal removal to validate the assumptions used in this study.

Figure 34 - Recommended Signal Removal Process





## CHAPTER 4 - OPERATIONAL IMPROVEMENT PLAN

Using the calibrated traffic models and the field collected data, an operational analysis was conducted and minor infrastructure improvements were evaluated and recommended. Recommendations addressed any transportation deficiency or improvement opportunity that cannot be corrected via signal timing or coordination improvements. Improvements will first focus on low-cost high-impact improvements such as the transition to the Flashing Yellow Arrow (FYA) or right-turn overlaps. After those improvement options have been exhausted, intersection geometry improvements (e.g., the addition of a turn lane) will be analyzed. The analysis regarding delay and level of service are based on existing traffic volumes; future analysis was not part of the scope and is not included in this study.

### Signal Phasing Improvements

The addition or removal of left-turn phasing can significantly influence traffic operations and safety. Intersections were analyzed to determine where left-turn phasing is needed and which type of signal head should be used to employ left-turn phasing. This included special consideration to flashing yellow arrow implementation, which provides safety benefits versus traditional protected/permitted signal phasing and operational benefits versus protected-only signal phasing.

#### *Left-Turn Phasing*

Traffic operations and WYDOT left-turn phasing criteria were reviewed to determine if left-turn phasing should be used at each of the 54 study intersections. Using guidelines from the WYDOT Traffic Studies Manual, the following approaches were used to determine whether a separate left-turn phase should be implemented or removed:

**Volumes:** The volumes considered include the number of vehicles per hour making the left-turn movement and the number of opposing (conflicting) through and right-turn movements during the same hour. Left-turn phasing may be warranted if there are at least 100 left turns during the peak hour, and the number of left turns multiplied by the number of opposing through and right turns during the peak hour exceeds 100,000 on a 4-lane street, or 50,000 on a 2-lane street.

**Delay:** Excessive delays experienced by left-turning vehicles may warrant left-turn phasing. Left-turn phasing may be warranted if the average delay per left-turning vehicle exceeds 35 seconds. This corresponds to LOS “D”, or a deficient movement under WYDOT and City of Casper standards.

The WYDOT Traffic Studies Manual has a third phasing criteria that was not analyzed as part of this study: crash history. Crash analysis was outside the scope of this report. The crash history left-turn phasing criteria focuses on high-frequency crashes between left-turning vehicles and opposing through or right-turning vehicles.

Based on the criteria described above, locations where left-turn phasing should be considered can be seen in **Table 10**.



Table 10 - WYDOT Traffic Studies Manual - Left Turn Phasing Criteria

WYDOT Traffic Studies Manual - Left-Turn Phasing Criteria																
Intersection	A.M. Left Turn Phasing				Midday Left Turn Phasing				P.M. Left Turn Phasing				Off-Peak Left Turn Phasing			
	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB
2nd Street and McKinley Street												Delay				
2nd Street and Conwell Street												Delay				
2nd Street and Beverly Street		Delay	Delay	Delay		Delay	Delay	Delay		Volume	Delay	Volume & Delay				
2nd Street and Country Club Road						Volume				Volume & Delay						
2nd Street and Walsh Drive			Delay			Volume	Delay	Delay	Volume	Delay	Delay	Delay			Delay	
2nd Street and Eastridge Mall/Walmart									Volume							
2nd Street and Landmark Drive			Delay								Delay					
Center Street, 5th Street and Collins Drive	Delay		Delay	Delay	Delay											
Durbin Street and 15th Street										Volume						
McKinley Street and 15th Street				Delay												
Beverly Street and 12th Street	Delay								Delay							
Beverly Street and 15th Street												Delay				
12th Street and Country Club Road	Volume															
12th Street and Walsh Drive	Volume								Volume							
15th Street and Missouri Avenue										Volume						
Blackmore Road and Landmark Drive									Volume							
Legend: Blank Cells indicate Left-Turn Phase not warranted; intersections with no Left-Turn Phase warrants not listed in this table.																

## LEFT-TURN PHASING IMPROVEMENT PLAN

As was documented in the signal warrants analysis chapter, Casper currently has many unwarranted signals. Similarly, many signals have unwarranted left-turn phasing, which impacts traffic flow due to increased cycle lengths required to accommodate left-turn phasing. Many of the left-turns throughout the study area are phased as protected-only or protected plus permissive; however, during the signal timing optimization, a large number of those left-turns will almost exclusively be operated as permissive-only lefts.

### Protected Only Left-Turn Phasing

Protected-only signal heads are the greatest hindrance to corridor progression, particularly if they are unwarranted. Two intersections were recently improved to include protected-only signal heads on the side streets. These intersections are:

- » 2nd Street and Conwell Street
- » Beverly Street and 15th Street

Installing protected/permitted signal heads at these two locations would dramatically improve traffic operations, particularly in low volume situations where the minor street protected left-turn signal phase is essentially lost time that could be given to the mainline.

### Protected/Permitted Left-Turn Phasing

It is not recommended the City remove their protected/permitted left-turn phasing heads in favor of permitted-only heads. Rather, it is recommended that the left-turn phase be allowed to be skipped in favor of improved corridor progression. This can be determined during final signal timing development and field implementation. This is not uncommon as skipping of the left-turn phase is common at low



volume movements when traffic is not present. Anecdotal experience has found that a left-turn phase experiencing 50 or fewer left-turning vehicles per hour is skipped more than 50 percent of the time.

The problem arises with five-section protected/permitted left-turn heads that have both a green ball and left-turn arrow. When the left-turn arrow is skipped, drivers often think the arrow is broken and will complain to the City. Thus, it is recommended that a flashing yellow arrow be implemented at these locations.

### Flashing Yellow Arrow (FYA)

The implementation of the flashing yellow arrow at signalized intersections is growing in popularity around the country due to the associated safety and operational benefits. The use of a FYA as part of normal traffic operations has been shown to reduce intersection delay, reduce driver error and enhance intersection safety when used in place of the circular green yield indication. Studies have shown that the use of a FYA to indicate permissive turns are safer than displaying a solid circular green ball to indicate permissive left-turns because a flashing yellow arrow tends to convey more caution.

*Figure 35 -  
Flashing Yellow  
Arrow*



FYA signal heads can replace the use of five-section heads and the three-section signal heads. A study conducted by the Oregon Department of Transportation found that an intersection that was converted from a five-section permitted plus protected signal head to the four-section FYA signal head (see **Figure 35**) reduced the left-turn related crashes from 1.1 crashes per year per intersection to 0.35 crashes per year per intersection. This is a 68 percent reduction in the amount of left-turn related crashes.

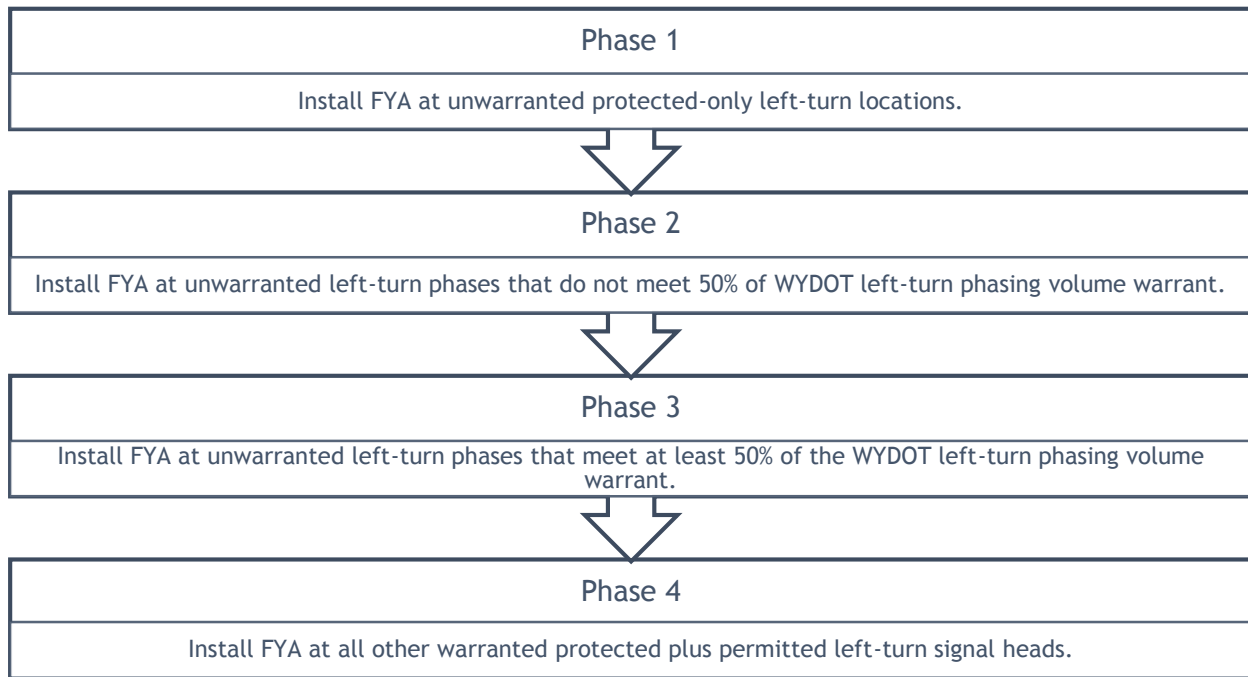
The decision to shift to FYA is typically a system-wide decision. In 2011, the Wyoming Department of Transportation adopted the FYA as a standard for all state intersections where left-turn arrows operate in protected-permissive mode. The FYA made its introduction into the Casper metro area in 2013 when WYDOT completed upgrades at six intersections along the Wyoming Boulevard corridor on the east side of Casper.

FYA is often operated as a lagging left-turn phase (not possible with a 5-section protected left-turn head due to left-turn trap), is often implemented without the protected left-turn phase during certain times of day, and is relatively new. This combination of factors will lead to less confusion and complaints when the protected left-turn arrow does not come on.

### Implementation Strategy

For safety, operations and consistency, the City of Casper should pursue the following Flashing Yellow Arrow Implementation Strategy:

*Figure 36 - Flashing Yellow Arrow Implementation Strategy*

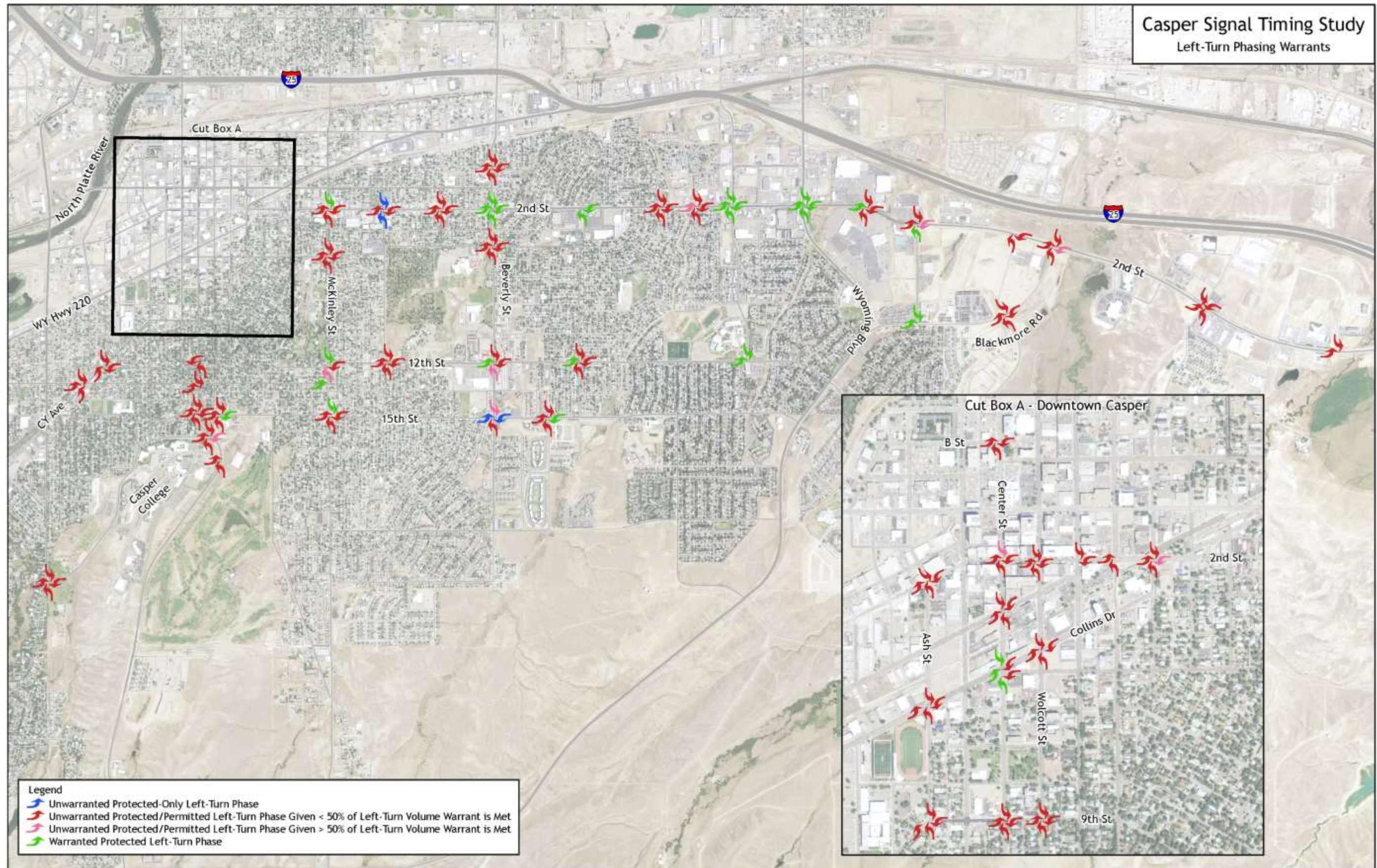


To summarize, the major benefit of replacing the unwarranted left-turn heads with FYA heads is as follows:

- » Improved safety versus five-section left-turn heads.
- » Improved functionality versus five-section left-turn heads and improved operations versus protected-only left-turn heads.
- » Improved intersection operations and corridor progression by skipping the protected-only left-turn phase when unwarranted.
- » Minimized confusion when left-turn arrow is skipped.
- » Allows for protected left-turn phasing in the future at unwarranted locations without changing heads. Also beneficial during detours or special events when a left-turn phase is required.



Figure 37 - Left-Turn Phasing Warrants





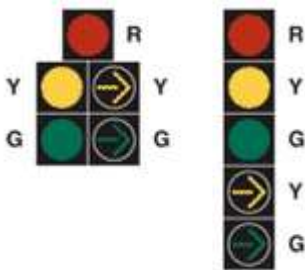
## Right-Turn Overlap

Throughout the City of Casper, most right-turn movements are classified as the traditional permissive. This means that drivers may make a right-turn when the corresponding through movement has a green signal or any subsequent gap in conflicting traffic. Right-turns on red are permitted at all study locations except the following:

- » Center Street, 5th Street and Collins Drive
- » CY Avenue and 12th Street
- » CY Avenue and 13th Street
- » 9th Street and Center Street
- » 5th Street and McKinley Street

There are options or enhancements that can be made for right-turns that can increase the overall efficiency of a traffic signal. One such option is the right-turn overlap. A right-turn overlap operates in such a way that an exclusive right-turn lane will receive a protected phase when a non-conflicting left-turn has a protected phase. For instance, a westbound right-turn lane can overlap a southbound protected left-turn. An example of signal heads that could be used for a right-turn overlap are illustrated in **Figure 39**.

**Figure 39 - Right Turn Overlap Signal Examples**



For the purposes of this study, KLJ analyzed the potential benefit of providing a right-turn overlap signal if the following three conditions were present:

- » Exclusive right-turn lane
- » Non-conflicting protected left-turn phase
- » Right-turning traffic of more than 100 vehicles per hour

While several intersections throughout the study area qualify for right-turn overlaps, the City of Casper should consider implementing the overlap at those locations where it would have the greatest benefit, as seen in **Table 11** and **Figure 40**.

**Figure 38 - Right-Turn Overlap Example**

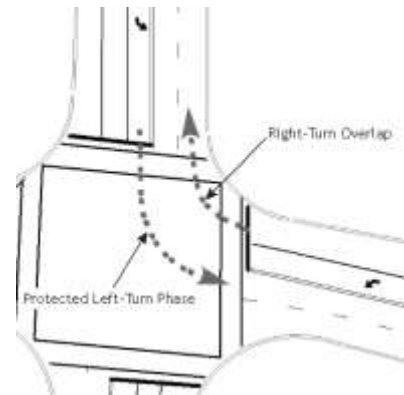


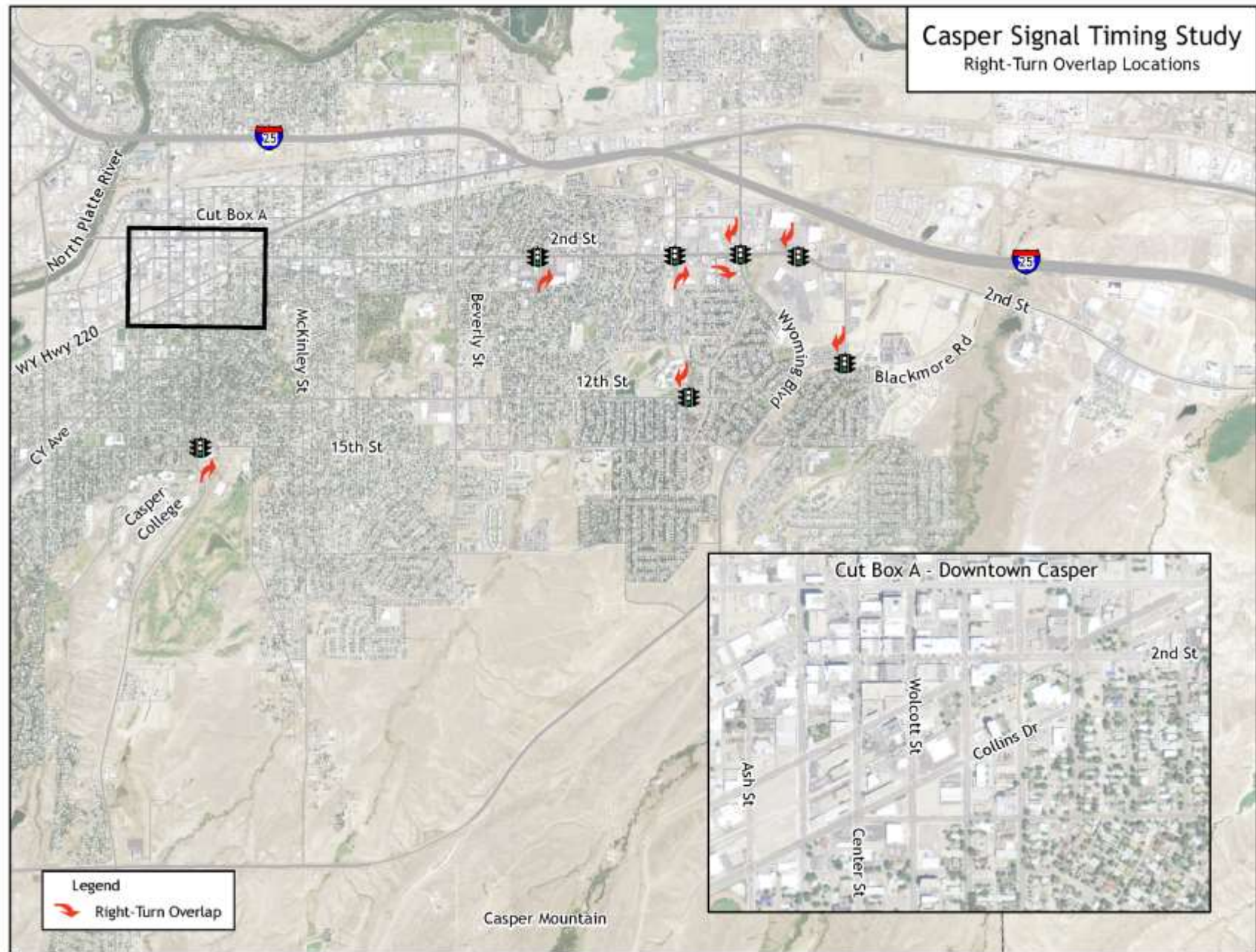


Table 11 - Right-Turn Overlap

Right-Turn Overlap Before and After Implementation											
Intersection	Condition	Intersection Operations		Approach Operations							
				Eastbound		Westbound		Northbound		Southbound	
		Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS	Delay (s)	LOS
2nd Street and Country Club Road	Existing	7.2 (9.1)	A (A)					21.4 (23.6)	C (C)		
	Right-Turn Overlap	7.2 (8.7)	A (A)					21.4 (22.4)	C (C)		
2nd Street and Walsh Drive	Existing	13.8 (39.7)	B (D)					12.0 (52.7)	B (D)		
	Right-Turn Overlap	13.8 (45.3)	B (D)					12.0 (53.4)	B (D)		
2nd Street and Wyoming Boulevard	Existing	25.5 (58.5)	C (E)			17.1 (33.6)	B (C)			24.4 (98.7)	C (F)
	Right-Turn Overlap	26.1 (58.9)	C (E)			16.9 (34.8)	B (C)			24.6 (99.1)	C (F)
2nd Street and Eastridge Mall/Walmart	Existing	6.5 (12.2)	A (B)							22.6 (23.3)	C (C)
	Right-Turn Overlap	6.5 (12.3)	A (B)							22.6 (22.1)	C (C)
Durbin Street and 15th Street	Existing	11.0 (11.0)	B (B)					15.4 (16.8)	B (B)		
	Right-Turn Overlap	11.0 (10.0)	B (B)					15.4 (14.4)	B (B)		
12th Street and Walsh Drive	Existing	17.3 (13.5)	B (B)							9.1 (8.0)	A (A)
	Right-Turn Overlap	17.0 (13.2)	B (B)							7.7 (7.3)	A (A)
Blackmore Road and Landmark Drive	Existing	4.6 (13.2)	A (B)							14.9 (20.0)	B (C)
	Right-Turn Overlap	4.6 (12.4)	A (B)							14.9 (17.4)	B (B)
Notes: A.M. (P.M.); blank cells indicate no benefits from a right-turn overlap; intersections with no right-turn overlaps are not listed in this table											

As illustrated by the operations, the benefits of overlaps are minimal. In fact, the models actually project increased delays at certain locations. The study team does not believe this to be accurate as momentary delay and driver behavior is not entirely captured with the equation-based model. This does, however, highlight the minimal benefits. Thus, it is recommended these be considered when signal improvements are planned and budget permits. These are not essential for efficient traffic operations.

Figure 40 - Potential Right-Turn Overlap Locations







## Late-Night Flash

The City of Casper utilizes late-night flash at a majority of its signalized intersections. While there is significant variation between the times of late-night flash across intersections, it is primarily between 11:00 P.M. and 7:00 A.M. Over the past decade, late-night flash has been steadily phased out throughout the nation. Removing late-night flash has several benefits:

- » *Safety.* Studies have shown that removing late-night flash reduces crash potential by approximately 50 percent.
- » *Operations.* If a traffic signal has side-street detection, the signal operates most efficiently in Free, while resting in green on the mainline. When a vehicle approaches on the side street, the traffic signal can respond and provide the right-of-way.
- » *Traffic Control Needs.* Typically, locations where late-night flash is used have very low traffic volumes. This is often an indication of an unwarranted traffic signal. Unwarranted traffic signals lead to increased delays and often increased crash potential.

With these benefits, a two-fold approach is recommended in regards to late-night flash:

- » For intersections with side-street detection, late-night flash should be removed.
- » For intersections without side-street detection, side-street detection should be installed and late-night flash be eliminated. Detailed detection information was not provided to the study team. However, field surveys and timing sheet reviews indicate that the majority of the signals have detection.

If the City of Casper chooses to continue with late-night flash operations, the city should consider implementing a late-night flash policy similar to that from Fort Collins, Colorado:

- » Signals that flash during low volume periods should flash yellow on the major street and red on the minor street.
- » Only Semi-Actuated or Fixed Time intersections will be considered for the flashing operation. Fully Actuated intersections, those with side-street detection, will not be flashed during low traffic periods.
- » Adequate intersection sight distance as per the AASHTO Green Book.
- » A minimum of four consecutive hours with less than 300 vehicles per hour on the major street and a ratio of major to minor street traffic of at least three to one during those same hours.
- » For existing low volume flash locations, two or fewer right angle crashes during the late-night flash operation in the prior two years. For possible new flash locations, two or fewer right angle crashes during normal traffic operations in the previous two years.

## Signal Equipment Improvements

Besides signal phasing, a variety of options can still be employed to improve operations throughout a network, such as detection, interconnect, controllers and adaptive traffic control. The City of Casper has made several significant investments in the past few years to upgrade its traffic signal network. This has included updating all 54 City of Casper traffic signals with microwave radar detection, Ethernet wireless connectivity and ASC/3 controllers. ASC/3 controllers are required for modern signal solutions such as the flashing yellow arrow, the HAWK signal (Pedestrian Hybrid Beacon) and adaptive traffic control.



## ***Adaptive Traffic Control***

Adaptive traffic signal control can be a powerful tool to improve traffic flow and extend the life of newly implemented signal timing and coordination plans. Adaptive signal control technologies are indicative of their name - adaptive. They can adjust when green indications begin and end to accommodate current traffic patterns to promote smooth flow and help ease traffic congestion. The main benefits of an adaptive traffic signal control over a conventional signal system is that it can:

- » Automatically adapt to unexpected changes in traffic conditions (e.g., events, traffic accidents, construction, Emergency Vehicle Preemption (EVP), etc.)
- » Improve travel time reliability.
- » Reduce congestion and fuel consumption.
- » Prolong the effectiveness of traffic signal timing.
- » Reduce the complaints that agencies receive regarding outdated signal timings.
- » Enable the city to be proactive in addressing operational issues by monitoring and responding to gaps in performance.

With the City of Casper implementing Centracs, the adaptive traffic signal control would be Centracs Adaptive, which runs the ACS Lite adaptive software. ACS Lite was developed by the Federal Highway Administration (FHWA) and is a reduced scale version of Adaptive Control Software (ACS). ACS Lite offers small and medium-size communities a low-cost traffic control system that operates in real time.

Characterizing the improvements of the Adaptive system can be complicated as there are many variables that can contribute to both short and long-term benefits. For instance, a poorly timed signal system might show dramatic improvements, whereas a well-timed system might show little initial improvement. However, even if the initial impact may not be substantial, installing the Centracs Adaptive software alongside the implementation of a new well-timed signal-timing plan would save agency resources by deferring retiming plans longer than normal three to five years as recommended by the FHWA.

The Centracs Adaptive software utilizes each intersection's signal-timing plan as a base and can follow time of day schedules.

If the City of Casper would decide to proceed with Centracs Adaptive, the positioning and view of the radar detectors would need to be reviewed. To receive the maximum potential for the adaptive software, the phase utilization detection should be on a lane-by-lane basis.

The Centracs Adaptive software will only work with the ASC/3 and Cobalt Econolite controllers; older controllers such as the ASC/2 are not capable of operating the Centracs Adaptive software. Licensing for Centracs Adaptive has three components:

- » Centracs Module - \$35,000
- » Per Intersection License Fee (includes remote integration) - \$5,000 per intersection
- » Annual Software Maintenance Agreement - \$5,000 per year

The benefits of adaptive control are best suited for corridors that see inconsistent volumes by the week, season or during special events. A prime location for adaptive control is by the Eastridge Mall where traffic volumes will dramatically increase between Thanksgiving and Christmas. If pursued, it is recommended that 2nd Street from Landmark Drive to Center Street serve as a case study for Centracs Adaptive.



## Minor Geometric Improvements

Intersection geometrics have a direct influence on signal operations and safety. Even subtle changes can have a significant influence on signal timing. The following small-scale geometric improvements were evaluated as part of this study:

- » Lane Reconfiguration
  - Approaches and movements at a LOS “D” or worse after the preliminary timing optimization were evaluated to determine if reconfiguration of turn lanes would help reduce vehicle delay.
  - Lane reconfiguration pertains to restriping turning lanes within the existing curb lines.
  - Examples of such lane reconfiguration analysis include:
    - Side streets with a left-turn lane and a shared through/right-turn lane where the dominant movement is right-turning traffic might experience improved operations if the approach was switched to a shared left-turn/through lane and a right-turn lane.
    - Removing side-street parking in favor of adding a right-turn lane.
- » New Turn Lanes
  - Approaches operating at LOS “D” or worse after the preliminary signal timing optimization were evaluated to determine if the addition of a turn-lane would mitigate vehicle delay.
  - Right-of-way (ROW) impacts on surrounding properties resulting from new turn lanes were included in this analysis.
- » Full Intersection Reconfiguration
  - While outside the scope of this project, some intersections or corridors have been identified with geometric or operational issues that cannot be solved with small-scale turn-lane and timing improvements. These intersections should be studied in more detail.

Peak hour traffic operations were reevaluated after preliminary signal timing improvements at all study intersections using the Synchro software. As noted previously, analysis in this study will consider traffic operations at LOS “A”, “B” and “C” as acceptable, per WYDOT and City of Casper standards. LOS “D”, “E” and “F” will be considered deficient, with locations operating at these levels of service being candidates for improvements. During the field signal timing implementation, a turn lane review will also be completed to identify any additional locations that would benefit from lane reconfiguration or new turn lanes.

Level of service analysis was performed for both A.M. and P.M. preliminary timing models. Approach LOS deficiencies were observed at 9 of the 54 study intersections; however, only three intersections were observed to have operations resulting in overall intersection levels of service “D” or worse:

- » 2nd Street and Walsh Drive
- » 2nd Street and Wyoming Boulevard
- » Center Street, 5th Street and Collins Drive

An overview of locations with overall intersection operational deficiencies (intersection LOS “D” or worse) or approach operational deficiencies (approach LOS “D” or worse) can be seen in **Table 12**.



Table 12 - Preliminary Timing Peak Hour Operational Deficiencies

Intersection	Preliminary Timing Period with Deficiency (LOS "D" or Worse)				
	Overall Intersection Deficiency	Approach Deficiency			
		EB	WB	NB	SB
2nd Street and Beverly Street				P.M.	
2nd Street and Walsh Drive	P.M.			P.M.	P.M.
2nd Street and Wyoming	P.M.	P.M.			P.M.
Center Street, 5th Street and Collins Drive	A.M.		A.M.		A.M.
CY Avenue, Spruce Street and 12th Street			P.M.		A.M. & P.M.
CY Avenue, Walnut Street and 13th Street		A.M. & P.M.			A.M. & P.M.
McKinley Street and 13th Street				A.M.	
McKinley Street and 5th Street		P.M.			
12th Street and Country Club Road					A.M.
Legend: Black cells indicate no deficiencies; intersections with no deficiencies are not listed in this table					

Every turn lane has implications, either to right-of-way or to parking. While there are many locations where turn lanes would be convenient, they were only considered where an operational deficiency existed. It is important to note that it may be better to have a low volume side street with a deficient LOS to provide more green time to a high volume mainline. This results in an overall reduced total intersection delay because more vehicles benefit. Where signal timing could be adjusted to mitigate a deficient approach at the expense of the overall intersection, modifications were not considered.

## 2nd Street and Beverly Street

The northbound approach of Beverly Street at its intersection with 2nd Street currently operates deficiently, per WYDOT and City of Casper standards, with a delay of 42.9 seconds (LOS “D”). The existing layout of this approach consists of two southbound receiving lanes, a northbound left-turn lane, a northbound through lane and a northbound through/right-turn lane.

**Recommendation:** Construct a northbound right-turn lane, as can be seen in **Figure 41**.

**Cost:** \$60,000

As can be seen in **Table 13**, the addition of a right-turn lane improves the northbound level of service to acceptable given the WYDOT and City of Casper traffic operations standards.

*Table 13 - 2nd Street and Beverly Street Improvements*

Intersection:	2nd Street and Beverly Street			
Improvement:	Add a Northbound Right-turn lane			
Northbound	A.M.		P.M.	
	Delay (s)	LOS	Delay (s)	LOS
Existing	24.3 (17.6)	C (B)	42.9 (23.4)	D (C)
Improvement	21.0 (16.2)	C (B)	31.0 (19.2)	C (B)
Legend: Approach (Intersection)				

**Past Study:** In 2013, a study was completed by KLJ for the intersection of 2nd Street and Beverly Street. The report listed several short-term operation and safety improvements, including:

- » Updating the traffic signal controller.
- » Replacing the existing five-section protected/permitted signal heads with four-section protected/permitted flashing yellow arrow heads.
- » Update the walk, pedestrian clearance, yellow and all-red timings.
- » Restripe the existing crosswalks.
- » Implement LED no right turn blank out sign on each approach that can be activated during conflicting pedestrian walk phases.
- » Restrict parking within 30 feet of the intersection (applicable to the north and south approaches) to minimize conflicts between vehicles parked adjacent to the intersection and right-turning traffic at the intersection.

Figure 41 - 2nd Street and Beverly Street Improvements





## 2nd Street and Walsh Drive

The 44-foot wide southbound approach of Walsh Drive at the intersection of 2nd Street and Walsh Drive currently consists of one northbound receiving lane, a southbound left-turn lane and a southbound-shared through/right-turn lane.

**Recommendation:** To help relieve delay during the evening peak hours, the City of Casper should consider constructing a southbound right-turn lane, as seen in **Figure 42**.

**Cost:** \$60,000

The addition of the Walsh Drive southbound right-turn lane does not completely solve the deficiency for the southbound approach as it is still expected to operate at a LOS “D” even with the turn lane. Given that approximately 30 percent of the southbound traffic is making a right-turn, the addition of an exclusive right-turn lane lowers the approach delay from 72.5 seconds to 37.3 seconds, an almost 50 percent reduction in driver delay, as can be seen in **Table 14**.

The additional southbound right-turn lane can also provide benefits for the northbound Walsh Drive approach. Under the existing lane configuration, the northbound Walsh Drive, under the preliminary timings, will experience a delay of 40.7 seconds or LOS “D”. However, with the addition of the southbound right-turn lane and revising the timings needed for this intersection, the northbound delay would decrease to 31.8 seconds or LOS “C”, an acceptable state given the WYDOT traffic operation standards.

Figure 42 - 2nd Street and Walsh Drive Improvements



Table 14 - 2nd Street and Walsh Drive Improvements

Intersection:	2nd Street and Walsh Drive			
Improvement:	Construct a Southbound Right-Turn Lane			
Southbound	A.M.		P.M.	
	Delay (s)	LOS	Delay (s)	LOS
Existing	38.2 (17.7)	D (C)	72.5 (37.5)	E (D)
SB RT Lane	24.8 (14.9)	C (B)	37.3 (24.4)	D (C)
Legend: Approach (Intersection)				

### 12th Street and Country Club Road

Existing lane geometry for the northbound and southbound approaches for Country Club Road at the intersection consists of a shared left-turn/through/right-turn lane and one receiving lane. With the preliminary signal timing optimization, the southbound approach is still operationally deficient with an approach delay of 53.3 seconds (LOS “D”) during the typical morning peak period.

**Recommendation:** To help alleviate delay during the A.M. peak hour, it is recommended that the City of Casper restripe the southbound approach to include a left-turn lane, through/right-turn lane and one receiving lane.

Country Club Road at this approach is more than 40 feet wide, leaving sufficient room to include a southbound left-turn lane while not offsetting southbound through traffic by more than a few feet. As can be seen in **Table 15**, the addition of a southbound left-turn lane can significantly reduce the overall delay for the entire southbound approach.

**Cost:** \$20,000

**Optional:** Reconfigure the northbound Country Club Road approach to consist of a left-turn lane and a through/right-turn lane. While this option has minimal traffic operations benefits, there are some advantages and disadvantages of such a change.

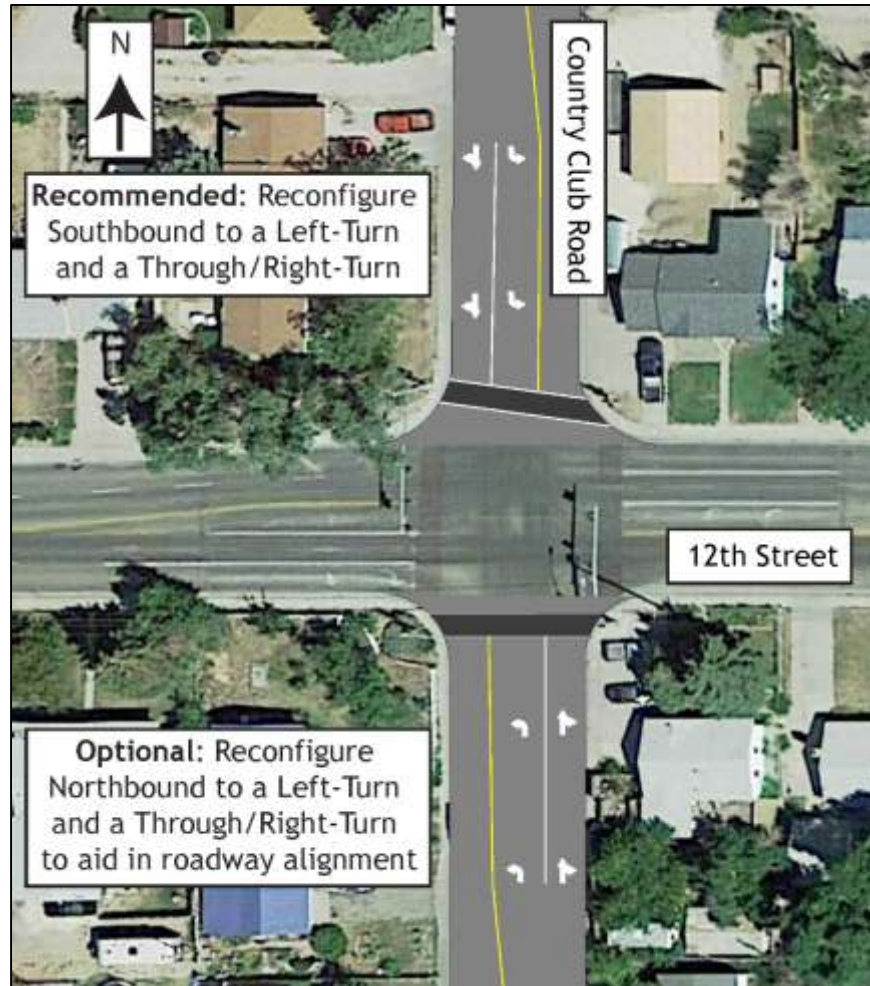
- » Advantages
  - Northbound through alignment matches that of its receiving lane
  - Mirror operations of the southbound Country Club Road approach
- » Disadvantages
  - Removal of 4 parking spaces south of the driveway located near the intersection

**Cost:** \$20,000

*Table 15 - 12th Street and Country Club Road Improvements*

Intersection:	12th Street and Country Club Road			
Improvement:	Convert Southbound to Left-turn and Through/Right-turn lanes			
Option:	Convert Northbound to Left-turn and Through/Right-turn lanes			
Southbound	A.M		P.M.	
	Delay (s)	LOS	Delay (s)	LOS
Existing	47.8 (19.7)	D (B)	33.2 (16.5)	C (B)
SB LT Lane	24.0 (15.8)	C (B)	27.8 (13.6)	C (B)
SB+NB LT Lane	23.6 (15.5)	C (B)	27.7 (13.5)	C (B)
Legend: Approach (Intersection)				

Figure 43 - 12th Street and Country Club Road Improvements





### ***Beverly Street and 15th Street***

Under the existing lane configuration at the intersection of 15th Street with Beverly Street, the eastbound approach is striped for one receiving lane along with a left-turn, a through and a right-turn lane. However, given the eastbound approach width of only 36 feet, this is essentially only wide enough for three travel lanes.

**Recommendation:** Widen eastbound right-turn lane from 3 feet to 12 feet to allow vehicle access. Most cities will use a minimum of 9-foot turn lanes, with 10 feet or wider preferred.

**Cost:** \$50,000

*Figure 44 - Beverly Street and 15th Street Improvements*



### ***Full Intersection Reconfigurations***

While most of the signalized intersections within the study area operate at an overall intersection LOS “C” or better, the following four intersections have approaches that have been deemed operationally deficient and cannot be fixed with small-scale projects or signal timing improvements.

- » Center Street, 5th Street and Collins Drive
- » CY Avenue, 12th Street and Spruce Street
- » CY Avenue, 13th Street and Walnut Street
- » McKinley Street and 5th Street

*Figure 45 - Deficient Offset Intersections*



The common problem with the four intersections is that they all have unconventional geometries, as can be seen in **Figure 45**, all resulting in the requirement for split signal phasing. A more in-depth analysis for these intersections is outside the scope of this study; however, some potential solutions include:

- » Street/intersection realignment
- » Roundabout
- » Roadway closures
- » Other various alternate intersection designs

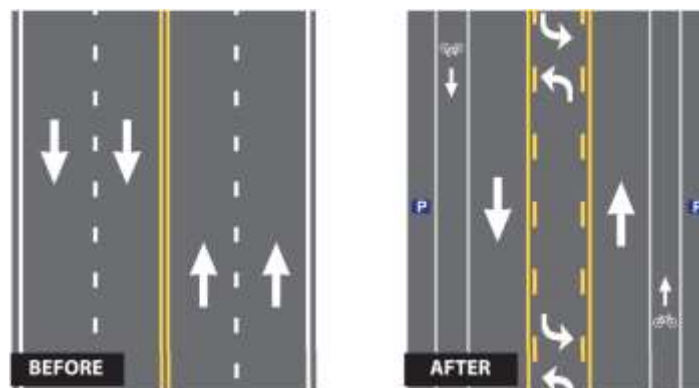
This analysis would require geometric design, traffic operations and safety analysis of the various alternatives. The intersection impacts would also require public involvement. This is beyond the low-cost minor improvements included in this chapter. The fact that multiple intersections exist with unique configurations provides an opportunity for a detailed study at all four locations.

## Road Diet

Four-lane undivided roadways have a history of increased crashes as traffic volumes rise, due to motorists sharing the inside lane for higher speed through movements and left-turns. Additionally, as active transportation increases, communities desire more livable spaces, pedestrian and bicycle facilities and transit options, which are not easily accommodated by four-lane undivided roadways. One solution that benefits all modes is a road diet.

A road diet, as seen in **Figure 46**, is generally described as removing vehicle lanes from a roadway and reallocating the extra space for other uses or traveling modes, such as parking, sidewalks, bicycle lanes, transit use, turn lanes, medians or pedestrian refuge islands.

*Figure 46 - Example of a Road Diet Before and After*





As shown in the Casper Area Long Range Transportation Plan (Casper LRTP), **Figure 47** illustrates the relative Average Daily Traffic to Level of Service relationship. While these values are not definite, they can serve as a guideline when considering how well a given roadway would function. For example, both Wolcott Street, with an ADT of 4,950, and 12th Street, ADT of 10,300, would appear to operate efficiently as either a 4-lane or a 3-lane (road diet) roadway.

*Figure 47 - Casper LRTP LOS Threshold by Functional Classification*

LOS Threshold	A-C	D	E	F
<i>Upper Limit V/C Cutpoints</i>				
<b>Freeways</b>	0.70	0.80	0.98	>0.98
<b>Arterials/Collectors</b>	0.58	0.75	0.92	>0.92
<i>(Daily Capacity Per Lane - 20,000)</i>				
<b>Freeway/Interstate</b>				
4 Lane	56,000	64,000	78,400	n/a
6 Lane	84,000	96,000	117,600	n/a
<i>(Daily Capacity Per Lane - 9,000)</i>				
<b>Principal Arterial</b>				
2 Lane	10,440	13,500	16,560	n/a
3 Lane	14,094	18,225	22,356	n/a
4 Lane	20,880	27,000	33,120	n/a
6 Lane	31,320	40,500	49,680	n/a
<i>(Daily Capacity Per Lane - 7,000)</i>				
<b>Minor Arterial</b>				
2 Lane	8,120	10,500	12,880	n/a
3 Lane	10,962	14,175	17,388	n/a
4 Lane	16,240	21,000	25,760	n/a
<i>(Daily Capacity Per Lane - 6,000)</i>				
<b>Collector</b>				
2 Lane	6,960	9,000	11,040	n/a
3 Lane	9,396	12,150	14,904	n/a
4 Lane	13,920	18,000	22,080	n/a

Road Diets have the potential to improve safety, provide operational benefits and increase the quality of life for all road users. Some of the benefits include:

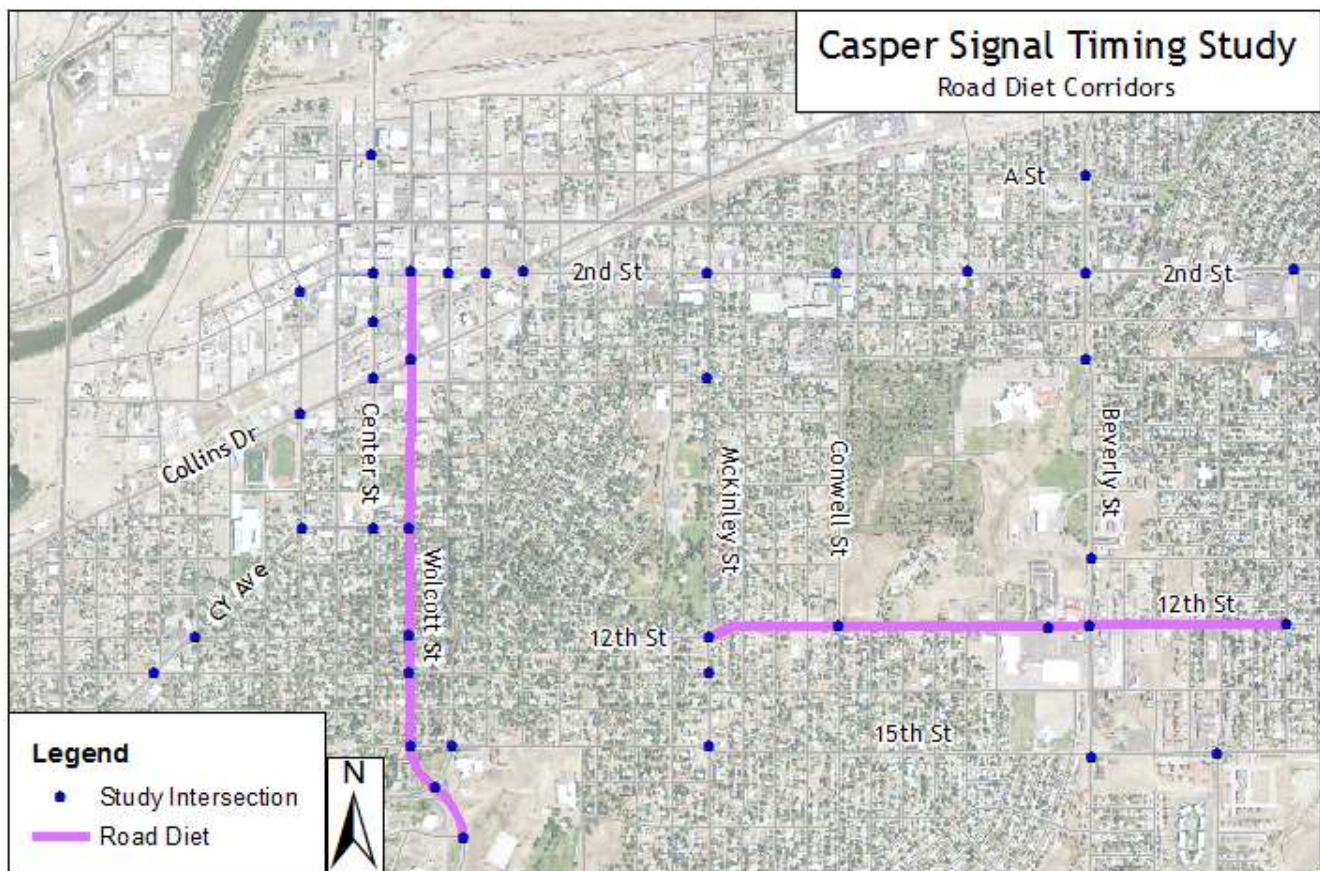
- » Allowing opposing left-turning movements to occupy the same lane, reducing the needed roadway width.
- » Remove left turning vehicles from the through lane, thus reducing total crashes by approximately 30 percent or more compared to corridors without turn lanes.
- » Calms operating speeds by one to two mph compared with multiple through lane corridors.
- » Can be accomplished through only pavement marking revisions.
- » Allows space for bicycle lanes without expanding the roadway.
- » Improves pedestrian safety by reducing the vehicle exposure (four-lane undivided conversion to three-lane TWLTL).



Road diets can be relatively low in cost if planned in conjunction with reconstruction or resurfacing projects since implementing a road diet primarily consists of restriping. Road diets along the following corridors were found to have a negligible impact on traffic operations.

- » Wolcott Street from 2nd Street to Campus Drive
- » 12th Street from McKinley Street to Country Club Road

*Figure 48 - Road Diet Corridors*





The results of implementing a road diet on the existing Wolcott Street and 12th Street four-lane roadways can be seen in **Table 16**.

*Table 16 - Road Diet and TWLTL Level of Service*

Existing Conditions vs. Road Diet Level of Service								
	Intersection		Intersection		Northbound		Southbound	
			Delay	LOS	Delay	LOS	Delay	LOS
Wolcott Street Corridor	Wolcott Street at Collins Drive	Before	8.8 (14.4)	A (B)	1.9 (3.6)	A (A)	3.8 (24.9)	A (C)
		After	15.0 (17.3)	B (B)	2.6 (3.2)	A (A)	4.3 (28.2)	A (C)
	Wolcott Street at 9th Street	Before	5.3 (5.7)	A (A)	1.2 (1.4)	A (A)	1.5 (1.0)	A (A)
		After	6.1 (6.7)	A (A)	1.7 (2.6)	A (A)	2.3 (1.8)	A (A)
	Wolcott Street at 12th Street	Before	9.8 (8.6)	A (B)	8.1 (11.0)	A (B)	14.9 (16.2)	B (B)
		After	12.6 (11.7)	B (B)	9.7 (6.8)	A (A)	12.8 (19.7)	B (B)
	Wolcott Street at 13th Street	Before	14.1 (9.6)	B (A)	20.4 (10.1)	C (B)	24.2 (12.1)	C (B)
		After	16.3 (13.0)	B (B)	21.9 (12.9)	C (B)	16.3 (14.2)	B (B)
	Wolcott Street at 15th Street	Before	14.8 (14.0)	B (B)	9.5 (15.4)	A (B)	4.7 (2.5)	A (A)
		After	16.8 (13.9)	B (B)	15.2 (8.4)	B (A)	6.5 (3.1)	A (A)
	Wolcott Street at College Drive	Before	12.4 (8.7)	B (A)	25.6 (15.5)	C (B)	20.3 (15.5)	C (B)
		After	11.9 (9.2)	B (A)	23.7 (11.9)	C (B)	18.7 (14.1)	B (B)
Wolcott Street at Campus Drive	Before	3.7 (6.1)	A (A)	2.1 (3.1)	A (A)	0.6 (0.8)	A (A)	
	After	4.3 (6.4)	A (A)	3.0 (3.5)	A (A)	1.3 (1.3)	A (A)	
	Intersection		Intersection		Eastbound		Westbound	
			Delay	LOS	Delay	LOS	Delay	LOS
12th Street Corridor	12th Street at McKinley Street	Before	10.1 (10.7)	B (B)	-	-	10.3 (7.3)	B (A)
		After	10.7 (11.7)	B (B)	-	-	10.8 (11.6)	B (B)
	12th Street at Conwell Street	Before	9.2 (14.4)	A (B)	5.0 (10.2)	A (B)	4.3 (8.8)	A (A)
		After	12.9 (19.1)	B (B)	5.3 (12.3)	A (B)	12.3 (14.8)	B (B)
	12th Street at Beverly Street	Before	17.4 (11.5)	B (B)	26.6 (12.2)	C (B)	16.8 (18.5)	B (B)
		After	24.7 (14.2)	C (B)	24.9 (13.1)	C (B)	30.8 (22.2)	C (C)
	12th Street at Country Club Road	Before	19.7 (15.6)	B (B)	5.6 (12.1)	A (B)	15.7 (16.1)	B (B)
		After	19.8 (15.4)	B (B)	5.5 (10.9)	A (B)	15.8 (15.2)	B (B)
Legend: A.M. Peak Hour (P.M. Peak Hour)								

As shown throughout **Table 16**, implementing a road diet on the four-lane roadways of Wolcott Street and 12th Street has a negligible effect on traffic operations, while at the same time increasing the safety, calming the driving speed and increasing the livability along the corridors.

Road diets were also considered on Beverly Street and Collins Drive, but significant traffic impacts were felt at the following two intersections and therefore not recommended:

- » Beverly Street at 12th Street
- » Collins Drive at Center Street/5th Street



According to the City of Casper's Travel Demand model, traffic volumes are expected to double and even triple through stretches of the Wolcott Street corridor by the year 2040. If the City of Casper implements a road diet on Wolcott Street, corridor ADTs should continually be monitored to determine if the traffic operations impacts by the growth in traffic start to outweigh the safety and livability benefits of the road diet. It is also recommended that the City of Casper weigh the immediate benefits of safety and livability against the long-term costs of possibly needing to re-convert the corridor back into a four-lane roadway to allow for increased capacity.

The 15th and 21th Street Subarea Study completed by KLJ in November of 2013 recommended two-way left-turn lanes (TWLTL) along McKinley Street and 15th Street corridors.

**Recommendation:** It is recommended that the City of Casper consider road diets to the following corridors:

- » Wolcott Street from 2nd Street to Campus Drive
- » 12th Street from McKinley Street to Country Club Road

### ***Case Study - Genesee County, Michigan***

In 2009, Genesee County in Michigan began to implement road diets on several corridors. A technical study was completed to assess every four-lane road within the county's jurisdiction for the potential of conversion to three lanes, ranking the desirability of each for road diet consideration. The study first focused on lower volume roadways (6,000 to 8,000 ADT), then after a few successful road diet implementations the county began selecting higher volume roadways, those up to 15,000 vehicles per day, for a road diet.

For comparison, the following ADTs were collected as part of this study:

- » Wolcott Street south of Collins Drive - 3,350
- » Wolcott Street north of 15th Street - 4,950
- » 12th Street east of Beverly Street - 10,300

Genesee County completed a before-and-after crash study at seven locations where the road diet was implement and as can be seen in **Table 17**, each of the road diet locations experienced a decrease in the overall amount of traffic crashes.

*Table 17 - Genesee County Annual Crash Reduction Rates*

Average Annual Crash Reduction Rates After Road Diets in Genesee County								
Crash Type	Davison Rd	Dupont St	Flushing/Fifth Ave	ML King Jr Blvd	Miller Rd	University Ave	Vienna Rd	OVERALL
Head-on	-17%	-31%	-100%	129%	-43%	-100%	-62%	-32%
Head-on Left Turn	-28%	-74%	-100%	-41%	-37%	-100%	-24%	-58%
Rear End	-16%	-54%	-29%	-46%	-29%	-53%	-21%	-35%
Rear End Left Turn	92%	-79%	-100%	-17%	-37%	-100%	-13%	-36%
Side Swipe Same Side	-18%	-56%	-48%	-42%	-15%	-31%	-20%	-33%
Side Swipe Opposite Side	-31%	-5%	-100%	-17%	-33%	-100%	-55%	-39%
All Non-alcohol & Non-deer	-16%	-47%	-42%	-38%	-23%	-35%	-26%	-32%



## Chicago, Illinois - Franklin Boulevard - Case Study

As part of Chicago's plan to expand the mileage of bicycle lanes, a  $\frac{3}{4}$ -mile road diet on Franklin Boulevard transformed a 4-lane roadway to a 3-lane roadway with separated bicycle lanes in each direction. Franklin Boulevard (similar to parts of Casper) has a relatively low daily traffic of approximately 3,000 vehicles per day, and traffic congestion was not an issue on this corridor.

As speeding and congestion were not the issues for the Franklin Boulevard Corridor, the road diet study instead focused on the positive "livability" or "quality of life" changes, such as:

- » Residents along Franklin Boulevard felt the re-design improved both safety and the ability of children to bicycle to school.
- » A veteran's home along Franklin Boulevard, which provides bicycles to their residents and visitors, expressed appreciation for the addition of the separated bicycle lanes in the area to keep this particularly vulnerable user group safe and mobile.
- » The additional bicycle lanes connect three area parks - Garfield Park, Central Park Boulevard, and Franklin Square - lengthening the mileage for recreational bicyclists.
- » The additional bicycle lanes improved the connectivity to public transit, community institutions, and several parks.

## Intersection Functional Area

Throughout the site survey, several instances were noted that violate design standards specified in the American Association of State Highway and Transportation Officials' *A Policy on Geometric Design of Highways and Streets* (AASHTO Green Book) as well as the MUTCD and the Casper Municipal Code.

### Parking

Per the Casper Municipal Code Chapter 10:

- A. It shall be unlawful to park a motor vehicle within the city limits of Casper:
  5. *Within an intersection.*
  8. *Within twenty feet of a crosswalk or an intersection.*
  9. *Within thirty feet upon the approach to any flashing beacon, stop sign or traffic control signal located on the side of the road.*

It is recommended that the City of Casper make parking restrictions more apparent, whether through pavement markings or signage according to the most up-to-date MUTCD, AASHTO Green Book and Casper Municipal Code.


Figure 49 - Parking Infraction at CY Avenue and 12th Street



### Access Management

Access management is the process of balancing the competing needs of traffic movement and land access. Access points introduce conflicts and friction into the traffic stream. Allowing dense uncontrolled access spacing results in safety, operation and aesthetic deficiencies:

- » According to NCHRP Report 420, *Impact of Access Management Techniques*, every unsignalized driveway increases the corridor crash rate by approximately two percent.

- 
- » Research included in the Highway Capacity Manual found that roadway speeds were reduced an average of 2.5 miles per hour for every 10 access points per mile.
  - » The safety and operational issues caused by dense access spacing potentially makes an area less attractive to developers and the general traveling public. Multiple national studies have shown most people have no problem making a slightly longer trip, including U-turns, to access destination businesses so long as the ride is pleasant and congestion free.

According to driveway spacing guidelines outlined in the City of Casper Municipal Code, desired access spacing on arterials or high volume collector streets is 200 feet with 125 feet being the minimum acceptable spacing for developed areas.

The majority of coordinated corridors violate this access spacing standard, creating challenges to corridor progression. The majority of violations are residential homes with no other potential access location. Eliminating these homes would be unrealistic, costly and controversial. There are, however, a variety of access revisions possible on commercial corridors such as 2nd Street which would provide significant operational and safety benefits. It is recommended that the City of Casper staff look for opportunities to implement access revisions wherever possible (e.g., rehabilitation/reconstruction projects, corridor studies, etc.). Potential access improvements on commercial corridors include the consolidation of closely spaced accesses, removing redundant accesses and relocating access to side streets.

## Recommendations

In summary, it is recommended that the City of Casper consider implementing the following signal phasing, signal equipment and geometric improvements.

### *Signal Phasing Improvements*

- » Adopt the following Flashing Yellow Arrow (FYA) Implementation Strategy
  - Phase 1
    - Install FYA at unwarranted protected-only left-turn locations.
  - Phase 2
    - Install FYA at unwarranted left-turn phases that do not meet 50% of WYDOT left-turn phasing volume warrant.
  - Phase 3
    - Install FYA at unwarranted left-turn phases that meet at least 50% of the WYDOT left-turn phasing volume warrant.
  - Phase 4
    - Install FYA at all other warranted protected plus permitted left-turn signal heads.
- » Consider implementing right-turn overlap at the following locations:
  - 2nd Street and Country Club Road - Northbound Approach
  - 2nd Street and Walsh Drive - Northbound Approach
  - 2nd Street and Wyoming Boulevard - Westbound and Southbound Approach
  - 2nd Street and Eastridge Mall/Walmart - Southbound Approach
  - Durbin Street and 15th Street - Northbound Approach
  - 12th Street and Walsh Drive - Southbound Approach
  - Blackmore Road and Landmark Drive - Southbound Approach



### ***Signal Equipment Improvements***

- » Install the detection, whether mainline or side street, needed to discontinue late-night flash operations.
- » Replace the outdated ASC8000 and ASC/2 signal controllers with ASC/3 controllers before field implementation.

### ***Minor Geometric Improvements***

- » Consider implementing the following minor geometric improvements:
  - 2nd Street and Beverly Street Northbound Approach
    - Weigh the cost of construction versus the operational benefits of constructing a right-turn lane.
  - 2nd Street and Walsh Drive
    - Construct a southbound right-turn lane
  - 12th Street and Country Club Road Southbound Approach
    - Convert the southbound approach to a left-turn and through/right-turn lane.
    - Optional - to aid in roadway alignment, restripe the northbound approach to a left-turn lane and a through/right-turn lane
  - Beverly Street and 15th Street
    - Widen eastbound right-turn lane from 3 feet to 12 feet.

### ***Road Diet and TWLTL***

- » Consider implementing road diets along the following corridors:
  - Wolcott Street from 2nd Street to Campus Drive
  - 12th Street from McKinley Street to Country Club Road

### ***Intersection Functional Area***

- » The City of Casper shall evaluate its current striping and signs related to no parking zones and implement the guidelines listed in the City of Casper Municipal Code
- » Review the driveway spacing guidelines set forth in the City of Casper Municipal Code. Desired spacing is at least 200 feet with the minimum set as 125 feet.
- » Look for opportunities to provide access management improvements.





## CHAPTER 5 - SIGNAL TIMING METHODS AND ASSUMPTIONS

*The purpose of this chapter is to detail the methods and assumptions used to develop clearance intervals, cycle lengths, offsets, splits, recalls and time of day plans. These parameters are defined below and are the foundation of a signal timing and coordination plan.*

**Clearance Intervals:** The intent of the clearance interval is to provide a safe transition between two conflicting phases, i.e., NB/SB to EB/WB. It consists of a yellow change interval, red change interval and the corresponding walk and pedestrian clearance intervals. The clearance interval timings for each of the 54 study intersections can be seen in **Appendix D**.

**Yellow Interval** - The purpose of the yellow change interval is to warn drivers of the impending change in right-of-way and is typically based upon driver perception-reaction time.

**Red Interval** - The purpose of the red interval, also known as All Red, is to allow time for vehicles that entered the intersection during the yellow-change interval to clear the intersection prior to the next phase.

**Walk Interval** - The walk interval typically begins at the start of the corresponding green interval and is used to allow pedestrians time to react to the signal phase change and move into the crosswalk.


**Pedestrian Clearance Interval** - Commonly referred to as the Flashing Don't Walk (FDW), the pedestrian clearance interval follows the walk interval and informs the pedestrian that the phase is ending.

**Cycle Length:** Cycle length defines the time required for a complete sequence of indications. The cycle length is the most important signal timing parameter. In order for signal coordination to work, all intersections along the arterial must have the same cycle length (or be a multiple of each other). Many alternative cycle length scenarios were evaluated to determine the most efficient corridor operation. Cycle lengths will be selected based on the following key considerations:

- » Long enough to accommodate mainline traffic volume demand.
- » Maximizes directional flow during peak periods, while managing cross-street queue lengths and delays.
- » Best maximizes two-way progression given existing signal spacing, signal phasing limitations, vehicle speeds and traffic volume dynamics.
- » Best addresses any identified traffic operations concerns.
- » Compatible with half-cycle or third-cycle operation at lower volume intersections.
- » Compatible with cross-coordination progression for intersecting corridors.

**Offsets:** The term *offset* defines the time relationship between coordinated phases at subsequent traffic signals. The primary objective of the offset optimization process is to maximize two-way vehicle progression. Multiple offset scenarios will be studied by adjusting phase sequencing. For example, the corridor green band may be improved by adjusting a critical intersection from lead/lead left-turn phasing to lead/lag phasing.

**Splits:** Within a cycle, splits are the portion of time allocated to each phase at an intersection. The splits are calculated based on intersection phasing and expected demand. Intersection splits will be optimized to minimize delay along the mainline corridor, while providing adequate time to cross-street



traffic movements. Further refinement to the intersection splits will be completed by determining the green time required to serve the expected vehicle queue per cycle.

**Recall:** Normally a traffic signal will, in the absence of actuation, rest on the last phase serviced. By means of a recall switch, the signal can return to a particular phase's green interval. While there are various types of recall, the following were used as part of this study:

**No Recall:** Side streets will have *No Recall*, meaning that the side street split may be skipped if there are no vehicles detected, i.e., no *call* was placed.

**Min Recall:** Coordinated phases will be set in *Minimum Recall*; this will allow the signal to become actuated during free mode operations.

**Pedestrian Recall:** A *Pedestrian Recall* is a situation where there is a continuous call for the pedestrian phase, which means the Walk and FDW will appear on each recurring cycle. Intersections with *Pedestrian Recall* will also have *Rest-In-Walk*, as *Rest-In-Walk* allows the signal to rest in the walk interval until a conflicting call is received or the split has timed out. However, due to low pedestrian volumes and to aid in coordination, many intersections will not have pedestrian recall. If a pedestrian call is placed at an intersection with *No Pedestrian Recall*, coordination will be temporarily broken. When low pedestrian volumes are present, no pedestrian recall will benefit coordination throughout the majority of the day.

**Time of Day Plans:** Timing plans for different periods of the day were developed to better accommodate varying traffic patterns throughout the day. A majority of the parameters will remain constant between TOD plans. However, the cycle length, intersection splits and intersection offsets will be optimized and will vary for each TOD plan.

## Major Coordination Barriers

There are a variety of changes that can be made to improve system-wide operations and coordination potential. Each key barrier is detailed below.

### **WYDOT Signal at Wyoming Boulevard**

Coordination near Wyoming Boulevard could be greatly improved if the Wyoming Boulevard and 2nd Street signal were to be optimized and coordinated within the West-Central and/or East Casper zones, as discussed later in this section. Without coordination at Casper's busiest intersection along its most travelled roadway, driver frustration could ensue when stopping at three consecutive red lights.

Currently, Wyoming Boulevard and 2nd Street is running free to maximize operational benefits at this intersection at the expense of corridor progression, both on 2nd Street as well as Wyoming Boulevard. WYDOT has spent a considerable amount of time and effort in the past to make this intersection to operate efficiently. During a recent meeting with WYDOT staff, it was made clear that this intersection would not be shifted from free to coordinated. As such, this corridor will continue to be a barrier to progression along 2nd Street after field implementation of timing plans occurs.

*Figure 50 - At-Grade View of 2nd Street and Wyoming Boulevard*



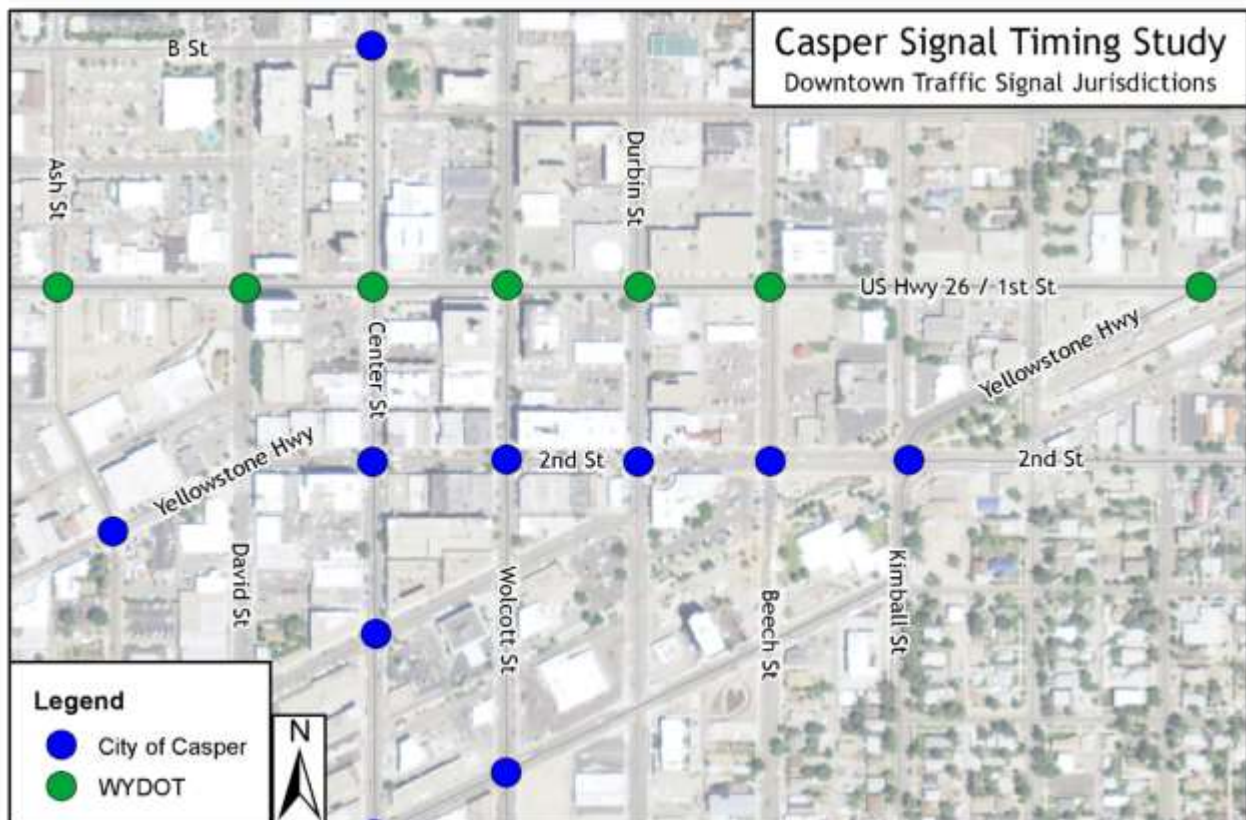
### ***WYDOT Signals on 1st Street (US HWY 26)***

WYDOT operates traffic signals on 1st Street at Ash Street, David Street, Center Street, Wolcott Street, Durbin Street, Beech Street and at Yellowstone Highway. This 0.6-mile stretch of 7 traffic signals has major implications to north/south progression through downtown Casper. Including this corridor within the West-Central Casper Zone would produce significant benefits to downtown traffic flow and operations.

Currently, WYDOT operates a pretimed system on 1st Street with a 72-second cycle length throughout the day. The 72-second cycle length is unique and does not match the optimal cycle lengths for the rest of the network during peak periods. A review of the downtown signal operations will be conducted during field implementation to determine which of the following configurations is more beneficial to the overall system:

- » Calibrating the City of Casper downtown signals to match 1st Street cycle lengths and not coordinate the downtown signals with the rest of the City's system.
- » Utilize the optimal cycle length for the downtown signals and coordinate with the rest of the City of Casper's system as proposed later in this chapter.

*Figure 51 - City of Casper vs WYDOT Signals in Downtown Casper*





### ***AWSC at 2nd Street/Yellowstone Highway and David Street***

The AWSC at 2nd Street/Yellowstone Highway and David Street prohibits efficient progression between the traffic signal at Yellowstone Highway at Ash Street and 2nd Street at Center Street. It is recommended that this AWSC be converted to TWSC with stop signs on the north and south approaches of the intersection. This intersection currently does not meet warrants for AWSC (see **Table 18**) and operates less than a second differently when converted from AWSC to TWSC.

*Table 18 - 2nd Street and David Street AWSC Warrant*

	EB	WB	NB	SB
	(Major)	(Major)	(Minor)	(Minor)
MUCTD Guideline	300	300	200	200
2nd Street and David Street	133 (173)	174 (162)	93 (172)	169 (102)
Legend: A.M. Peak Hour (P.M. Peak Hour)				

### ***Access Management***

Data included in the *Highway Capacity Manual* denotes that for every 10 unsignalized access points/mile, traffic speeds and progression is reduced by 2.5 mph. For example, the stretch of McKinley Street from 12th Street to 15th Street (a 0.22-mile section of corridor) has five roadway access points, 19 residential driveways and a speed limit of 30 mph. Slow-moving traffic enters the traffic stream and slows progression. These issues are exacerbated in areas without turn lanes, such as McKinley Street between 12th Street and 15th Street where a motorist attempting to turn left could completely block traffic for long periods of time during peak hours.

*Figure 52 - McKinley Street between 12th Street and 15th Street*



Corridors like McKinley Street have hundreds of driveways that cannot be removed in order to improve corridor progression. This is an irreconcilable issue along McKinley Street and exemplifies why field implementation is so critical to coordination. Existing access management was held constant and the network was partitioned to respond to this deficiency.

## Network Partition

Network partition can be defined as the division of the traffic signal network into smaller subareas in order to achieve maximum operational efficiency. The Casper network was partitioned using Synchro Coordinatability Factors, a detailed review of traffic volumes, ideal cycle lengths and understanding of key roadway and context characteristics.

Coordinatability Factor (CF) is defined as the measurement of desirability to coordinate or not to coordinate adjacent intersections and is based on the following criteria:

- » Travel time between signalized intersections
- » Distance between signalized intersections
- » Traffic volume
- » Platoon ratio of traffic
- » Cycle length

Using the information above, the partition plan, as illustrated in **Figure 54**, includes the following two coordinated zones.

- » West-Central Casper
- » East Casper

There can be some slight modification by time of day during the timing implementation process as traffic patterns and signal coordination are witnessed firsthand, but the current applications appear applicable for the A.M., midday, and P.M. peak periods. Off-peak timing plans are an augmentation of the midday peak periods, with a proportioned reduction factor based off of the daily traffic counts. As such, the off-peak period will also use the proposed partition plan.

The partition plan will also be revisited once decisions are made regarding signal removal, phasing and geometric revision recommendations.

*Figure 53 - Network Partition Parameters*

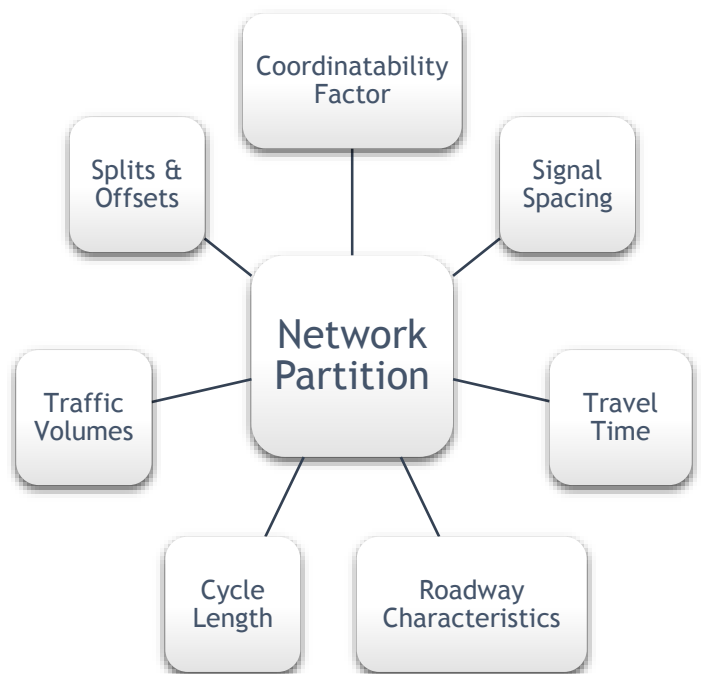
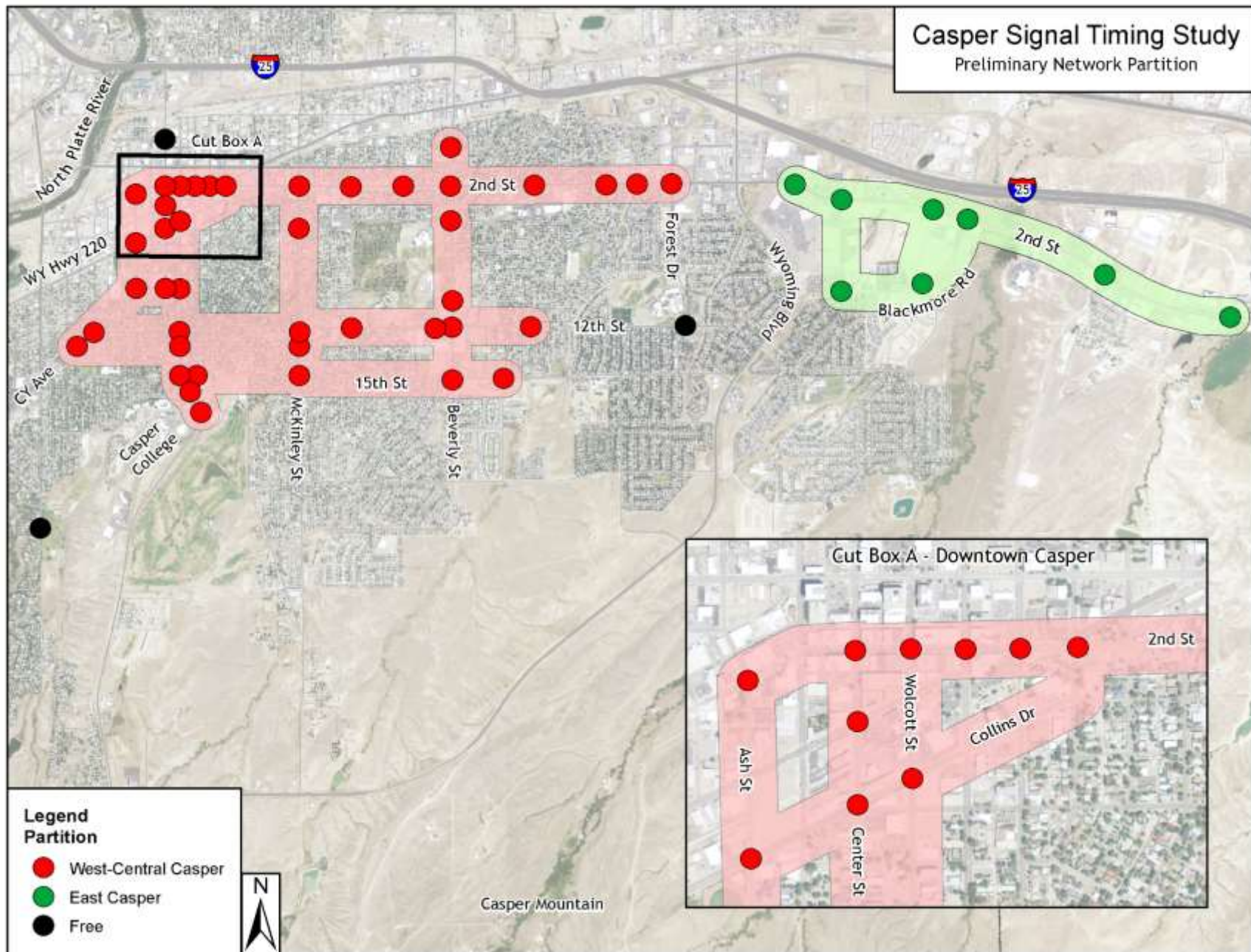


Figure 54 - Preliminary Network Partition





## Isolated Intersections

Under the proposed partition plan, the following intersections will run fully actuated in isolation:

- » **Poplar Street and 25th Street** - clearly isolated from other City of Casper Signals.
- » **12th Street and Walsh Drive** - to be studied in greater detail during field implementation. The hope would be to include this signal in the West-Central partition segment to provide a contiguous coordinated corridor along 12th Street. However, the dense access spacing and 0.75-mile distance between this signal and the traffic signal at 12th Street and Country Club Road at 30 mph make efficient platooning unlikely.
- » **Center Street and B Street** - This traffic signal is isolated due to the inability to revise the WYDOT timing plan at 1st Street (US Highway 26) and Center Street.

## Operations Without Partitioning

As illustrated in **Table 19**, the cycle lengths for the two partition segments are very similar. Another option to increase system-wide coordination would be to consolidate the two partition segments into one combined network. The advantages of this approach is a contiguous coordinated system on all major arterials. The disadvantages are listed below:

- » Forces the entire system to have one cycle length (or a multiple of the same cycle length). This means traffic patterns in downtown on 2nd Street (lower vehicular volumes, high pedestrian volumes, slower speeds) would be accommodated with the same cycle as 2nd Street adjacent to the Eastridge Mall (high vehicular volumes, low pedestrian crossing volumes, higher speeds). As noted above, the cycles are estimated to be very similar, but this could change slightly during field implementation.
- » When an intersection is coordinated in two directions, it essentially operates at pretimed to maintain coordination in both direction. This limits signal responsiveness to varied traffic patterns.

*Table 19 - Partitioned and Combined Network Cycle Lengths*

Network	Zone	Cycle Length	
		A.M.	P.M.
Partitioned Network	West-Central	80	70
	East	70	70
Combined Network		80	70

To compare the partitioned network to the combined network, network-wide measures of effectiveness (as seen in **Table 20**) were compared using Synchro to highlight the benefits of the partitioned network.

*Table 20 - Partitioned Network vs. Combined Network Measures of Effectiveness*

Network Partition Measures of Effectiveness			
Scenario	Total Delay (hrs)	Total Stops (#)	Performance Index
Partitioned Network	220 (296)	25,518 (33,938)	71 (94)
Combined Network	224 (297)	25,040 (33,409)	70 (93)
Legend: A.M. Peak Hour (P.M. Peak Hour)			



## Time of Day Schedules

Time of day (TOD) schedules are based on 15-minute interval counts collected throughout the City of Casper study area in April and May 2015. While this is a small sample to represent a “typical” day, it is a good starting point and can be adjusted in the field during the signal timing implementation process. It is recommended that the City of Casper continue to monitor the network volumes to revise the TOD schedules as appropriate.

As shown in **Figure 56**, each partition zone will receive their own TOD schedule. While peak hour turning movement counts were collected for the A.M., midday and P.M. time periods via video or physical counts, the following approaches were applied to the Off-Peak and potential Afternoon School Peak TOD signal timing plans.

### ***Afternoon School Peak Period***

Numerous Natrona County Schools play a large role in the necessity of traffic signals throughout the City of Casper. Not only are schools traffic destination hubs but they have sharp peaks in traffic volume related to the start and end of the typical school day.

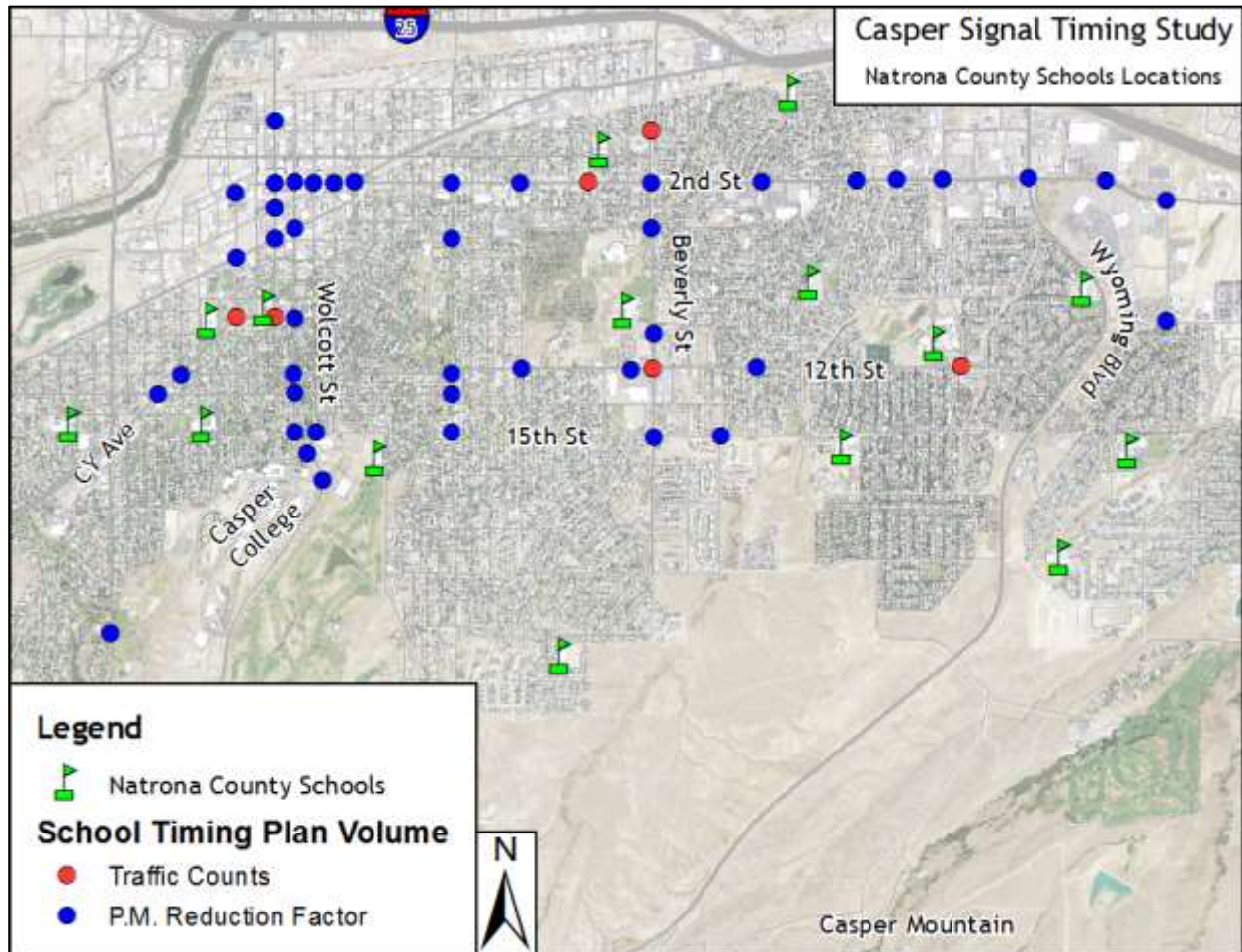
School starting times correspond with the A.M. peak traffic period; whereas the school release times occur approximately 30 minutes to an hour before the typical P.M. peak traffic period. Therefore, the following two-step approach was used to develop a timing plan for the afternoon school peak hour:

- » ***Traffic Counts*** - After school peak turning movement counts were collected at adjacent study intersections of the following Natrona County Schools:

▪ Kelly Walsh High School	Begin 8:20 A.M.	End 3:20 P.M.
○ 12th Street and Walsh Drive		
▪ Natrona County High School	Begin 8:20 A.M.	End 3:24 P.M.
○ Ash Street and 9th Street/CY Avenue		
▪ Frontier Middle School	Begin 7:45 A.M.	End 2:35 P.M.
○ Beverly Street and 12th Street		
▪ Park Elementary	Begin 8:40 A.M.	End 3:35 P.M.
○ Center Street and 9th Street		
▪ Willard Elementary School	Begin 8:40 A.M.	End 3:35 P.M.
○ 2nd Street and Elk Street		
○ Beverly Street and A Street		
- » ***Reduction Factors*** - For the study intersections not directly adjacent to a school, it was assumed that the patterns would not dramatically change during the school peak hour, only volumes. At these locations, the P.M. peak hour TMCs were used along with an applied reduction factor that correlates the daily traffic volume outputs for this time compared to the P.M. peak hour.

The Natrona County Schools that are within the study area along with their approach type for the School timing plan can be seen in **Figure 55**.

Figure 55 - Natrona County Schools

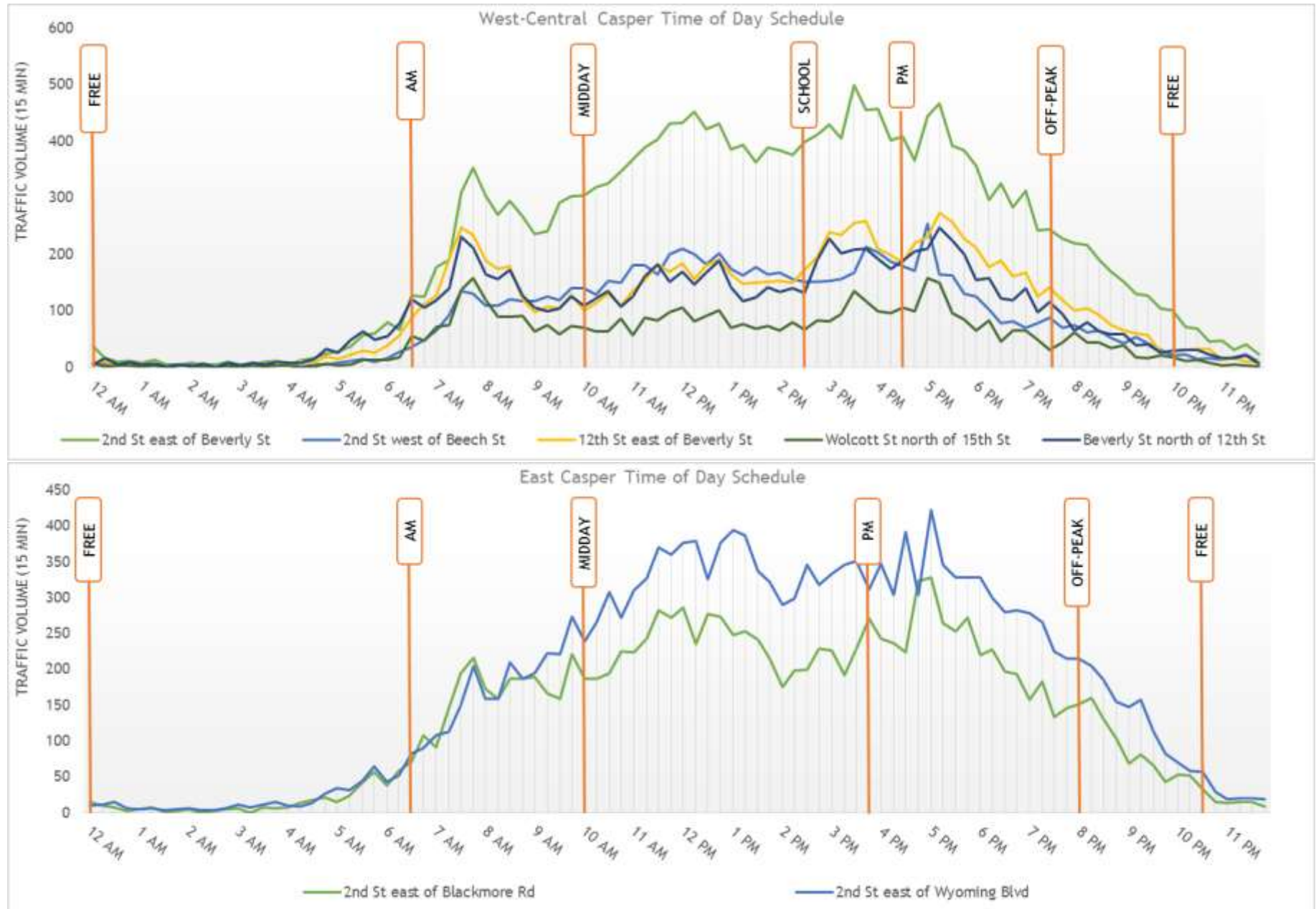


### Off-Peak Time of Day

Collecting off-peak intersection turning movement data was outside the scope of the study. Therefore, off-peak timing plans were developed based on proportional hourly volume differences when compared to the midday peak hour. The midday peak hour was chosen as the base of the off-peak TOD plan since the midday TMCs tend to be more directionally balanced while patterns in the A.M. and P.M. peak tend to have a more pronounced directional flow imbalance.



Figure 56 - Casper Signal Timing Study - Preliminary Time of Day Schedules





## CHAPTER 6 - BEFORE AND AFTER ANALYSIS

Travel time studies will be completed once timing plans are implemented and field calibrated to quantify actual benefits from new timing plans. This report was finalized prior to field activities. A supplemental technical memorandum will be developed and submitted to City staff once field activities are completed and after studies are analyzed.

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## CHAPTER 7 - IMPLEMENTATION PLAN

Funding constraints prohibit any major infrastructure improvements to be implemented prior to implementation of new signal timing plans. Improvements will, however, be implemented in phases as funding becomes available. As infrastructure improvements are implemented, signal-timing plans will need to be adjusted.

The improvements detailed in the body of the report are recommended for implementation in the following fashion:

### Immediate

#### ***Signal Timing and Coordination Optimization***

As part of this study, signal-timing plans will be optimized, implemented and calibrated to field conditions. According to computer model estimates, signal retiming will reduce overall hours of delay by 38% and 32% in the A.M. and P.M. peak hours, respectively.

It is important to note that signal-timing plans should be periodically updated. Studies have found that under normal growth rates, a well-tuned TOD signal plan can age between 5-12% each year. As such, timing plans are typically updated every 5 years or sooner on developing corridors.

#### ***Late-Night Flash Removal***

Late-night flash has been systematically phased out throughout the nation over the past few decades. Removing late-night flash has both safety, 50% reduction in crashes, and traffic operational benefits.

Instead of operating late-night flash, it is recommended that the City of Casper configure traffic signals to rest in green on the mainline. This improves responsiveness to side-street motorists approaching a quiet intersection. For signals to operate in this fashion, detection must be provided on the side streets.

### Short-Term

The following improvements are recommended for implementation as funding becomes available. It would be recommended that all of the proposed improvements be implemented in the next 5 years.

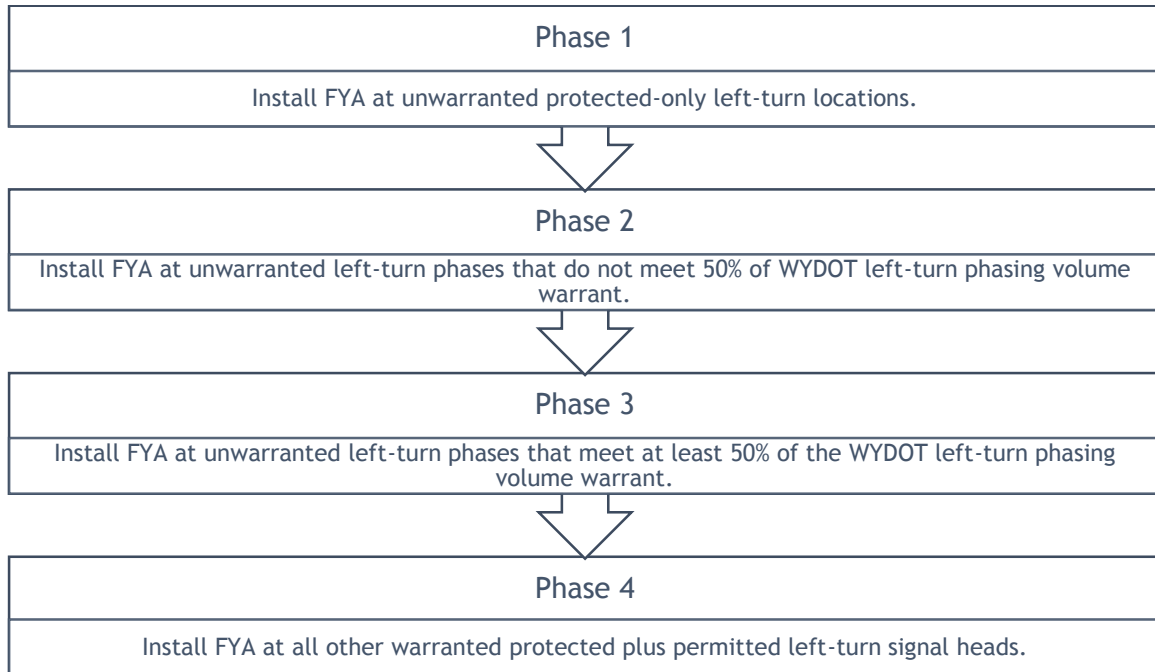
#### ***Signal Phasing Improvements***

##### **FLASHING YELLOW ARROW (FYA)**

The use of the flashing yellow arrow has grown exponentially across the nation over the past decade. In 2011, WYDOT adopted the FYA as the standard for all state intersections where the left-turn operates as protected plus permissive. It is recommended that the City of Casper adopt a Flashing Yellow Arrow Implementation Strategy (**Figure 57**) to start the transition to flashing yellow arrow operations.



*Figure 57 - Flashing Yellow Arrow Implementation Strategy*



FYA has safety advantages over traditional five-section left-turn heads and allows for flexibility in time of day operations by allowing the protected-only left-turn arrow to be skipped.

### **RIGHT-TURN OVERLAPS**

Right-turn overlaps provide momentary delay reductions that are not fully captured with the computer models used in this study. While the traffic operations benefits of implementing the right-turn overlap are not overwhelming, these upgrades can be considered when signal improvements are planned and budget permits. The right-turn overlaps that are identified to provide the greatest overall benefit to the City of Casper are listed below:

- » 2nd Street and Country Club Road - Northbound Approach
- » 2nd Street and Walsh Drive - Northbound Approach
- » 2nd Street and Wyoming Boulevard - Westbound and Southbound Approach
- » 2nd Street and Eastridge Mall/Walmart - Southbound Approach
- » Durbin Street and 15th Street - Northbound Approach
- » 12th Street and Walsh Drive - Southbound Approach
- » Blackmore Road and Landmark Drive - Southbound Approach



## ***Minor Geometric Improvements***

Intersection geometries have a direct influence on signal operations and overall safety. Even subtle changes can have a significant influence on signal timing. The following minor geometric improvements were identified as part of this study:

- » 2nd Street and Beverly Street
  - Construct southbound right-turn lane.
  - Improvement reduces P.M. approach delay by 28%.
  - Improvement costs \$60,000.
- » 2nd Street and Walsh Drive
  - Construct southbound right-turn lane.
  - Improvement reduces P.M. approach delay by nearly 50%.
  - Improvement costs \$60,000.
- » 12th Street and Country Club Road
  - Convert the southbound approach to a left-turn and through/right-turn lane.
  - Improvement reduces A.M. approach delay by nearly 50%.
  - Improvement can be implemented with striping only and cost \$20,000.
  - *Optional* - to aid in roadway alignment, northbound approach can be striped to a left-turn lane and a through/right-turn lane. This will have minimal benefits on capacity and will require removal of four parking spaces.
- » Beverly Street and 15th Street
  - Widen eastbound right-turn lane from 6 feet to 12 feet to allow for effective utilization of this turn-lane.
  - Improvement will cost \$50,000.

## ***Remove Unwarranted Signals***

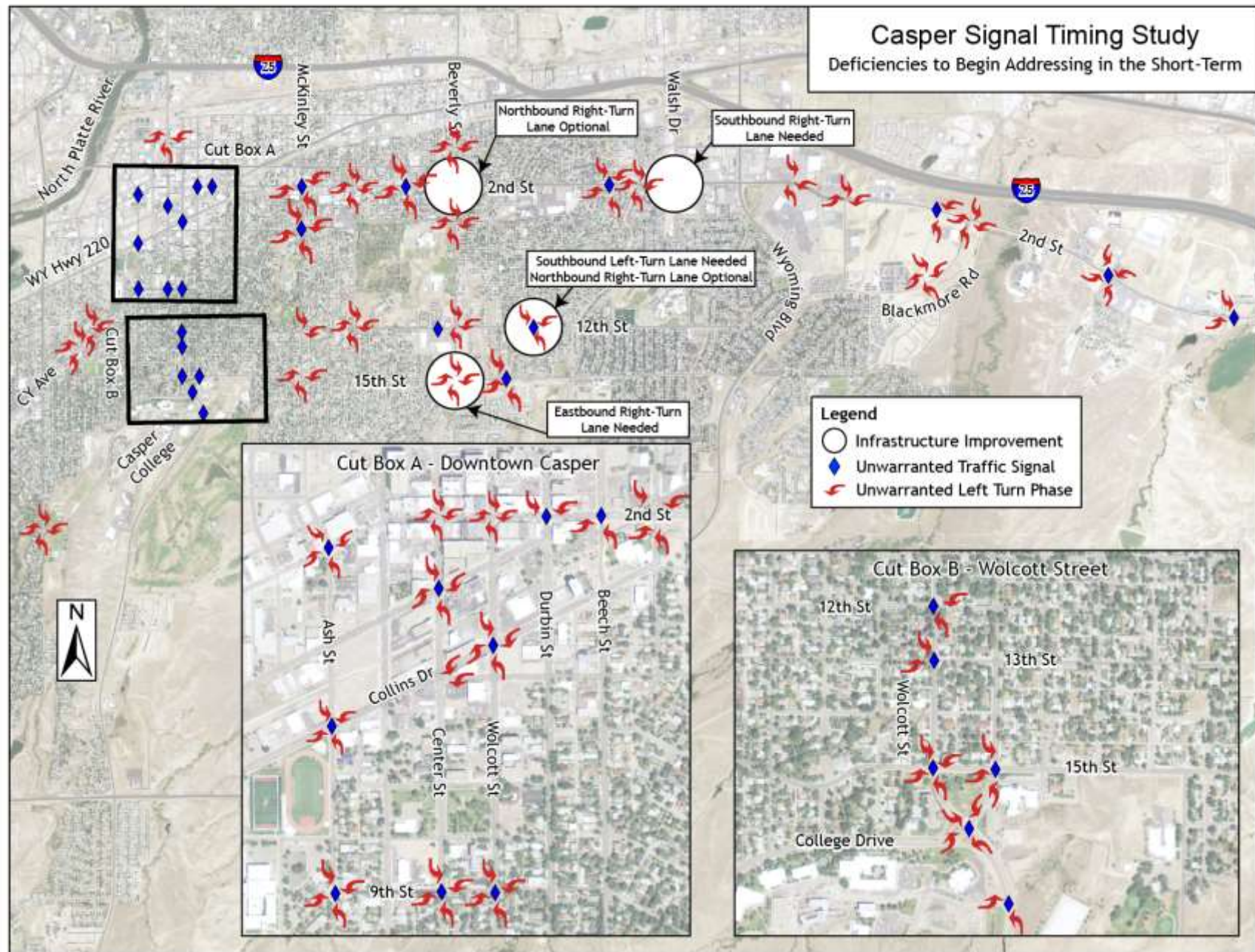
Unwarranted traffic signals are a major hindrance to operations and safety throughout Casper. Of the City's 54 traffic signals, 27 are unwarranted. Signal removal can be controversial, particularly in neighborhood settings. The public tends to associate traffic signals with increased safety and is generally unaware of the negative outcomes at unwarranted signals. It is recommended that an incremental approach be adopted toward signal removals, with the process being initiated at the following four locations where signal removal would offer the greatest benefit with the least impacts.

- » 9th Street and Center Street
- » 9th Street and Wolcott Street
- » Casper Mountain Road and Campus Drive (new YMCA entrance)
- » 12th Street Midblock Pedestrian Crossing

Once removed, the City can perform before-and-after analysis to highlight the benefits. This information will be valuable when the removal process is initiated at more controversial locations. Transparent public involvement in the signal removal process is critical to garner public support in order to avoid scenarios where political will, rather than empirical evidence, is used to support maintaining unwarranted signals. Public involvement steps are provided below under the "Next Steps" heading.

Once the City of Casper has designated a traffic signal for removal, the process set forth in the *Guidelines for Activation, Modification or Removal of Traffic Control Signal* produced by the Institute of Transportation Engineers should be followed.

Figure 58 - Short-Term Implementation Plan







## Further Study Needed

The following recommendations require further analysis and public involvement before determining if and/or when improvements should be implemented.

### ***Full Intersection Reconfiguration***

Four intersections, as listed below, were found operationally deficient and could not be fixed with small-scale projects or signal-timing improvements. The common deficiency with all four intersections is that they have uncommon geometries.

- » Center Street, 5th Street and Collins Drive
- » CY Avenue, 12th Street and Spruce Street
- » CY Avenue, 13th Street and Walnut Street
- » McKinley Street and 5th Street

It is recommended that the City of Casper take a more in-depth analysis into each one of these intersections in order to find a solution. These full intersection reconfiguration impacts would also require public involvement.

### ***Road Diet***

Road Diets, particularly on 4-lane roadways, are inexpensive options that can have many operational, safety and livability benefits. A few of the benefits include traffic calming, allowing space for bicycle and/or parking lanes and reducing corridor crashes by approximately 30 percent.

Two corridors, as listed below, are identified as prime candidates for road diets. Public input should be garnered when and if the City of Casper wishes to pursue implementing road diets.

- Wolcott Street from 2nd Street to Campus Drive
- 12th Street from McKinley Street to Country Club Road

### ***Policy Violations***

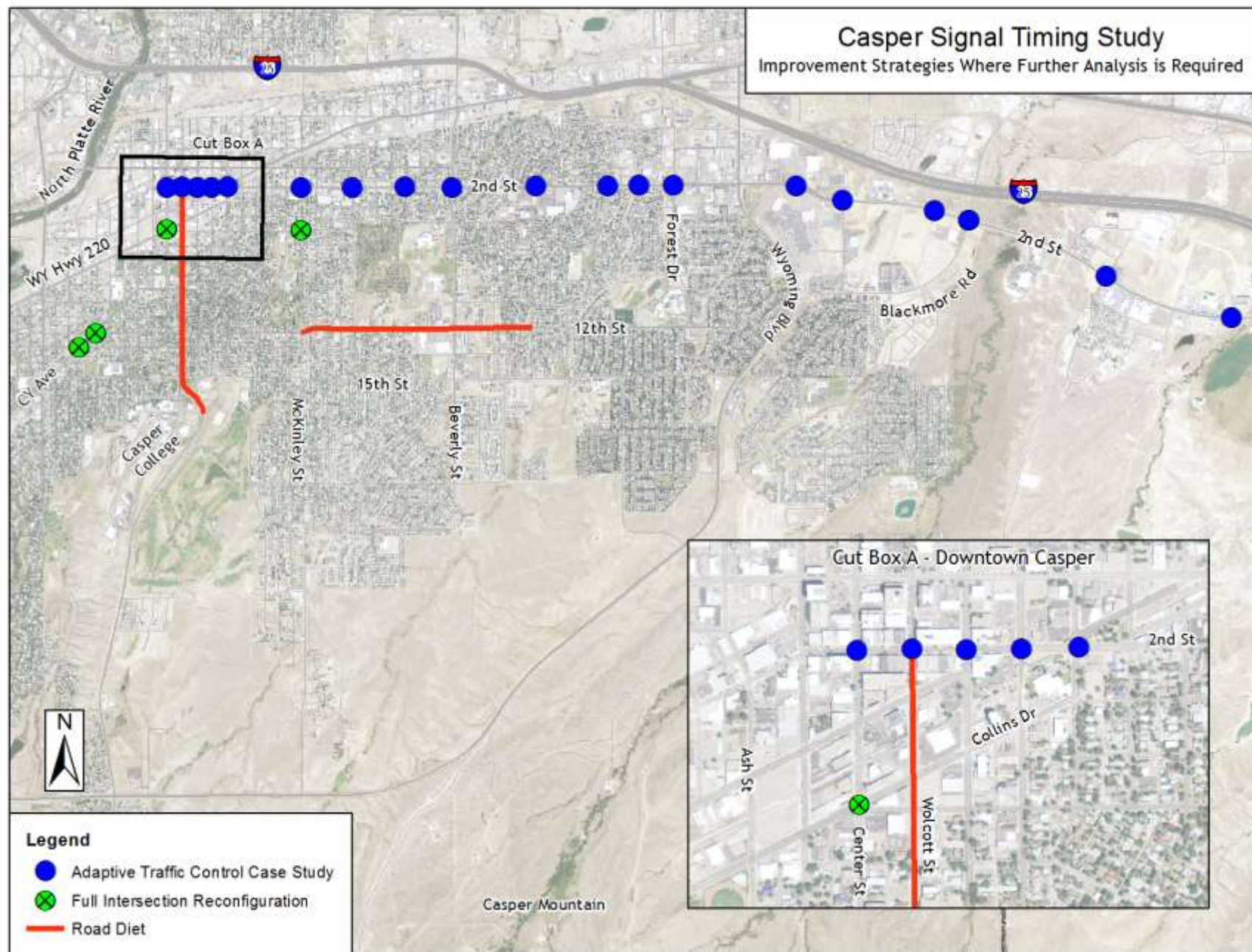
Throughout the duration of the Signal Timing Study, several areas were uncovered that violated either the City's access management or parking within the intersection functional area code. Parking influences intersection operations and dense access can contribute to increased crash potential and reduced corridor progression.

Parking issues are easily fixed. Access management, however, is a complicated deficiency that cannot be easily fixed, especially on residential corridors. The City should continually review access management and parking when roadways are rehabilitated or reconstructed to look for improvement opportunities. As new roads are built in Casper, special attention should be made to meeting these policy requirements.

### ***Adaptive Traffic Control***

Adaptive traffic signal control is a powerful tool to both improve traffic flow as well as extend the life of newly implemented signal timing and coordination plans. Adaptive traffic signal control is best suited for corridors that see traffic pattern variability throughout the day, week and/or season, have special events and/or are expected to see significant growth. A prime location is near the Eastridge Mall where traffic volumes will dramatically increase between Thanksgiving and Christmas. If pursued, it is recommended that 2nd Street serve as a case study for Centrac's Adaptive.

Figure 59 - Recommended Improvements where Further Study Needed





## APPENDIX A - TURNING MOVEMENT COUNTS





## **APPENDIX B - SIGNAL WARRANT ANALYSIS**



## APPENDIX C - SYNCHRO REPORTS



## **APPENDIX D - CLEARANCE INTERVALS**





## APPENDIX E - TIMING PLANS

This appendix will be submitted once timing plans are calibrated in the field.