MAG NON-RECURRING CONGESTION STUDY

MAG Contract No. 418 Project No. PL10-1
Technical Memorandum No. 3 – Data Collection Results and Estimation of the Impacts of Non-Recurring Congestion

INTRODUCTION

The Lee Engineering/TTI team is conducting a study on non-recurring congestion (NRC) for the Maricopa Association of Governments (MAG). This technical memorandum is the third in a series to document the effort on the study. This technical memorandum summarizes the work completed for Task 3 of the study which entailed data collection and analysis. The data used was generated from in-field collections and review of historical databases. All of the information reviewed and analyzed culminated in the determination of NRC causes, the estimated delay due to NRC, and the concluded impact of NRC (and the benefits from reducing its effect). The overall goal of the study is to identify appropriate countermeasures that would help recover lost roadway capacity due to NRC. This could effectively delay the immediate need for costly new road capacity construction.

DATA COLLECTION PLAN

The approach to obtaining and quantifying NRC delay was documented in the previous Tech Memo 2. The effort was divided between arterial roadways and freeways, with the subject corridors presented to and approved by the Study Advisory Group in advance. The assessment of each roadway system relied on two general components: 1) traffic characteristics (e.g., volume, speed) and 2) NRC events which could manifest as incidents (crashes), work zones, weather, special event traffic, and/or traffic signal malfunction. The arterial corridor traffic characteristic data was accumulated primarily through the Anonymous Wireless Address Matching (AWAM) collection methodology. NRC events were compiled from a variety of sources, which will be discussed in the next section. The freeway corridor traffic characteristics were gathered from an extensive review of the 2009 database from ADOT's Freeway Management System (FMS). NRC events relating to the studied freeway corridors were documented primarily from information compiled from NAVTEQ/Traffic.com.

ARTERIAL DATA COLLECTION & ANALYSIS

The selection of the arterial corridors analyzed in this study was based on several factors: potential for crashes; proximity to special event locations (e.g., sporting venues); cross-section geometry; feedback from the Study Advisory Group; and jurisdiction. The length of the corridors was dictated by the

available number of AWAM devices (14) and the maximum spacing of devices (2 miles) that still yielded acceptable sample data. With five months allotted in the study schedule for data collection, the study corridor data was collected in three deployments ranging in duration from a few weeks to a couple of months. An initial test deployment, which ultimately contributed to the overall data set, was installed in May 2010 and remained in place for 3.5 months. This initial testing/use of the AWAM devices provided valuable data to convey to the Study Advisory Group and to refine the collection methodology for subsequent deployments. The characteristics of the segments created within the corridors by the AWAM device placement are documented in Table 3-1 below while the geographic extents of the deployments and the location of the AWAM devices are shown in Figure 3-1 on the next page.

Table 3-1. Arterial Study Corridor Characteristics

	PRIMARY CORRIDORS				
Arterial Corridors (Directional Segment I.D. Numbers)	**35th Ave** (3-16)	**51st Ave** (17-26 & 35-40)	**Indian School Rd** (33-34 & 41-48)	**7th Street** (49-60)	**Rural Road** (61-70)
Terminus (N or W)	Bell Rd	Bell Rd	67th Ave	Northern Ave	McKellips Dr
Terminus (S or E)	Buckeye Rd	Buckeye Rd	7th St	Washington/ Lincoln	Southern Ave
Direction	N-S	N-S	E-W	N-S	N-S
Jurisdiction(s)	Phoenix	Glendale & Phoenix	Phoenix	Phoenix	Tempe
Centerline Miles	14	11	8	7.25	4
Average Cross-Section (N to S, W to E)[1]	2-1-3(NB)	2-1-3(NB)	2-1-3(WB) 3-M-3 3-1-4 3-1-2(WB)	2-R-3(NB) 3-1-3	3-1-3
Approx. Average Daily Traffic[2]	30,500['10]	26,000['10]	37,500['10]	27,500['10]	38,100['10]
No. of Top 100 Crash Locs[3]	13	7	5	3	3
No. of Top Crash Locs per mile	0.93	0.64	0.63	0.41	0.75
Serve as Fwy Diversion Rte?	YES (I-17)	NO	NO	NO	NO
Special Event Proximity	NO	NO	NO	YES (Chase Field)	YES (ASU)

	SECONDARY CORRIDORS						
Arterial Corridors (Directional Segment I.D. Numbers)	**Bell Road** (1 & 2)	**Thunderbird Rd** (27-28)	**Peoria Ave** (29-30)	**Northern Ave** (31-32)	**University Ave** (71-72)	**Mill Ave** (73-74)	**Rio Salado Pkwy** (75-76)
Terminus (N or W)	51st Ave	51st Ave	51st Ave	51st Ave	Mill Ave	Rio Salado Pkwy	Mill Ave
Terminus (S or E)	35th Ave	35th Ave	35th Ave	35th Ave	Rural Rd	University Ave	Rural Rd
Direction	E-W	E-W	E-W	E-W	E-W	N-S	E-W
Jurisdiction(s)	Phoenix	Phoenix	Phoenix/ Glendale	Phoenix/ Glendale	Tempe	Tempe	Tempe
Centerline Miles	2	2	2	2	0.75	0.50	0.85
Average Cross-Section (N to S, W to E)[1]	3-M-3	3-M-3	2-1-3(WB)	2-1-3(WB)	2-1-2	1-M-1	2-M-2
Approx. Average Daily Traffic[2]	37,800['10]	37,230['10]	32,750['10]	28,100['10]	26,640['08]	18,200['06]	11,900['07]
No. of Top 100 Crash Locs[3]	1	3	0	1	1	0	0
No. of Top Crash Locs per mile	0.50	1.50	0.00	0.50	1.33	0.00	0.00
Serve as Fwy Diversion Rte?	YES (L101)	NO	NO	NO	NO	NO	NO
Special Event Proximity	NO	NO	NO	NO	YES (ASU)	YES (ASU)	YES (ASU)

Notes:
1 - X-X-X represents # lanes in one direction, median use (M = raised median, "1" = two-way left turn lane, "R" = reversible lane), # lanes in other direction
2 - as collected for the study or from city/MAG data sources
3 - per a MAG study of crash rates

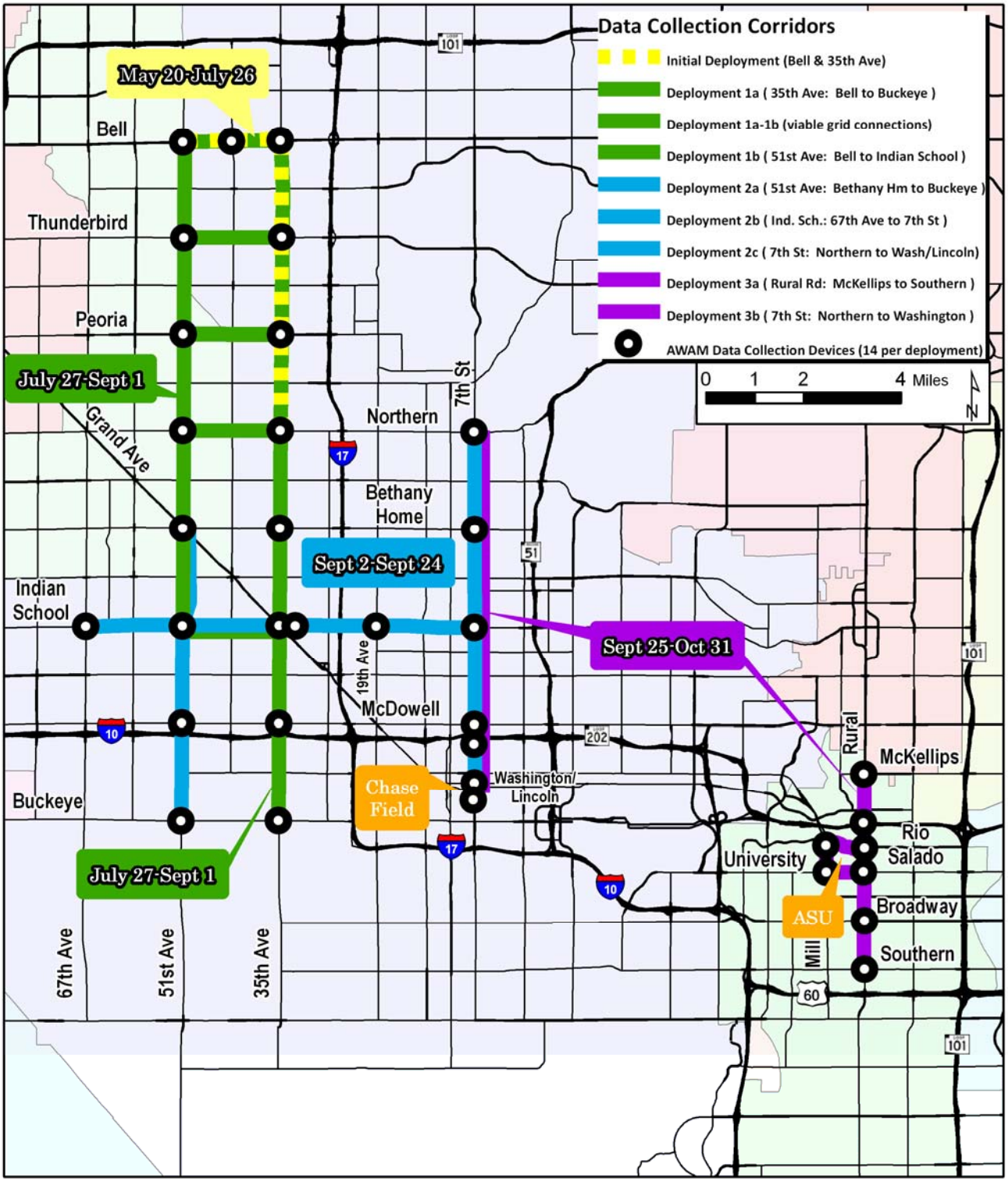

Figure 3-1. Arterial Study Corridors & Data Collection Plan

Although a constant monitoring of traffic volumes on the subject corridors is not mandatory for this study, representative volume counts are needed to facilitate computations of the overall impact of non-recurring congestion in the form of vehicle-hours of delay. Therefore, representative 24-hour (minimum) counts were collected for the various corridors during the course of the data collection period. The volumes were collected using automatic traffic recorders which permit delineation of the traffic volumes in 10-minute intervals to aid in estimating the amount of traffic affected by transient NRC events. Other volume data available from MAG was used to supplement as necessary. Appendix A displays the volume data in tabular and graphical form.

Speed and Travel Time Data

Travel time data was obtained through the use of the AWAM devices, following the methodology presented in Tech Memo 2. The anonymous matching of the in-vehicle devices yielded travel time determinations for the segments defined by the deployment of the AWAM devices. Since the distances between the devices were also known, average travel speeds for the detected vehicles could also be determined. For the purpose of this study, the calculated travel times were used in the analysis since this measure correlates directly with delay incurred.

The AWAM device deployment covered 71 centerline miles and 377 centerline week-miles. There were 460,444 ten-minute intervals total for the 76 study roadway segments. For the recurring (baseline) weekday calculation, 264,449 intervals out of 309,445 (86%) were used. For the recurring (baseline) weekend, 128,448 intervals out of 150,999 (85%) were used.

Events that cause non-recurring congestion were recorded during the AWAM device deployment. There were 73,456 ten-minute intervals of NRC events out of 460,444 ten-minute intervals total (16%).

Table 3-2 shows a breakdown of the data collected by ten-minute interval. Table 3-3 summarizes the match rate obtained through AWAM. Table 3-4 shows a breakdown of the NRC events that occurred simultaneous to data collection by 10-minute interval.

Table 3-2. Number of 10-Min Intervals for the Data Collection Period

	10-MINUTE INTERVALS COLLECTED	10-MINUTE INTERVALS WITH 1 OR MORE VEHICLE MATCH	INDIVIDUAL VEHICLE MATCHES	10-MINUTE INTERVALS IN BASELINE CALCULATION	VEHICLE MATCHES IN BASELINE CALCULATION
WEEKDAY	309,445	214,666	777,400	264,449	655,090
WEEKEND	150,999	107,033	328,952	128,448	281,818
TOTAL	460,444	321,699	1,106,352	392,897	936,908

AWAM match rates, relative to through traffic, were calculated using the 24-hour volume counts collected. This study deployed AWAM devices approximately 2 miles apart, collecting approximately 23 daytime (6 AM – 7PM) hourly valid matches or about 4 matches every 10 minutes. This match rate does allow for adequately matching travel time to non-recurring event data. The match rates for this study are slightly lower than those observed in College Station, Texas and Houston, Texas where AWAM devices were deployed using 0.5 mile to 1.3 mile spacing.

Table 3-3. AWAM Match Rate Summary

# Links	AADT Range	Length	Hourly Valid Matched Samples		Hourly Valid Match Rates	
			Average	Daytime Avg.	Average	Daytime Avg.
16	6,900 – 21,000	0.4 – 0.8	19	26	3.5%	3.0%
10	16,200 – 23,200	1.0 -1.8	21	28	3.0%	2.6%
50	6,200 – 30,800	2.0 – 2.2	15	21	2.8%	2.4%
76	**6,200 – 30,800**	**0.4 – 2.2**	**17**	**23**	**2.9%**	**2.6%**

Notes:
1. Daytime averages were weekdays from 6 AM – 7 PM.
2. Hourly valid match rates were hourly average valid matches divided by hourly directional traffic volumes.

Table 3-4. Number of 10-Min Intervals for the Following Events

	10-MIN INTERVALS FOR:						
	ALL NRC EVENTS	VEHICULAR INCIDENTS	FREEWAY DIVERSION	WEATHER	CONSTRUC -TION	SPECIAL EVENTS	ATYPICAL TRAFFIC SIGNAL
WEEKDAY	50,221	2,150	112	1,025	41,988	758	4,188
	100%	4%	0%	2%	84%	2%	8%
WEEKEND	23,235	704	60	654	16,576	3,364	1,877
	100%	3%	0%	3%	71%	15%	8%

Causes of Non-Recurring Congestion

Per the literature review from this study, non-recurring congestion (NRC) on the arterial roadways was considered to be generated by five types of events:

- Incidents/Crashes
- Diversions from adjacent freeway closures
- Weather
- Construction/Work Zones
- Special Events
- Atypical Traffic Signal control such as preemption or flash (i.e., power failure)

Incidents/Crashes

There were two sources used to generate the data set for vehicular, motorcycle, and pedestrian crashes (incidents) on the study corridors. The first, and primary source, was the Regional Archived Data Server (RADS) which is administered by the Maricopa County Department of Transportation. The RADS database compiles logs of fire and emergency vehicle dispatches for the Phoenix metropolitan area. The other source for incident data was NAVTEQ/Traffic.com which is run by NAVTEQ. They compile their information from four types of sources: digital traffic sensors, GPS/probe devices within the traffic stream, private and government partners, and staff monitoring traffic conditions at operations centers. Since the NAVTEQ/Traffic.com data provided accurate end times and the RADS data had the greatest incident coverage, the two data sources complement each other for the purposes of this study. List of the vehicular incidents from RADS by corridor is included in Appendix B.

The initial dispatch time is assumed to be the start of the incident for the data obtained from RADS. If there are multiple dispatch logs for an incident, the last log is assumed to be the end of the incident.

NAVTEQ/Traffic.com data provided incident start and end times. When the last log in the RADS data was compared with the NAVTEQ/Traffic.com end times, the duration of an incident lasted longer that the last dispatch indicated. Due to residual delay from a vehicular incident and the uncertainty of duration, a buffer was applied of 10 minutes before and 3 hours after the assumed/known start and end times, respectively. This is also consistent with the freeway analysis. Delay due to the incident that fell within these parameters was considered non-recurring. Application of this buffer allowed for calculation of delay without having a precise end time for the RADS data.

A comparative analysis of vehicular incidents collected by RADS and NAVTEQ/Traffic.com on 35th Avenue during the arterial deployment months of June 2010 through August 2010 was conducted for this study. Table 3-5 displays the results of the comparison. The comparison of the two incident sources revealed that RADS captured more vehicular incidents than NAVTEQ/Traffic.com on arterial roadways. Since NAVTEQ/Traffic.com checks their incidents with RADS, there were no NAVTEQ/Traffic.com incidents outside of the RADS data set.

Table 3-5. 35th Avenue RADS vs. NAVTEQ/Traffic.com Incident Comparison

Incident Type	Traffic.com	RADS	Match Rate
Injury Accident	40	64	63%
Motorcycle	1	5	20%
Pedestrian	1	5	20%
Bicycle	1	8	13%
Total	**43**	**82**	**52%**

Freeway Diversion

Freeway incidents on freeway segments parallel to the study corridors were obtained from the HCRS database, which provided start and end times plus detailed notes of each incident. Visual inspection of numerous freeway incidents indicated that 35th Avenue was the only arterial corridor in this study impacted by vehicle diversion when Interstate 17 had multiple or complete lane closures in either the northbound or southbound direction. Only freeway incidents that met these criteria and were adjacent to a corridor were included as a non-recurring event for that corridor.

Construction/Work Zones

With most of the study corridors located in the City of Phoenix, most of the construction/work zone information was obtained through querying of their Temporary Restriction and Closure System (TRACS) database. The database contains information, such as utility maintenance and roadway improvements, for planned/requested encroachments into the roadway right-of-way which could include roadway lane restrictions/closures. Systems similar to TRACS for tracking construction and work zone permits were not available for the other jurisdictions, so construction/work zone information was conveyed from phone interviews of the appropriate personnel. In these cases, the construction events either were deemed to be unrelated to the study corridor or were going to be occurring throughout the data collection period for the particular corridor/segment.

The available data does indicate which lane(s), if any, were blocked for construction; however, it is not known if and when the movement of construction equipment may be preventing vehicular travel on the open lanes adjacent to construction. For some construction activities, traffic signals may have been manually operated by police. Most construction permits required full traffic movements to be maintained at the intersections.

Weather

Weather patterns in the Phoenix metropolitan area are susceptible to isolated storms and events. Therefore, reliance on one weather station, such as Sky Harbor Airport, would not be a reasonable means of estimating non-recurring congestion effects from weather for the study corridors. Instead, the study relied on a network of individually run weather stations (see Figure 3-2 on the next page) whose data is compiled by the website *wunderground.com* (i.e., "weather underground"). The stations record a variety of weather conditions such as temperature, humidity, wind speed/direction, and rainfall recorded (and the rate at which it fell). The rainfall rate data was used in conjunction with a threshold value established for the study (i.e., rainfall rates greater than 0.1 inches per hour) to determine when weather events may contribute to non-recurring congestion.

Stations were assigned to the corridors based on a number of factors. First, the stations were narrowed down based on the availability of that weather station during the duration of deployment. Weather stations were then further refined based on whether they collected rainfall data as not all weather stations are fully equipped. Finally, the weather station in closest proximity was selected to be used for the particular corridor.

Special Events

Based on the selected study corridors, there are three types of special events that may contribute to NRC. The 7th Street corridor is a primary means of ingress and egress for Chase Field (Arizona Diamondbacks) so the associated concentration of traffic generates non-recurring congestion. The Rural Road study corridor is adjacent to the Sun Devil Stadium in Tempe (ASU football), so similar NRC will be generated by traffic arriving and departing during Saturday home games. The Rural Road corridor and its adjunct loop on University Drive/Mill Avenue/Rio Salado Parkway will also capture any NRC associated with special events at the Tempe Beach Park which has a main entrance located at the northwest corner of Mill Avenue and Rio Salado Parkway. Days and times of the events were obtained from various sources associated with the specific venues. Dozens of other venues/events were investigated, but not included in the analysis as their number of expected attendees was too small (e.g., Tempe Improv), the major access from the freeway was not the study corridor (e.g., Tempe Center for the Arts), or the venue was more than a half mile away from the corridor (e.g. Dodge Theater) to register an impact to delay per the study methodology.

Traffic Signal Control Changes or Servicing

Non-recurring congestion can be generated from atypical traffic signal operations at intersections. Signal control-related events that could cause NRC include emergency vehicle pre-emption, suspension of coordinated timing, when a signal goes into flash mode, manual operation of the signal, and signal control maintenance where lanes could be blocked to permit equipment replacement. Due to the collection effort, the traffic signal controller log data was generally obtained only for the intersections where AWAM devices were present even though signal controller events and NRC could be generated at the other traffic signals along the corridor. The logs were retrieved from the signal controllers or from city representatives with access to the information.

Several databases were created for the AWAM data with summaries of the non-recurring congestion events by ten-minute time period. A code was assigned to each event type according to the field definitions included electronically in Appendix C.

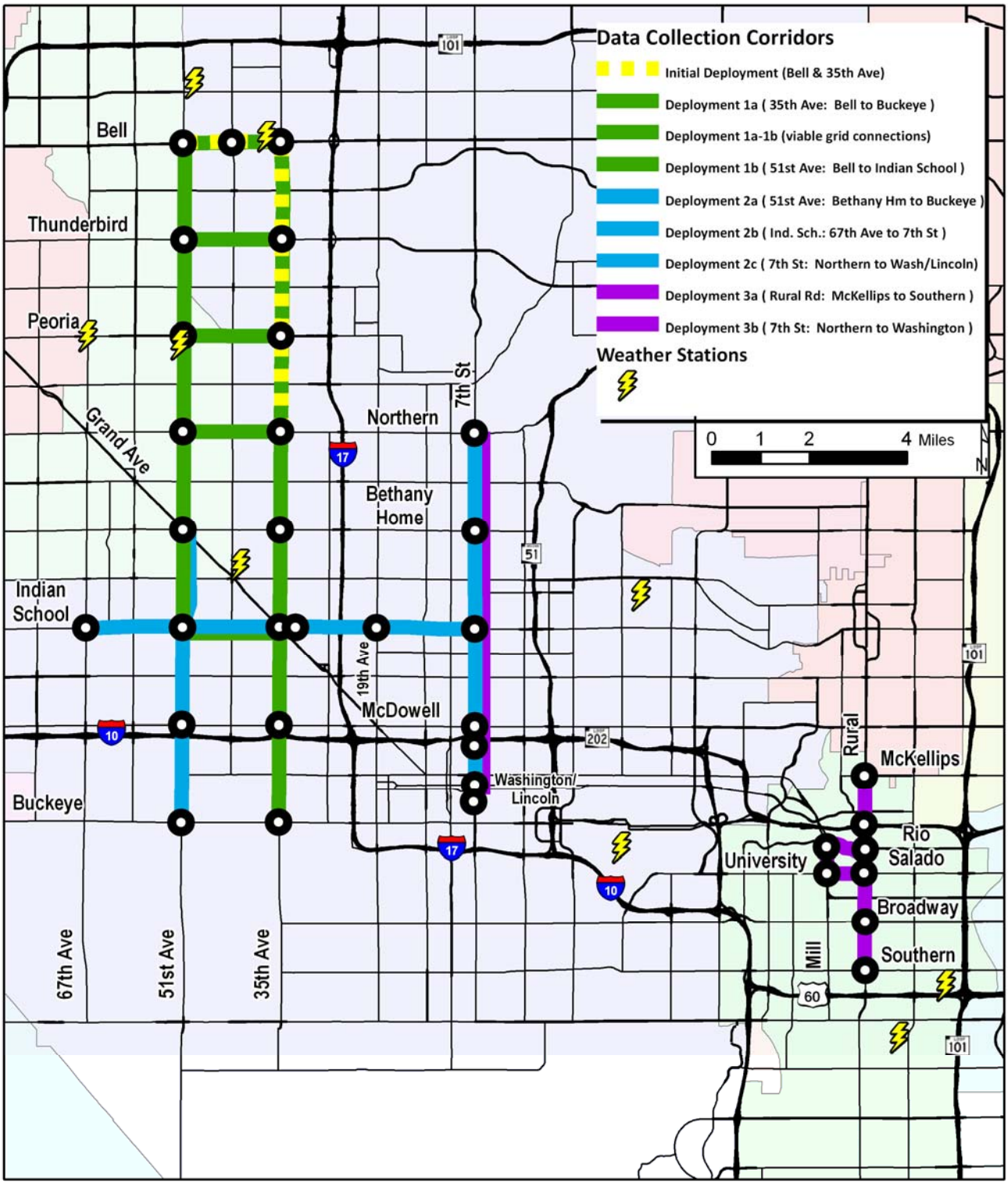

Figure 3-2. Weather Stations Relating to Arterial Study Corridors

Delay Due to NRC

"Normal" recurring travel time for weekdays and weekends was calculated separately for each of the 76 roadway segments. For the weekday calculation, data for weekend days, holidays, and furlough days were removed. Then time intervals were removed that had any vehicular incidents, freeway diversion, weather, special events, or atypical traffic control conditions. The remaining "normal" intervals were averaged per ten minute period of the day. These baseline conditions were then assigned, by time interval, to the complete weekday data set for a roadway segment. The weekend calculation of baseline conditions mirrored that of weekdays, except the weekend data set comprised wholly of weekend days, holidays, and furlough days combined.

A summary of the arterial roadway analysis for the 76 study roadway segments can be found in Appendix D. The complete arterial analysis is included electronically in Appendix E. Table 3-6 through Table 3-8 provide a brief arterial analysis summary for each study roadway segment for weekdays, weekday peak hours, and weekends, respectively. Figure 3-3 and 3-4 provide a visual display of the percent of non-recurring congestion per study segment for weekday and weekends, respectively.

Table 3-6. Arterial Analysis Weekday Summary

WEEKDAY RESULTS						
AWAM Equipped Segments	Recurring Delay (vehicle hours)	Non-Recurring Delay (vehicle hours)	Total Delay	% Recurring	% Non-Recurring	NRC Range
35th Ave Corridor (with Bell)	87,914	10,393	98,306	89%	11%	1% - 100%
51st Ave Corridor (with Thunderbird, Peoria, & Northern)	84,024	3,250	87,274	96%	4%	0% - 18%
Indian School Rd Corridor	48,526	11,951	60,477	80%	20%	1% - 76%
7th St Corridor	53,701	6,087	59,789	90%	10%	1% - 64%
Rural Rd Corridor (with Rio Salado, Mill, and University)	72,882	1,404	74,286	98%	2%	1% - 8%
Grand Total	**347,047**	**33,084**	**380,131**	**91%**	**9%**	**0% - 100%**

Table 3-7. Arterial Analysis Weekday Peak Hours Summary

WEEKDAY PEAK HOURS (6 - 9 AM and 3 - 7 PM) RESULTS						
AWAM Equipped Segments	Recurring Delay (vehicle hours)	Non-Recurring Delay (vehicle hours)	Total Delay	% Recurring	% Non-Recurring	NRC Range
35th Ave Corridor (with Bell)	36,631	3,413	40,043	91%	9%	1% - 100%
51st Ave Corridor (with Thunderbird, Peoria, & Northern)	37,952	1,082	39,035	97%	3%	0% - 21%
Indian School Rd Corridor	25,163	5,973	31,136	81%	19%	0% - 84%
7th St Corridor	29,253	2,056	31,309	93%	7%	1% - 64%
Rural Rd Corridor (with Rio Salado, Mill, and University)	31,943	838	32,780	97%	3%	0% - 9%
Grand Total	**160,941**	**13,362**	**174,303**	**92%**	**8%**	**0% - 100%**

Table 3-8. Arterial Analysis Weekend Summary

WEEKEND RESULTS						
AWAM Equipped Segments	Recurring Delay (vehicle hours)	Non-Recurring Delay (vehicle hours)	Total Delay	% Recurring	% Non-Recurring	NRC Range
35th Ave Corridor (with Bell)	25,144	4,620	29,764	84%	16%	1% - 71%
51st Ave Corridor (with Thunderbird, Peoria, & Northern)	27,618	2,133	29,751	93%	7%	1% - 33%
Indian School Rd Corridor	26,164	4,969	31,133	84%	16%	0% - 63%
7th St Corridor	15,901	5,906	21,807	73%	27%	0% - 94%
Rural Rd Corridor (with Rio Salado, Mill, and University)	30,167	4,397	34,564	87%	13%	0% - 56%
Grand Total	**124,993**	**22,025**	**147,018**	**85%**	**15%**	**0% - 94%**

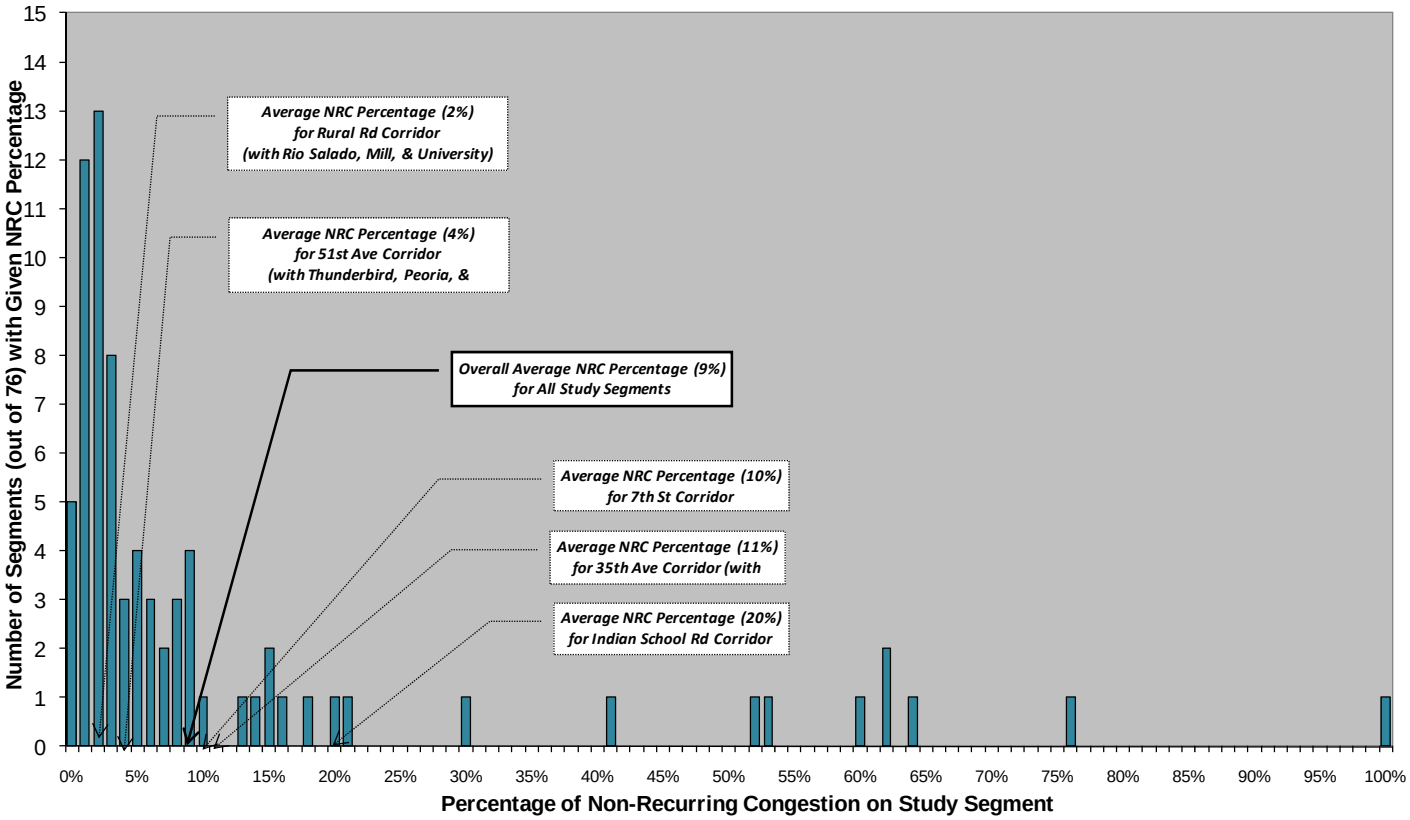

Figure 3-3. Study Segment NRC Percentages - Weekdays

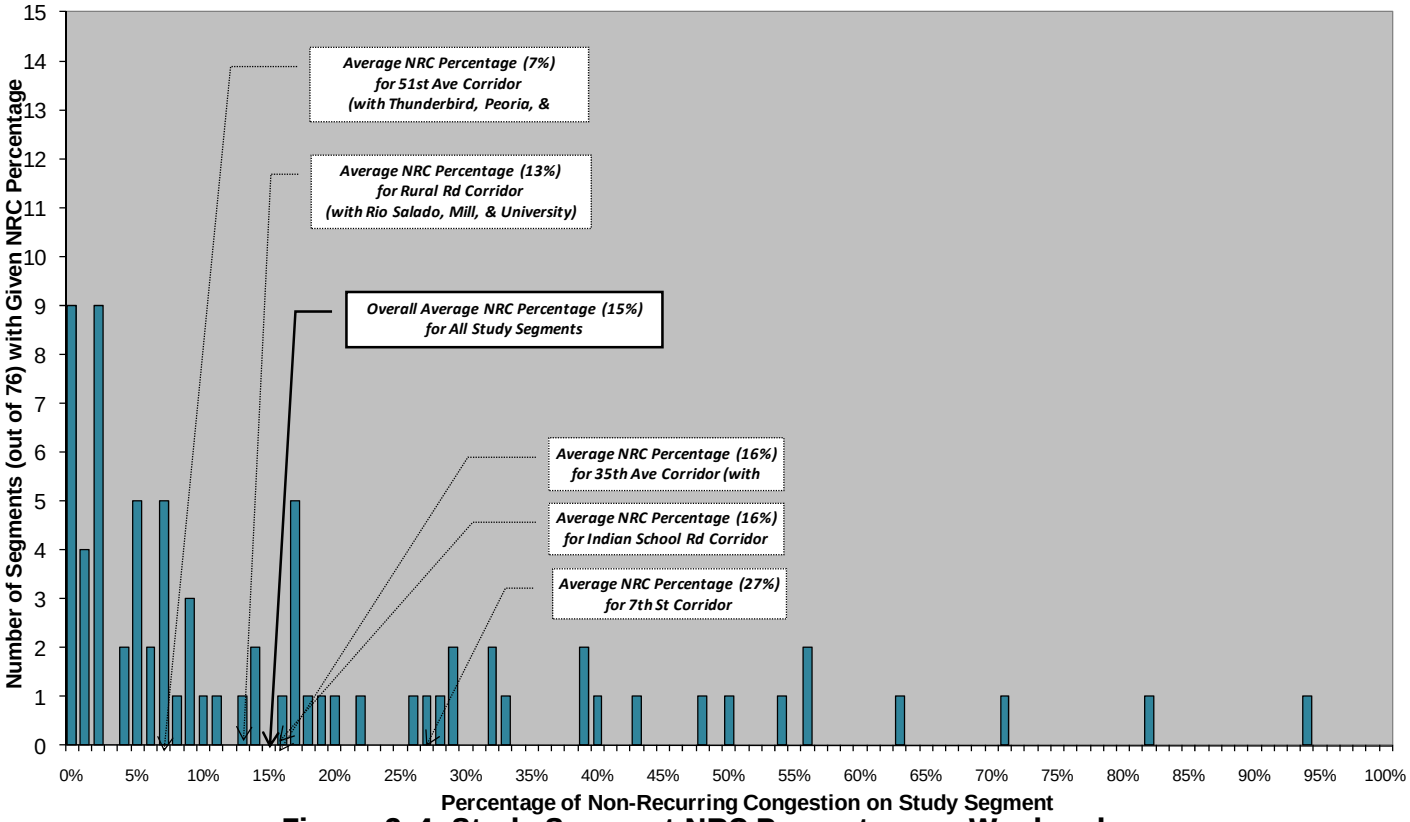

Figure 3-4. Study Segment NRC Percentages - Weekends

During the study period, the 35th Avenue corridor experienced numerous incidents and construction activities. Most construction activities were inactive during peak hours, but occurred during the day. Thirty-fifth Avenue, south of I-10, experiences a greater concentration of truck traffic due to industrial land uses in the area. Bell Road has an interchange with I-17, one mile east of 35th Avenue. Thirty-fifth Avenue has an interchange with I-10, one quarter mile south of McDowell Road. Grand Avenue intersects 35th Avenue at-grade at Indian School Road although eastbound/westbound through traffic on Indian School Road can avoid the intersection by using its existing overpass.

The 51st Avenue corridor traverses the Cities of Phoenix and Glendale and serves as a typical suburban arterial. The roadway has an interchange with I-10, about one quarter mile south of McDowell Road. Grand Avenue intersects 51st Avenue at-grade at Bethany Home Road although northbound/southbound through traffic on 51st Avenue can avoid the intersection by using its existing overpass. Due to this roadway configuration and the signal cabinet location, only a small number of AWAM matches were obtained for Bethany Home Road; therefore, Bethany Home Road was not included as a study corridor.

The Indian School Road corridor was under construction from approximately 6 AM to 6 PM during the entire data collection period according to TRACS; however, no construction was observed during an AWAM device inspection.

The 7th Street corridor was used by Chase Field traffic on game days, which occurred on both weekdays and weekends. This corridor is unique in that it has a reversible lane on a greater portion of the corridor (beginning/ending just north of McDowell Road). The reversible lane serves soutbound traffic during the AM peak period (6-9 AM) and northbound traffic during the PM peak period (4-6 PM). During these times, left-turns at major intersections are not permitted. Seventh Street has an interchange with I-10, one quarter mile south of McDowell Road.

The Rural Road corridor experienced very few incidents and deployed special event traffic control plans. The City of Tempe has an established traffic control plan for an extensive area surrounding the stadium. Restrictions include time-based controls (per the point in the football game) that may limit intersection turn options and/or complete closures of certain directions of roadways (whether collector or arterial classification). Special events at Sun Devil Stadium and Tempe Beach Park only occurred on weekends. Rural Road, University Drive, Mill Avenue, and Rio Salado Parkway, in the vicinity of Arizona State University, are also heavily used by bicyclists and pedestrians. Due to low average vehicular speeds on Mill Avenue, it is possible that some of the AWAM matches were obtained from Bluetooth devices carried by a bicyclist. Rural Road has an interchange with SR 202, one half mile north of Rio Salado Parkway, and with US 60, one half mile south of Southern Avenue.

Non-recurring congestion (NRC) is the difference between the recurring travel time (baseline conditions) and the actual travel time during an NRC event. To filter out the natural variation in travel time due to driver behavior and signal timing, NRC was only calculated when this difference was at least 30%. This threshold was based on visual inspection of numerous examples. The difference in travel time was multiplied by the volume for the time interval to convert the NRC to vehicle-hours.

Recurring congestion was calculated when the difference between the free flow travel time and the recurring travel time was at least 30% for each interval without an NRC event. The free flow travel time was taken as the minimum recurring travel time as determined from the field data. This difference in travel time was multiplied by the volume for the time interval to obtain vehicle-hours.

With six different sources of non-recurring congestion – vehicular incidents, freeway diversion, weather, construction, special events, and atypical traffic control conditions – the non-recurring delay could have been collected among 63 different possible combinations. For example, 1 = vehicular incidents, 2 = freeway diversion, 1+2 = vehicular incident + freeway diversion and so on. Combinations of NRC events greater than three occurring in any ten minute period was not captured during the data collection effort for this study.

Based on the TTI/Cambridge Systematics study, each NRC combination was proportioned to percentages shown in Figure 3-5. Freeway Diversion was proportioned using the percentage shown for Traffic Incidents.

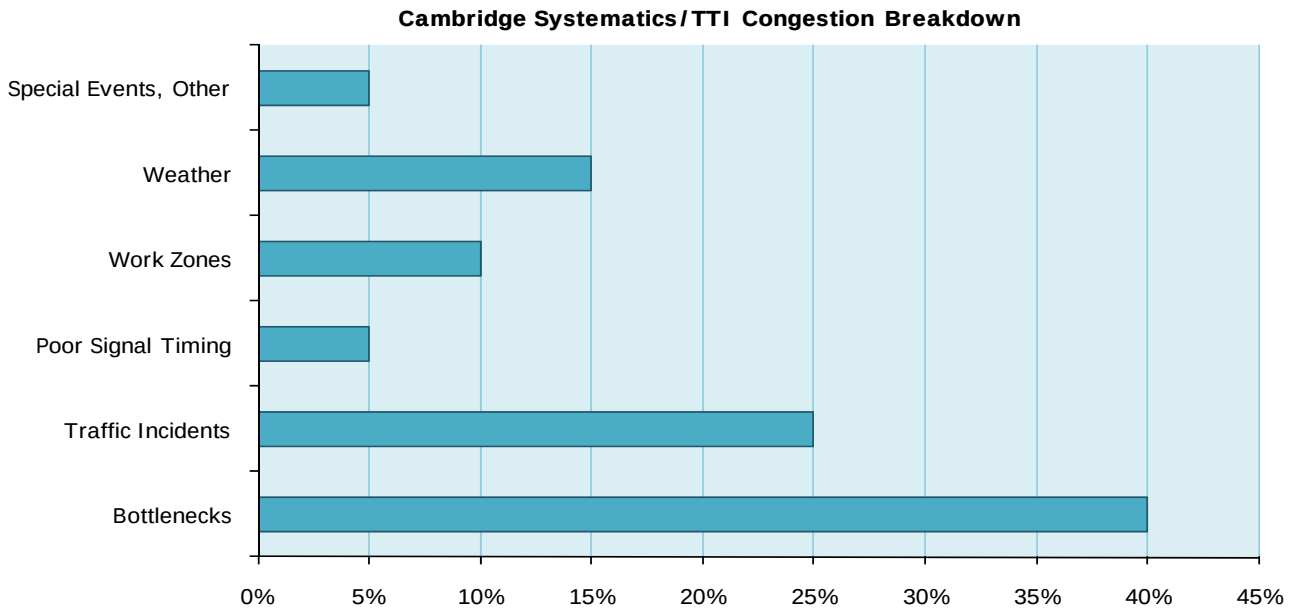

Figure 3-5. Sources of Congestion

A sensitivity analysis was conducted on the weekday data for the 35th Avenue and 7th Street corridors which recalculated NRC and recurring congestion using a 20% threshold. When the results were compared to the original analysis which used 30%, the difference was smaller than 1%. This sensitivity analysis confirms that a 30% threshold for the arterial corridor analysis was appropriate. Sensitivity analysis results can be found in Appendix F.

A second method of calculating NRC was investigated as part of this study. In the original methodology, NRC was only calculated if the travel time was 30% more than the recurring travel time. The second method of calculating NRC includes this additional criterion: for intervals where recurring delay was lower than the free flow threshold and when non-recurring travel time was above the free flow threshold, NRC was calculated as the difference between non-recurring travel time and free flow travel time. The threshold is 30% for arterials. Analysis results can be found in Appendix G. This second method of calculating NRC was applied to weekday data from the 35th Avenue corridor. NRC using this method was 13.10% compared to the original NRC of 10.57% for this corridor. Since the difference in the NRC percentage is small, the original methodology is suitable for this study.

Impact of NRC

Figure 3-6 shows the total weekday congestion as 91% recurring and 9% non-recurring. Figure 3-7 and Figure 3-8 break down the weekday NRC causes and the different combinations of those causes, respectively.

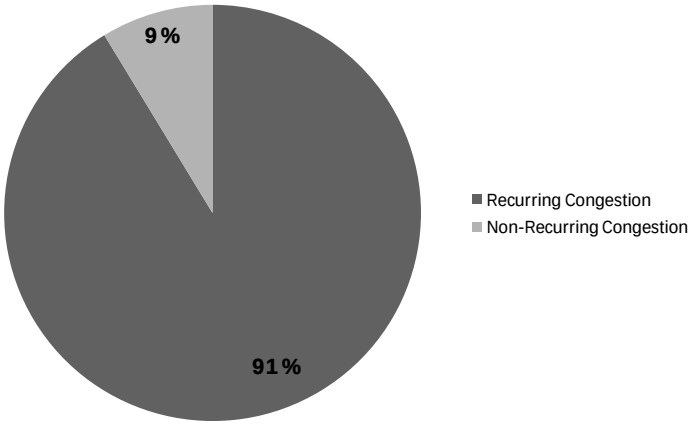

Figure 3-6. Weekday Arterial Roadway Causes of Congestion

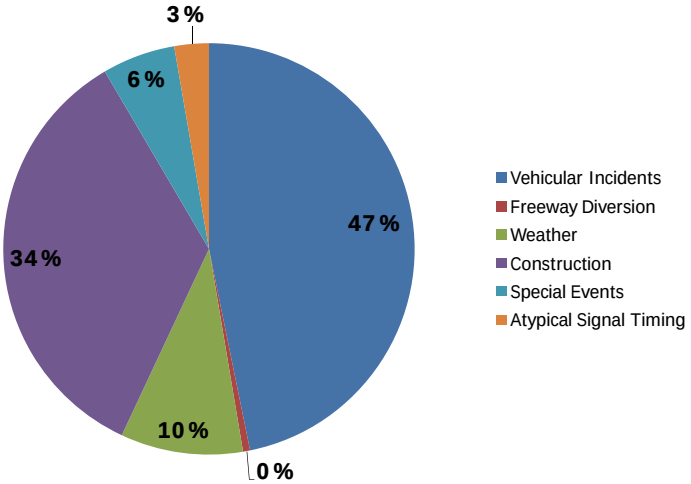

Figure 3-7. Weekday Arterial Roadway NRC Causes

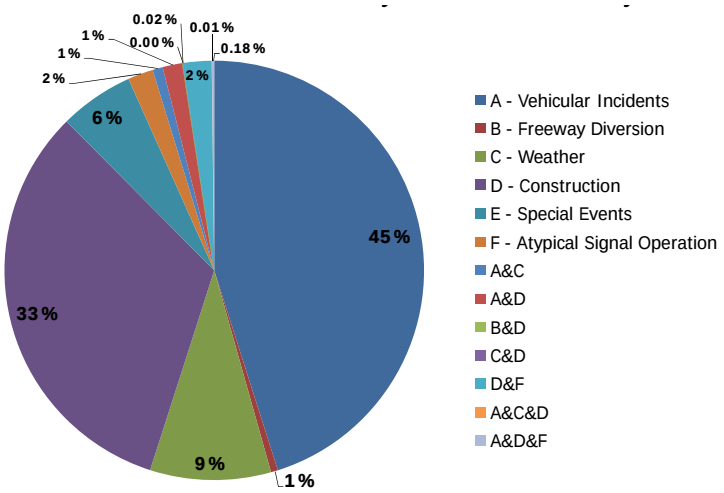

Figure 3-8. Combinations of Weekday Arterial NRC Causes

Figure 3-9 shows the total weekday peak hour's congestion as 92% recurring and 8% non-recurring. Figure 3-10 and Figure 3-11 break down the weekend NRC causes and the different combinations of those causes, respectively.

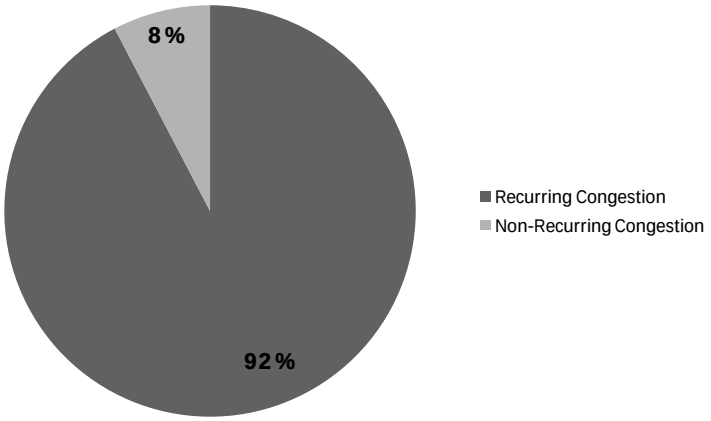

Figure 3-9. Weekday Peak Hours Arterial Roadway Causes of Congestion

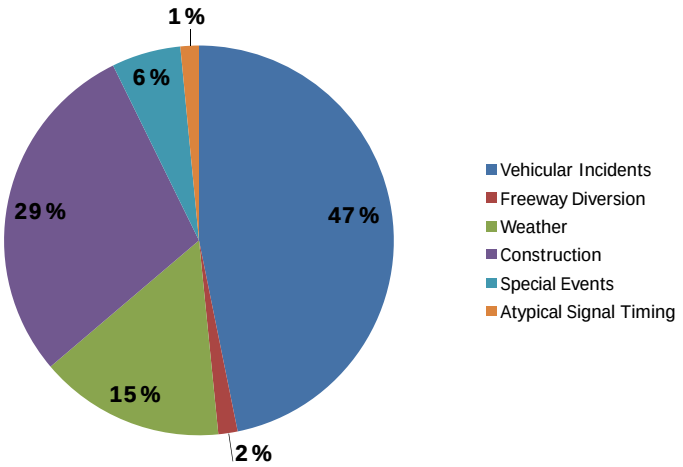

Figure 3-10. Weekday Peak Hours Arterial Roadway NRC Causes

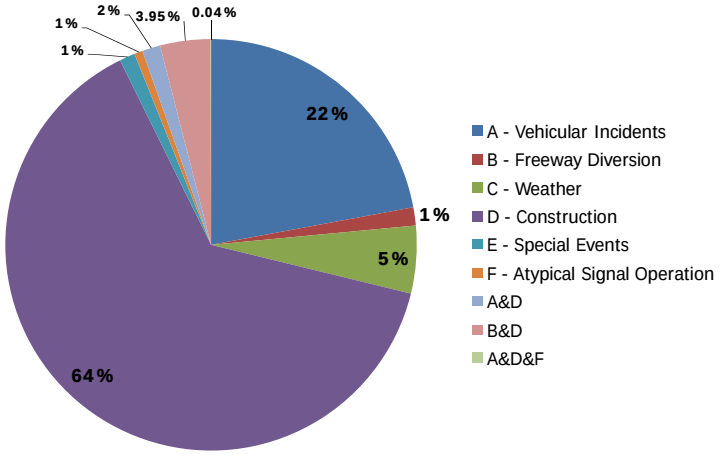

Figure 3-11. Combination of Weekday Peak Hours Arterial NRC Causes

Figure 3-12 shows the total weekend congestion as 85% recurring and 15% non-recurring. Figure 3-13 and Figure 3-14 break down the weekend NRC causes and the different combinations of those causes, respectively.

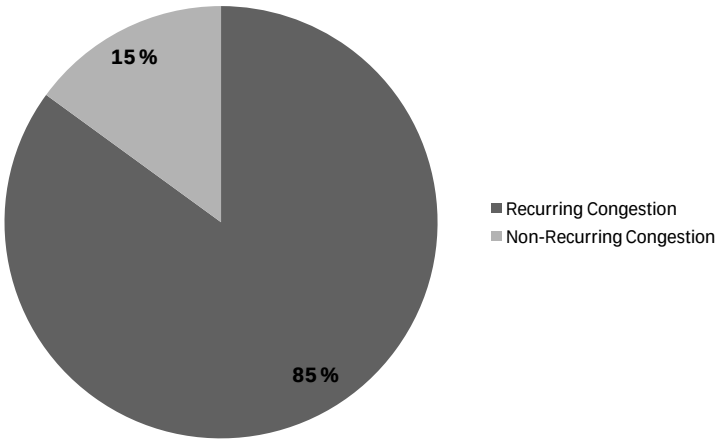

Figure 3-12. Weekend Arterial Roadway Causes of Congestion

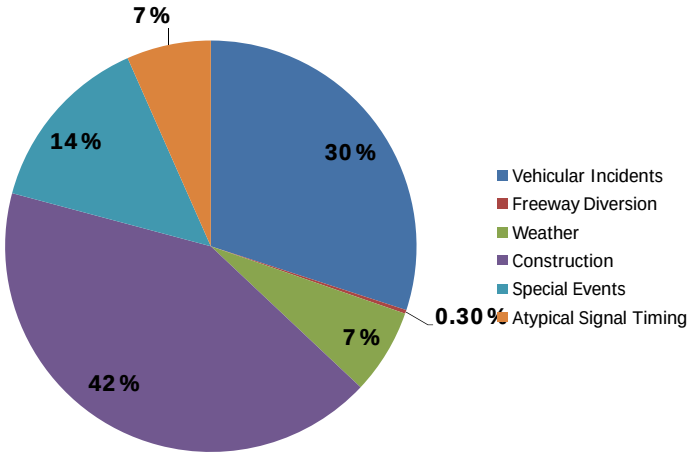

Figure 3-13. Weekend Arterial Roadway NRC Causes

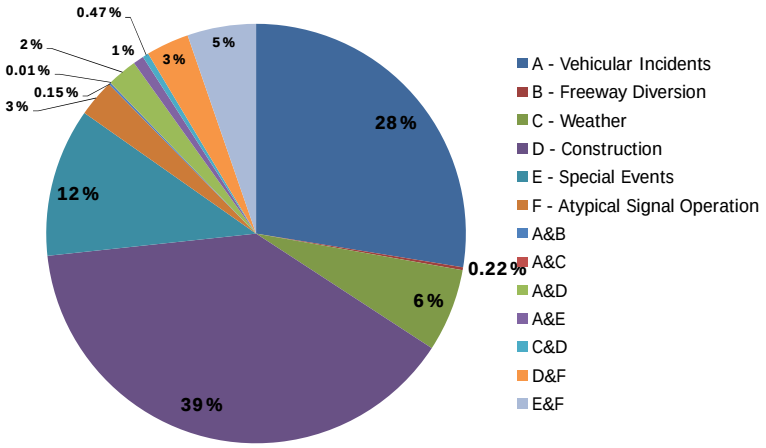

Figure 3-14. Combination of Weekend Arterial NRC Causes

Extrapolation of Congestion

There are an estimated 1.96 million vehicle-miles occurring daily on the study corridors. Regional estimates of arterial vehicle-miles from 2007 indicate 35 million vehicle-miles occur per day. By comparing these totals, the studied corridors could represent about 5.6% of the arterial traffic occurring in the metropolitan area. The observed/computed delay caused by NRC accumulated from the study corridors during the collection periods was about 1,280 vehicle-hours per day. For the same period of time, the delay estimate for the metropolitan area (other 94.4%) would be about 22,850 vehicle-hours per day. This regional estimate is likely overestimated in that the study corridors were chosen for their propensity for NRC such that the other arterials comprising the regional total would likely experience less NRC.

Study Segments NRC Vehicle-Hours of Delay per Weekday[1]	1,170
Study Segments NRC Vehicle-Hours of Delay per Weekend Day/Holiday[1]	1,558
Study Segments Weighted Daily Average NRC Vehicle-Hours of Delay[2]	1,280
Estimated Percentage of All Regional Arterials Represented by Study Segments[3]	5.6%
Estimated NRC Vehicle-Hours of Delay per Day for the All Regional Arterials[4]	22,850

Notes
1 - Based on collected data/calculations
2 - Simple weighting based number of days for a typical week
3 - Estimated based on 1.96 M veh-mi occurring on study segments, and 35 M veh-mi (2007 data) for regional arterials
4 - Study Segments Daily Average NRC Delay divided by Estimated Proportion of Regional Arterials

The composition of the arterial traffic region-wide can be estimated as follows (see next subsection for supporting information): about 97% personal vehicles, about 2% trucks, and less than 1% transit (buses). Based on ridership estimates, vehicle occupancy rates, and road user costs (which include

value of time, operating costs, etc.), the per-vehicle cost per hour of delay is estimated to be: almost $96/hour for buses; $106/hour for trucks; and about $28/hour for personal vehicles. At these rates, and given the estimated mode splits, delay caused by NRC costs vehicles (and their occupants) about $29.90 per hour. So, the regional cost relating to NRC on arterials is about $683,000 dollars per day.

Freight and Transit

Some of the study corridors were divided by crossing railroad (35th Avenue & Rural Road) or light rail lines (7th Street & Rural Road). Since the traffic delays generated by these regular impedances would be considered part of the normal traffic operating conditions, they were not considered sources for non-recurring congestion.

Of the 71 centerline miles studied, approximately 2.5 miles do not have Valley Metro bus services. These corridors are 51st Avenue from Greenway to Thunderbird, 51st Avenue from Van Buren Street to Buckeye Road, and Rio Salado Parkway from Mill Avenue to Rural Road. Rio Salado Parkway from Mill avenue to Packard Drive does have FLASH, which is a Tempe-sponsored local bus service serving the ASU campus. The following information breaks down typical traffic conditions for the purpose of highlighting the relative costs of transit, trucks, and personal vehicles.

	Overall Traffic Composition		
	Transit (Bus)	Freight (Trucks)	Autos
Weekday 7AM-7PM Volume (vehicles)[1]	23,000		
Representative Hourly Volume (vehicles)	1,900		
Avg. Bus Headway per Direction (minutes)[2]	22		
Truck Percentage[3]		2%	
Number of Buses per Hour	6		
Number of Trucks per Hour		38	
Number of Autos per Hour			1,856
Avg. Vehicle Occupancy (at any one time)[4]	5.97	1.00	1.19
Road User Cost ($/hour)[5]	$ 16.00	$ 106.00	$ 24.56
Road User Costs per Average Vehicle ($/hour)[6]	$ 95.52	$ 106.00	$ 27.60
Costs Incurred on Corridor for the Hour[7]	$ 573.12	$ 4,028.00	$ 51,228.65
Percentage of Corridor Road User Costs	1%	7%	92%

Notes

1 Based on average of NRC studied corridors

2 From a GIS review of July 2010 transit routes for peak time operation

3 Typical value used for urban arterials, supported by data from 2006 MAG Vehicle Occupancy Study

4 Transit value estimated calculated from Valley Metro ridership information systemwide; Auto value from 2006 MAG Vehicle Occupancy Study

5 Road user costs for Transit User based on 2009 TTI study that presented estimated value of time for a passenger in an automobile (i.e., no operating/owner costs included) as $16/hr. The Freight User Cost ($106/hr) was based on the 2009 TTI study which showed its user costs as comprised of value of time, fuel, depreciation, interest, general maintenance, tires, repairs, and other similar costs. Estimate of Auto User Costs comprised of basic value of time cost ($16/hr) plus Lee Engineering estimated operating costs of $8.56/hr given a driver's average annual mileage of 12,500 miles and IRS $0.50 reimbursement per mile.

6 Road user costs multiplied by average vehicle occupancies. For Autos, first occupant assumed to bear ownership costs while additional occupant(s) assumed to incur user costs the same as a Transit user.

7 Costs based on persons (or vehicles in the case of Trucks), with the cost to the Auto passengers (i.e., non-owner) applied at the Transit Road User Cost rate

FREEWAY DATA COLLECTION & ANALYSIS

To identify the top five freeway corridors below, the Team reviewed 2007-2009 sensor data from ADOT's Freeway Management System (FMS) that was used in the Urban Mobility Report. These corridors, or test sections, are also shown in Figure 3-15. These sections had the lowest reliability as measured by the planning index. The Planning index is statistically defined as the 95th percentile Travel Time Index (ratio of the average peak period travel time to an off-peak travel time). The Planning Index represents the extra time most travelers include when planning peak period trips. For example, a value of 1.60 means that travelers plan for an additional 60% travel time above the off-peak travel times to ensure 95% on-time arrival.

1. Loop 202 WB: 46th St to 22nd St
2. US 60 EB: I-10 to Loop 101
3. I-17 SB: Stack @ I-10 to I-17/I-10 Split
4. I-10 WB: Ray Road to Southern Ave
5. I-10 WB: Mini Stack @ L202/SR 51 to Stack @ I-17

<u>Freeway Traffic Data Reduction</u>
The freeway traffic data and incident data needed to be reduced and combined into an aggregate database for evaluation of non-recurring congestion. The 2009 freeway traffic data from ADOT's Freeway Management System was reduced to five-minute average speeds, travel times, and volumes. This data manipulation was done using Statistical Analysis System (SAS) routines developed by TTI as part of FHWA's national Urban Congestion Report Program.

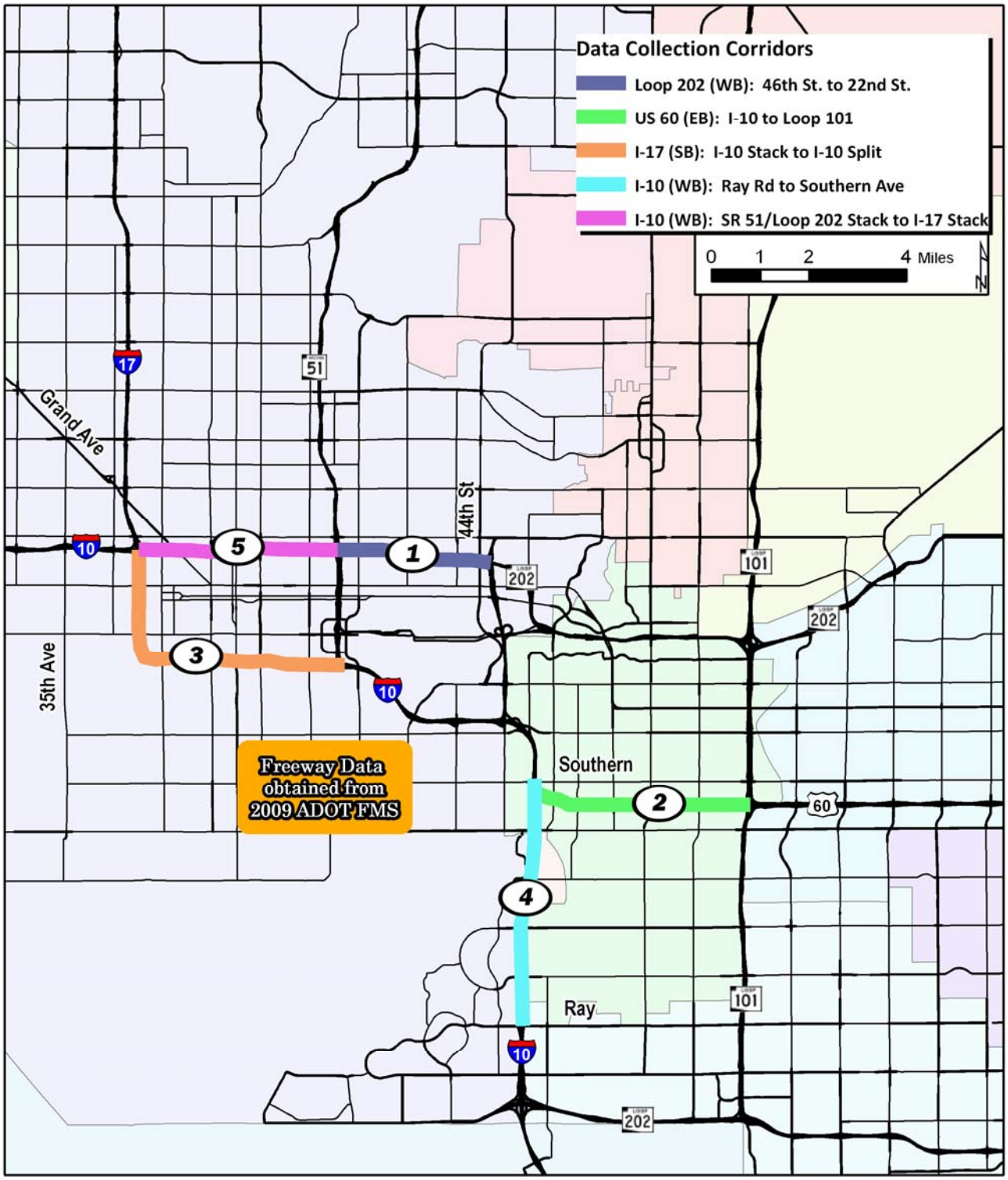

Figure 3-15. Freeway Study Corridors

Non-Recurring Congestion (Incident) Data Reduction

Incident data were in the general terms for crashes or vehicle breakdowns, work zones, weather events, and special events. For the incident data, private data from NAVTEQ/Traffic.com was used to identify incidents on the test corridors. The exception to this was weather related data. The entire 2009 database was reduced by the following steps:

1. Using latitude and longitude coordinates, NAVTEQ/Traffic.com incidents were plotted on a map to filter out potential incidents that could impact traffic along the test sections. With the exception of weather events, incidents that fell in sections within 1-mile of the test sections were also included to account for potential impacts resulting from downstream queues or upstream incidents.
2. Incidents were classified as one of four primary nonrecurring causes: Vehicular Incidents (crashes, disabled vehicles, debris, etc.), Weather, Construction, and Special Events. Each incident was input into the appropriate 5-minute interval according to its start and end time.
3. A code was assigned to each incident type according to the field definitions as shown in Appendix H. Generally, this code described the "severity" of the incident such as the number of lanes blocked during a crash. Note that if more than one vehicular incident and/or construction event occurred at the same time, the one that resulted in the most blocked lanes was input for that 5-minute interval.
4. Special events were limited to events that took place in major venues such as Chase Field or US Airways Center. These venues were within approximately 1.5 miles of the test sections and were selected based on local knowledge. This resulted in three of the five sections being potentially affected. Although there were other venues within 1.5 miles, they were geared towards concerts and had smaller capacities such as the Celebrity Theater and Dodge Theater in downtown Phoenix. Parades, demonstrations, foot and bike races, etc. in downtown Phoenix were not counted because the reported start and end times ranged from limited hours to all weekend and it was assumed that traffic to these events would not significantly affect operations on the surrounding freeways. The ASU games at the Tempe Diablo Stadium were not counted because it was just beyond the 1.5 mile range for the US 60 EB section and it was noted that it is not the primary freeway used by the game traffic.

An analysis of vehicular incidents collected by RADS and NAVTEQ/Traffic.com on I-10 WB from I-17 to SR 51 for the months of January 2009 and February 2009 was conducted for this study. Table 3-9 show the results of this comparison. The comparison of the two incident sources revealed that NAVTEQ/Traffic.com captured more vehicular incidents than RADS on freeways. This is an opposite trend than what was seen on arterials.

Table 3-9. 35th Avenue RADS vs. NAVTEQ/Traffic.com Incident Comparison

Traffic.com	**Jan '09**	**Feb '09**	**Jan + Feb**
Accident	35	31	66
Disabled Vehicle	7	5	12
Miscellaneous	1	0	1
Total Traffic.com	43	36	79
RADS			
Accident involving a pedestrian	1	2	3
Accident involving hazardous materials	1	0	1
Incident	0	1	1
Injury Accident	13	8	21
Vehicle on Fire	3	2	5
Medical Emergency	4	4	8
Total RADS	22	17	39
% of Traffic.com	**51%**	**47%**	**49%**

Weather

Because weather events are so isolated in the MAG region and the fact that Weather Underground has the closest data points to the test sections (NOAA data was limited to only airports within MAG area), it was decided to utilize Weather Underground's data for both the freeway and arterial test sections. Weather stations (one or more) within the *wunderground.com* network of stations were assigned to certain freeway corridors based on proximity and other factors relative to the corridor (see Figure 3-16). The stations record a variety of weather conditions such as temperature, humidity, wind speed/direction, and rainfall recorded (and the rate at which it fell). The rainfall rate data was used in conjunction with same threshold value established for the arterial corridors to determine when weather events may be attributable to non-recurring congestion.

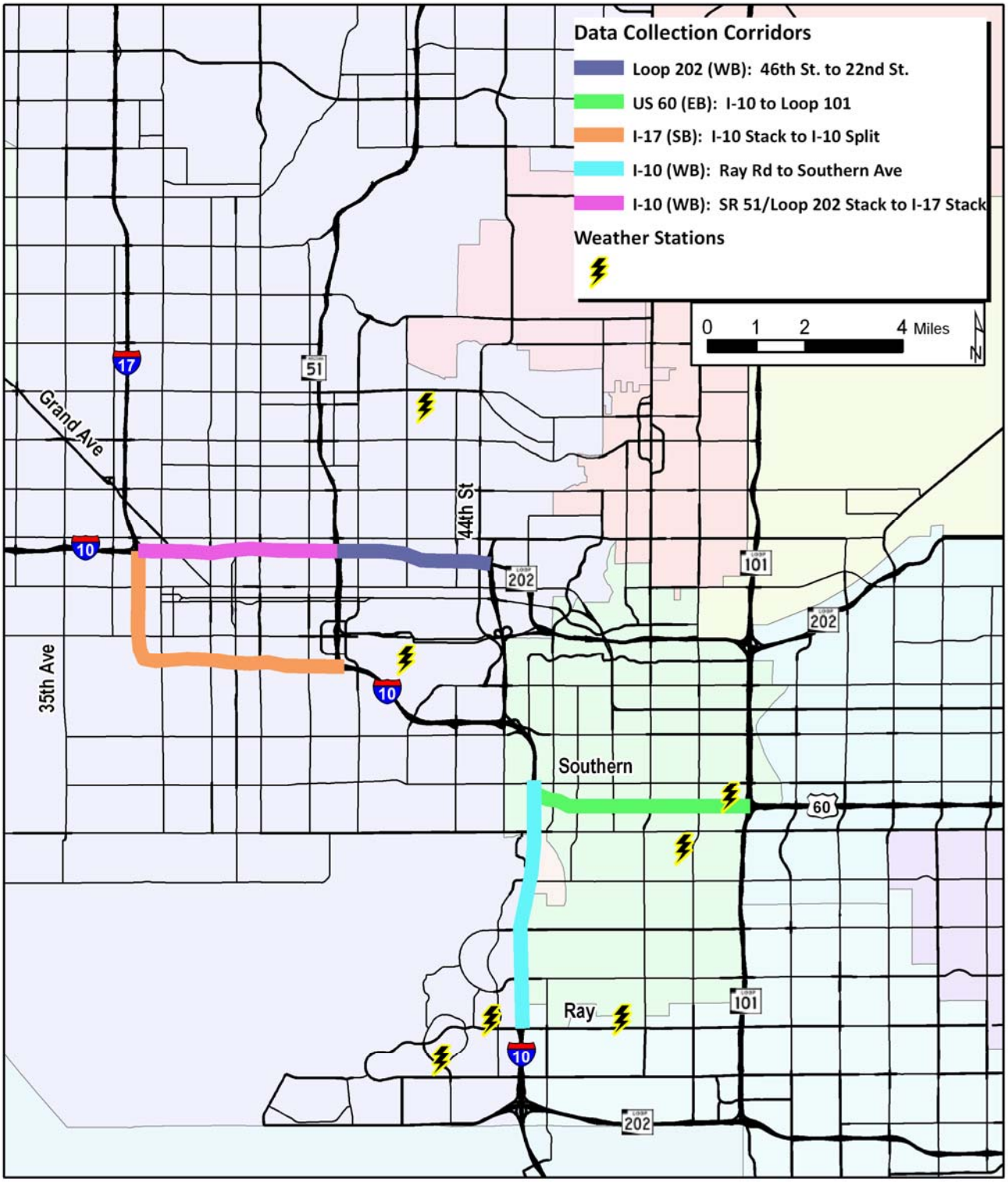

Figure 3-16. Weather Stations Relating to Freeway Study Corridors

Delay and Impact of NRC

The following steps were taken to calculate the recurring and nonrecurring congestion from the traffic data and incident data.

1. Calculate the "Normal" Recurring Speeds, Travel Time, and Volumes

Weekday example

1. Removed weekend days and holidays. This step was different than other studies but the Project Team wanted to account for weekday vs. weekend traffic and its impacts on congestion. It was noted there seemed to be more special events and construction on weekends vs. weekdays thus it was believed that the congestion impacts would in fact be different.
2. Removed intervals with any crashes, construction, weather, or special events
3. Calculate average speed, travel time, and volume from remaining "Normal" intervals

There were 525,600 five-minute intervals total for the five test sections. For weekday calculation, we used 275,695 intervals out of 375,840 (73%). For weekend, we used 110,553 intervals out of 149,760 (74%).

2. Non-Recurring Congestion (NRC) calculation

NRC, or NRC delay, is the difference between the recurring travel time (calculated in step 1) and the actual travel time during a NRC event. To account for the variability in "normal" travel time and speed, NRC was only calculated when this difference was greater than least 15 percent. This was based on visual inspection of numerous examples. Table 3-10 below shows range of the difference in travel time and speed at the different thresholds examined.

Table 3-10. Travel Time Difference (Congestion Thresholds)

	Weekday		Weekend	
Travel Time Difference (%)	Travel Time Difference (sec)	Speed Difference (mph)	Travel Time Difference (sec)	Speed Difference (mph)
5	9-35	1-3	9-24	2-3
10	20-68	3-6	20-45	5-6
15	31-100	4-8	31-68	7-8
20	43-131	5-10	42-86	9-10

One issue with merging the traffic data and incident data was that there were instances in which the full effects of the NRC due to crashes may not have been captured. If the start and end times of that crash are used from the incident data, the full congestion may not be included in that time interval. For example, Figure 3-17 on the following page shows there is delay well after the recorded end time of the crash. After further examination, the NRC was adjusted to include any delay that was 10 minutes before the start time or 3 hours after the end time, provided that it met the 15 percent threshold and there was no other NRC event present. The 10 minutes before the start time accounted for delay between the actual start time and the time it is reported. The 3 hours after the end time

accounted for residual delay even after the incident has been cleared and the affected lanes have been reopened to traffic. Although the duration varies, this residual delay has been observed and documented in other studies.

Finally, the difference in travel time was multiplied by the recurring volume for each time interval to convert the NRC to vehicle-hours.

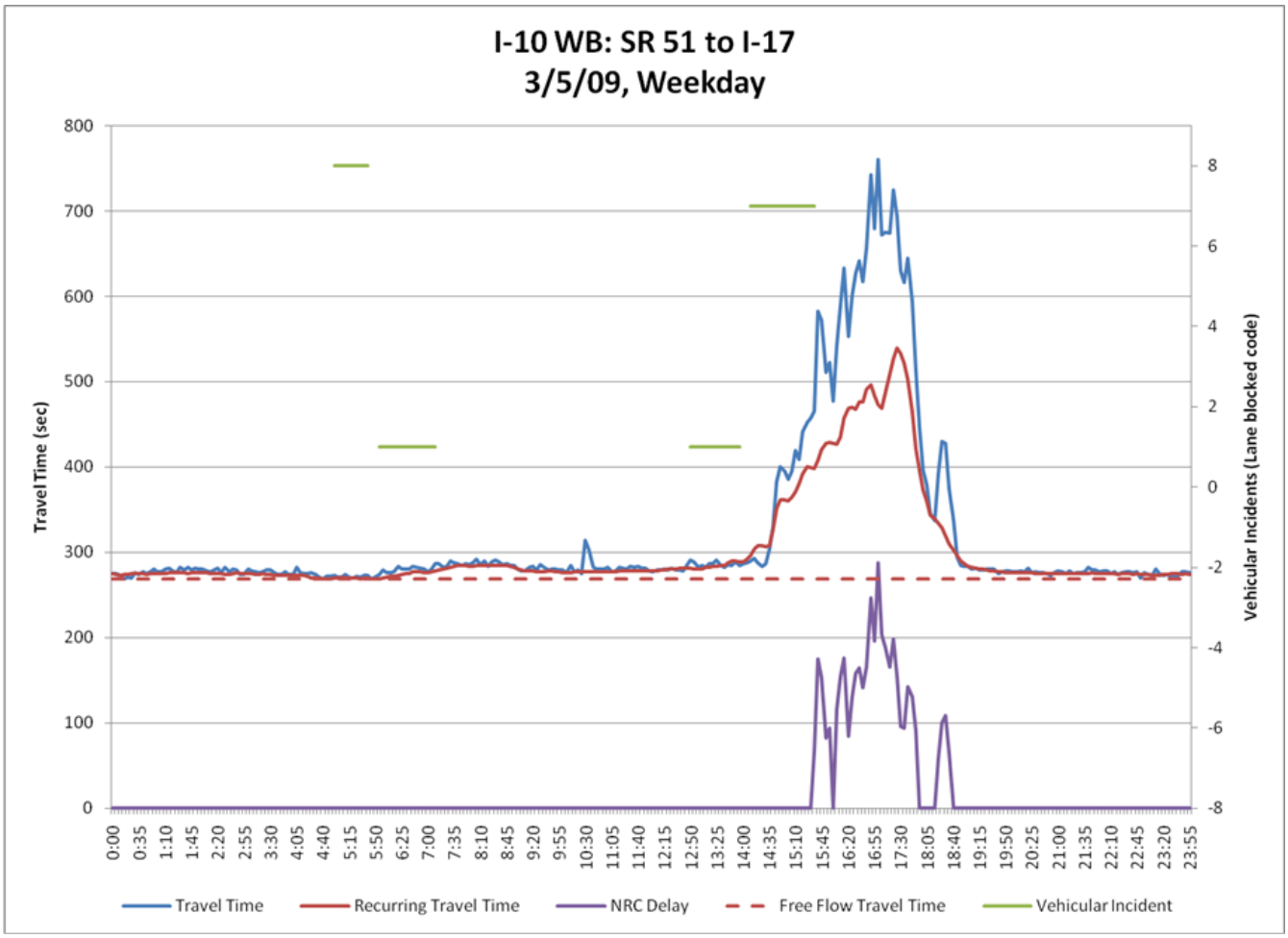

Figure 3-17. Residual Nonrecurring Congestion Example

3. Recurring Congestion calculation

Recurring congestion is the difference between the free flow travel time (minimum travel time of recurring travel time) and the recurring travel time (calculated in step 1) multiplied by the recurring volume for each interval without a NRC event. Recurring congestion was only calculated when this difference was greater than 15 percent.

4. Non-recurring Congestion (NRC)

The NRC delay was divided among 15 different possible combinations. For example, 1=vehicular incidents, 2=weather...1+2=vehicular incident + weather and so on. Each NRC combination was proportioned to the same congestion breakdown in the Cambridge Systematics/TTI study as shown in Figure 3-3. These proportions were summed to get the total percentages for the four primary causes: Vehicular Incidents, Weather, Construction, and Special Events.

Results

Table 3-11 shows the total weekday congestion as 54% recurring and 46% non-recurring. These results are very similar to past studies which show NRC between 50-70 percent of total congestion. Figures 3-13 and 3-14 break down the NRC causes by the primary ones and the different combinations of those causes ("SE" is special events).

Table 3-11. 2009 Weekday Recurring and Nonrecurring Congestion (vehicle-hours)

Section	Recurring	NonRecurring	Total	% Recurring	% NonRecurring
US 60 EB I-10 to Loop 101	23,299	82,017	**105,316**	22%	78%
I-10 WB Gold Poppy to Southern	140,080	39,324	**179,404**	78%	22%
I-17 SB I-10 to I-10	2,874	13,822	**16,696**	17%	83%
I-10 WB SR 51 to I-17	89,167	97,491	**186,658**	48%	52%
Loop 202 WB 46th St to 22nd St	68,514	40,407	**108,921**	63%	37%
Total	**323,933**	**273,062**	**596,994**	**54%**	**46%**

Similar to the arterial analysis, a second method of calculating NRC was investigated as part of this study. In the original methodology, NRC was only calculated if the travel time was 15% more than the recurring travel time. The second method of calculating NRC includes this additional criterion: for intervals where recurring delay was lower than the free flow threshold and when non-recurring travel time was above the free flow threshold, NRC was calculated as the difference between non-recurring travel time and free flow travel time. The threshold is 15% for freeways.

This method of calculating NRC was applied to weekday freeway data. NRC estimates per this second method were 47% compared to the original NRC of 46% for all freeway sections. Since there is essentially no difference in the NRC percentage, the original methodology is suitable for this study.

The next figure shows the breakdown of the causes of non-recurring congestion. The cause of congestion was assigned to the primary cause of congestion. In cases where two causes were happening simultaneously, the cause was proportioned to each cause. Figure 3-18 shows that weekday nonrecurring congestion was overwhelmingly due to vehicular incidents (80%) followed by construction (16%) then special events (3%) and weather (1%).

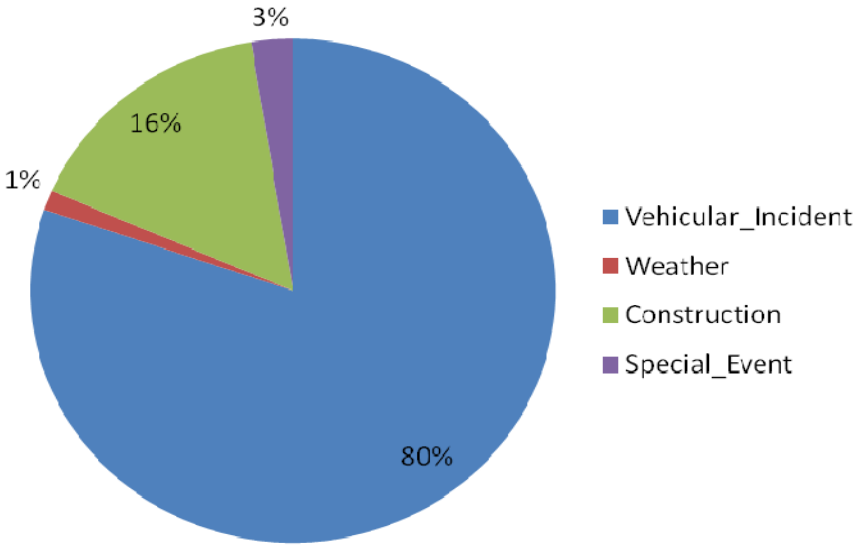

Figure 3-18. 2009 Weekday NRC Causes on Test Sections

The next figure shows the breakdown of the causes by each cause of non-recurring congestion including the combination of causes. Figure 3-19 also show that weekday nonrecurring congestion is mainly due to vehicular incidents (75%) followed by construction (14%) but it also shows that the combination of them made up 6% of the NRC.

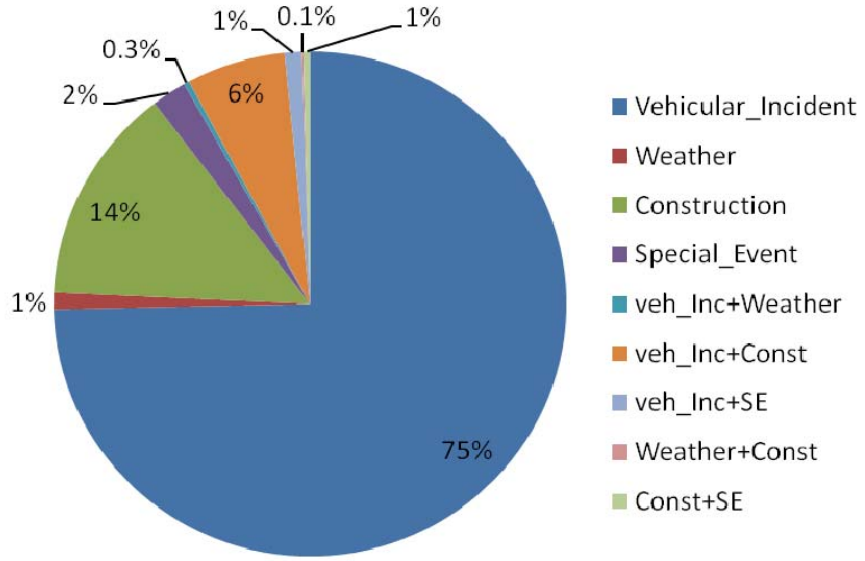

Figure 3-19. 2009 Weekday Combinations of NRC Causes on Test Sections

The same analysis was done for the weekend data. Table 3-12 shows the total weekend congestion as all non-recurring. In other words, there was no recurring congestion that exceeded the 15 percent threshold on weekends. This finding makes sense because there is very little commuting weekend traffic that may cause recurring congestion. Similar to weekdays, Figures 3-20 and 3-21 break down of the NRC causes by the primary and the different combinations of causes ("SE" is special events).

Table 3-12. 2009 Weekends Recurring and Nonrecurring Congestion (vehicle-hours)

Section	Recurring	NonRecurring	**Total**	% Recurring	%NonRecurring
US 60 EB I-10 to Loop 101	0	18,167	**18,167**	0%	100%
I-10 WB Ray to Southern	0	74	**74**	0%	100%
I-17 SB I-10 to I-10	0	2,567	**2,567**	0%	100%
I-10 WB SR 51 to I-17	0	2,097	**2,097**	0%	100%
Loop 202 WB 46th St to 22nd St	0	2,741	**2,741**	0%	100%
Total	**0**	**25,645**	**25,645**	**0%**	**100%**

As might be expected, Figure 3-20 paints a different picture of the NRC breakdown compared to weekdays. This figure shows that weekend nonrecurring congestion was evenly split between vehicular incidents (45%) and construction (46%). Special events also increased from 3 to 7 percent. These results likely reflect ADOT's encouragement of nights and weekend construction and the nights and weekend special events schedule.

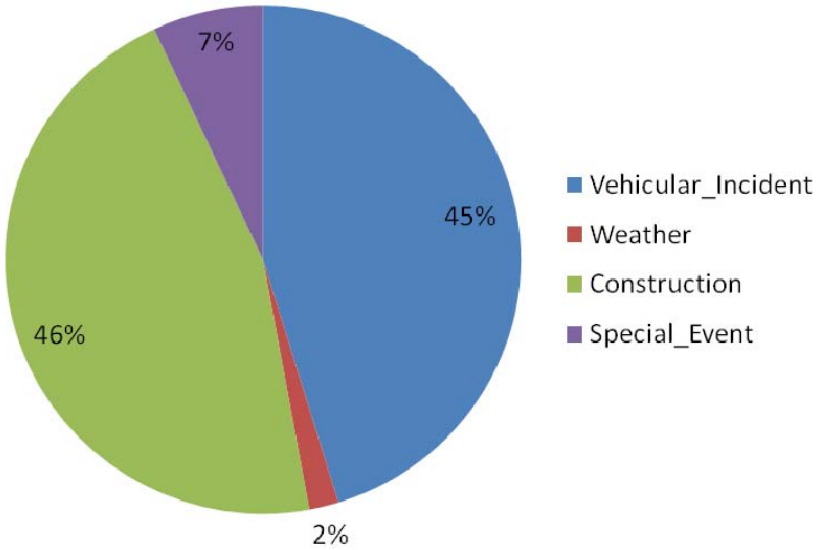

Figure 3-20. 2009 Weekend NRC Causes on Test Sections

When the analysis includes the primary causes and the combinations, Figure 3-21 show construction related congestion being the highest on weekends at 41% closely followed by vehicular incidents at 39%. Similarly to Figure 3-19, it also shows that the combination of them is 6% of the NRC.

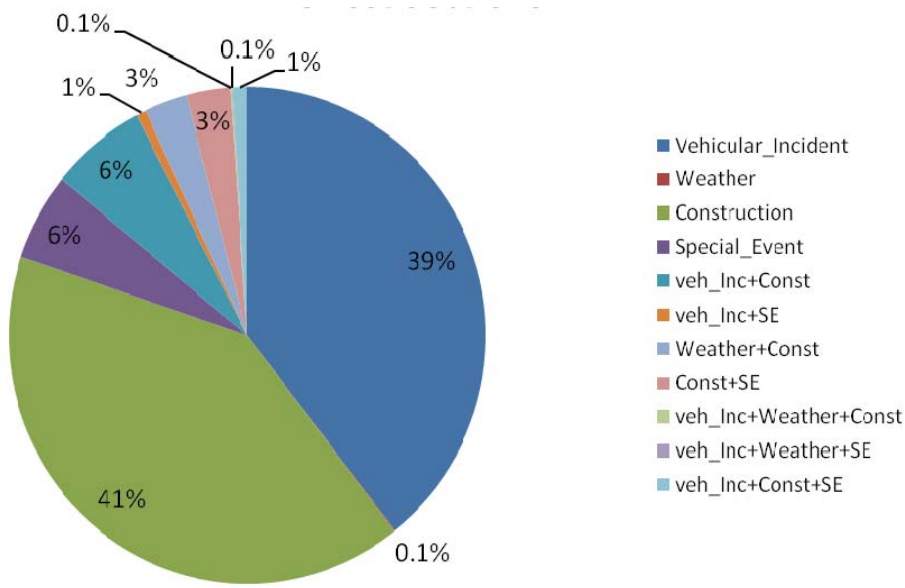

Figure 3-21. 2009 Weekend Combinations of NRC Causes on Test Sections

Extrapolation of Congestion

The final step was to expand the recurring and nonrecurring congestion from these five test sections to the rest of MAG's freeway system. Table 3-13A shows that the total vehicle miles traveled (VMT) for the five test sections is 6 percent of the systemwide VMT. Dividing the systemwide VMT by the test section's total VMT yielded an expansion factor of 17. This factor was mulitplied by the sum of the weekday (W) and weekend (WE) congestion to derive at the grand total of 10.6 Million vehicle-hours (MVH) of congestion.

Table 3-13a. Annual Total Freeway Congestion (vehicle-hours)

Test Sections	VMT	W+WE Recurring	W+WE NonRecurring	Total
I-10 WB: SR 51 to I-17	469,314	89,167	99,588	188,755
I-17 SB: I-10 to I-10	347,033	2,874	16,389	19,263
Loop 202 WB: 46th St to 22nd St	232,888	68,514	43,148	111,662
I-10 WB: Ray to Southern Ave	459,935	140,080	39,398	179,478
US 60 EB: I-10 to Loop 101	265,434	23,299	100,184	123,483
Total	**1,774,603**	**323,933**	**298,707**	**622,640**
Systemwide	**29,450,000**	**5,506,858**	**5,078,017**	**10,584,875**

Note: Systemwide VMT based on 2007 HPMS data.

Alternatively, the total freeway congestion was also estimated for only the 52 sections that are instrumented with traffic sensors. These sections make up approximately 43 percent of the lane miles but about 50 percent of the VMT within the urban area. This method resulted in an expansion factor of 8. Thus, the grand total was 4.9 MVH for the 52 instrumented sections.

Table 3-13b.Annual Total Freeway (Instrumented Sections Only) Congestion (vehicle-hrs)

Test Sections	VMT	W+WE Recurring	W+WE NonRecurring	Total
I-10 WB: SR 51 to I-17	469,314	89,167	99,588	188,755
I-17 SB: I-10 to I-10	347,033	2,874	16,389	19,263
Loop 202 WB: 46th St to 22nd St	232,888	68,514	43,148	111,662
I-10 WB: Ray to Southern Ave	459,935	140,080	39,398	179,478
US 60 EB: I-10 to Loop 101	265,434	23,299	100,184	123,483
Total	**1,774,603**	**323,933**	**298,707**	**622,640**
Systemwide (52 Sections)	**14,801,648**	**2,591,463**	**2,389,655**	**4,981,118**

Regardless of which expansion factor used, recurring and nonrecurring congestion was 52 percent and 48 percent, respectively, of the total congestion.

Freight and Transit

The Team gathered additional data to estimate the impact of NRC on freight and transit operations.

Truck AADT was estimated for freeways from truck factors provided by ADOT. Because trucks operate within the general purpose traffic, trucks will experience similar impacts of congestion and passenger cars. However, the economic impacts would be very different for trucks given that the value of time is significantly higher for commercial trucks as opposed to passenger cars. Thus, the impact on freight operations was estimated in terms of value of time.

Table 3-14 below shows the economic impact of non-recurring congestion on freeway truck traffic. Annually, there is $749 Million cost of non-recurring congestion to freight operations. This cost was calculated by summing the volume for each 10-minute interval where NRC was measured then multiplied by the average truck factor (weighted by section AADT), the value of time of commercial vehicles ($106/hr), and the expansion factor (17).

Table 3-14. Economic Impacts of NRC on Freeway Truck Traffic

	Annual Vehicle-Hours with NRC	Annual Truck-Hours with NRC	Annual $ Impact
Weeday	3,807,293	384,537	$ 692,934,941
Weekend	308,214	31,130	$ 56,095,564
Total	4,115,507	415,666	$ 749,030,505

Valley Metro is the major transit provider within the MAG region. Current “Express” and “RAPID” bus route maps from Valley Metro’s website were reviewed to get the total centerline miles and just the freeway’s portion for each route. Additionally, the daily weekday average ridership for each route was collected from the FY08-09 Annual Ridership Report. The average ridership on each route was calculated by multiplying the percent freeway miles by the annual ridership as shown in Table 3-15.

Table 3-15. Estimated Transit Ridership on Freeways

ID	ROUTE NAME	FWY MI.	TOTAL MI.	% FWY	FY08-09 Ridership	FWY Ridership	No. of Buses
510	Scottsdale Express	11.46	27.0	42%	23,598	10,003	1000
511	Tempe/Scottsdale Airpark	52.28	65.3	80%	10,514	8,412	2000
512	Scottsdale Express	12.8	42.6	30%	20,862	6,272	1000
520	Tempe Express	23	33.8	68%	34,274	23,328	2000
521	Tempe Express	23.0	36.3	63%	58,482	37,112	3250
531	Mesa/Gilbert Express	36.3	47.2	77%	87,105	66,940	3750
532	Mesa Express	30.9	40.9	76%	43,936	33,174	2000
533	Mesa Express	51.4	61.3	84%	103,170	86,509	2500
535	Red Mountain-Downtown Express	53.2	57.5	93%	28,815	26,663	1500
540	Chandler Express	25.1	40.3	62%	52,890	33,007	2000
541	Chandler Express	32.3	47.1	69%	91,703	62,901	2500
542	Chandler Express	49.7	54.4	91%	21,159	19,317	2000
560	Avondale Express	17.4	37.1	47%	17,783	8,350	1000
562	Goodyear-Downtown Express	30.7	37.1	83%	29,834	24,724	1500
573	Northwest Valley-Downtown Express	51.4	56.9	90%	54,641	49,418	3000
575	Northwest Valley-Downtown Express	44.4	50.5	88%	34,712	30,519	1500
581	North Mountain Express	16.6	34.3	48%	27,888	13,488	1500
582	North Mountain Express	14.0	28.4	49%	25,877	12,776	2000
590	Deer Valley Express	22.7	33.9	67%	31,884	21,365	2000
	EXPRESS Total	**598.7**	**831.8**	**72%**	**799,127**	**574,278**	
R1	SR-51 RAPID	28.4	48.6	58%	198,452	115,973	6500
R2	I-10 East RAPID	35.2	40.0	88%	233,318	205,502	7750
R3	I-10 West RAPID	17.52	24.6	71%	182,322	129,733	6750
R4	I-17 RAPID	26.68	38.3	70%	321,830	224,406	10750
	RAPID Total	**107.8**	**151.4**	**71%**	**935,922**	**675,615**	
	Grand Total	**706.5**	**983.3**	**72%**	**1,735,049**	**1,249,893**	**69,750**

Dividing the total freeway ridership by the total number of busses yields an average of 17.9 passengers per bus. Assuming these busses are part of the total weekday non-recurring congestion vehicle-hours, then there are 1.2 Million transit person-hours NRC delay as shown in Table 3-16. Using a value of time of $16/hr, there is $19.9 Million annual cost of non-recurring congestion on transit operations.

Table 3-16. Economic Impacts of NRC on Transit (Freeways)

	Weekday NRC Veh-Hrs	Transit Person-Hrs	Annual $ Impact
Test Sections	273,062		
Systemwide	4,642,046	1,246,389	$ 19,942,229

Appendix A

24 Hour Arterial Volume Data

(PDF)

Appendix B

RADS Arterial Vehicular Incidents Data

(Excel)

Appendix C

AWAM Databases

(electronic only, open with Excel 2007 or later)

Appendix D

Arterial NRC Analysis Summary

(PDF)

Appendix E

Arterial Analysis Charts and Tables

(electronic only, open with Excel 2007 or later)

Appendix F

Arterial Sensitivity Analysis Results

Appendix G

2nd NRC Methodology Analysis Results

Appendix H

Freeway Data Field Definitions

Day of Week			
null	weekday		
1	weekend		
2	holiday		
3	furlough		
Time of Day (TOD)			
1	6-9 AM, Mon-Fri		
2	3-7 PM, Mon-Fri		
null	NonPeak		
Avg Speed	**No of Samples**		
-1	0	No Data Available	
Vehicular Incident			
1	shoulder/median only		
2	1 lane blocked		
3	2 lane blocked		
4	3 lane blocked		
5	all lanes blocked		
6	HOV lane blocked		
7	Ramp blocked		
8	no lanes blocked or unknown number of lanes blocked		
Weather			
Code	Intensity (in/hr)		Event
null	NA	NA	Clear/Overcast/Partly Cloudy to Mostly Cloudy/Haze/Unknown/Fog
1	light	0.10	Light Rain
2	0.11	0.30	Moderate Rain
3	> 0.30		Heavy Rain
4	NA	NA	Windy/Dust Storm
source: www.weatherunderground.com			
According to the Federal Meteorological Handbook No.1,			
the intensity of precipitation shall be identified as light, moderate,			
or heavy in accordance with one of the following:			
(a) **Intensity of Rain or Ice Pellets**. The intensity of rain and ice pellets shall be based on			
the criteria given in Table 8-1, Table 8-2, and Table 8-3.			
Table 8-1. Intensity of Rain or Ice Pellets Based on Rate-of-Fall Intensity Criteria			
Light Up to 0.10 inch per hour; maximum 0.01 inch in 6 minutes.			
Moderate 0.11 inch to 0.30 inch per hour; more than 0.01 inch to 0.03 inch in 6 minutes.			
Heavy More than 0.30 inch per hour; more than 0.03 inch in 6 minutes.			
Work Zone		**Work Zone/Scheduled Construction (Freeways)**	
null	no	0	unknown number of lanes blocked
1	yes	1	shoulder/median only
		2	1 lane blocked
Scheduled Construction		3	2 lane blocked
null	no	4	3 lane blocked
1	yes	5	all lanes blocked
		6	HOV lane blocked
Special Event		7	Ramp blocked
null	no		
1	yes		