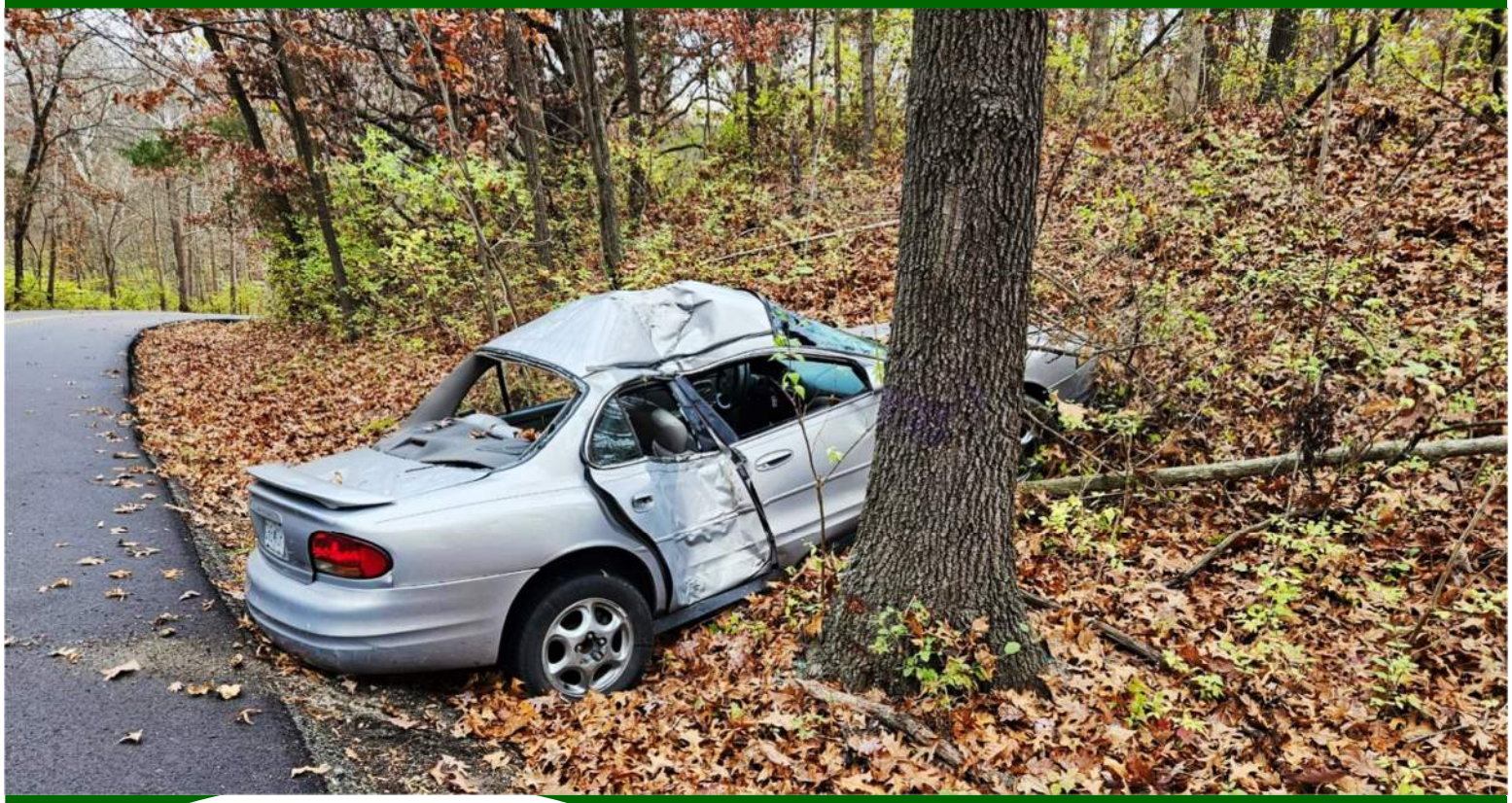
TERRA ENGINEERING LTD.

CITY OF WELDON SPRING
"BACK" WOLFRUM ROAD SAFETY STUDY



PROJECT ADDRESS

Wolfrum Road from MoDOT
Right-of-Way to Whitmoor Dr.
Weldon Spring, MO

PREPARED BY

Michael C. Hutchinson, P.E., PTOE
Senior Traffic Engineer

PREPARED FOR

City of Weldon Spring
5401 Independence Rd
Weldon Spring, Missouri 63304

DRAFT REPORT DATE

December 14, 2023

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

EXECUTIVE SUMMARY

This safety study was undertaken to evaluate the overall safety of the "back" stretch of Wolfrum Road in the City of Weldon Spring, Missouri. This included evaluating the traffic volumes, speeds, horizontal and vertical geometry, roadway width, edge drop-off, curve treatments, and signing along the route.

The analysis showed that the roadway geometry is deficient in several places due to the horizontal and vertical geometry not meeting MoDOT policy and design recommendations for the posted speed limit. This includes tight horizontal curves including a near 90-degree turn along the roadway and numerous vertical grades in the range of 10-15% which can be treacherous in wet or icy conditions. Additionally, the roadway widths were measured to be around 20-21 feet in width in most locations which equates to 10' lanes.

A review of the volumes and speeds collected by TERRA in 2022 and the City of Weldon Spring in 2023 show that a majority of drivers are exceeding the posted speed limit of 35 mph along Wolfrum Road. Over 75% of vehicles were measured to be traveling above the speed limit, with the majority of the drivers between 35-45 mph but many in the 45-50 range and some recorded as high as 70+ mph. These increased speeds with the geometric deficiencies create potential for higher crash rates along the corridor.

A review of the signing along Wolfrum Road shows that the overall signing plan is has improved over the last 15 years as many signs which were not in place have been added. However, it was noted that a number of signs are not functioning as intended as some signs have been struck by vehicles and are leaning to the side or missing completely. Other signs are obfuscated by dirt and debris, weathered, have reduced retroreflectivity, or are small and at locations where oversized signs should be considered for better driver identification. Also, there are several locations which do not provide advance signing or appropriate curvature warning signs.

A review of the crash history over the last 10 years shows 28 total crashes along Wolfrum Road which include 1 fatality and 14 injuries. A majority of these crashes involved vehicles leaving the roadway surface and striking fixed objects and 78% of the crashes occurred at curves. Numerous factors were identified as contributing to the crashes including speeds, pavement conditions, inattentiveness and inability to recover control when leaving the pavement surface. TERRA can investigate and recommend to Weldon Spring various treatments which could be implemented to reduce crashes and improve safety.

SECTION II

BACKGROUND INFORMATION

TERRA Engineering was contracted by the City of Weldon Spring to provide a safety evaluation of "Back" Wolfrum Road which is a 2.5-mile long section of roadway stretching from near Whitmoor Drive on the east to the location where the roadway hits the Missouri Department of Transportation (MoDOT) Right-of-way along Interstate 64 to the west. The roadway is a two-lane section with one lane in each direction of travel and is generally considered a "rural" roadway section.

The roadway through this section has a double yellow centerline stripe down the middle but does not provide edge striping near the outside of the lanes. Shoulders are not present at the edge of pavement. Much of the roadway length contains significant drop-offs at the edge of pavement which make it difficult for a vehicle whose tire has gone off the edge to reestablish control. The roadway has been overlaid numerous times which has raised the pavement elevation making this edge drop-off condition worse.

TERRA estimated the horizontal and vertical alignments along Wolfrum Road using available Light Detection and Ranging (LiDAR) data to develop approximate alignments. The Wolfrum alignment features some drastic vertical changes throughout the length with steep slopes through the study area. The horizontal alignment features numerous curves and reverse curves and a significant approximately 90-degree turn in the roadway near the Strathalbyn Farms Club and Old Wolfrum Road.

TERRA collected crash data along this section of Wolfrum Road from 2013 through 2023 which was available on the Missouri State Highway Patrol reporting website. This site provides data in reported crashes which were responded to by public safety officials. It is important to note that this database may not include all crashes because if the crash is not reported to police, then no report is filed, and they are not included in the database. This may include some minor crashes, single car crashes or cars which may go off the road but only require a tow truck to get back on the road. It is expected that there are more crashes than reported in the database, however the analysis can only consider the information which is public record and available for evaluation.

SECTION III

ROADWAY GEOMETRY

Wolfrum Road is functionally classified as a major rural collector. Geometric design features should be consistent with a design speed appropriate for the roadway. TERRA's team analyzed both the horizontal and vertical geometry to determine whether geometric conditions are present that may be contributing to the crashes. Wolfrum Road has a posted speed of 35 miles per hour (mph) which is an important factor for defining applicable design policy and standards.

For this project, TERRA utilized LiDAR data from the Missouri Spatial Data Information Service (MSDIS). The LiDAR data was utilized to generate a three-dimensional surface approximating the elevation of the roadway throughout the project limits. TERRA also approximated the horizontal roadway centerline of Wolfrum Road using aerial imagery.

Horizontal Geometry

According to the Engineering Policy Guide (EPG) published by the Missouri Department of Transportation (MoDOT), the minimum horizontal length of curve should be 525 feet for posted speed of 35 mph. Most curves along Wolfrum Road do not meet this policy. The shortest curve length is 127.8 feet, located at the intersection of Wolfrum Road and Willow Lake Ct. The only curve within our project limits that meets policy is approximately 500 feet west of the intersection of Wolfrum Road and Old Wolfrum Road, which is documented to be 813.8 feet.

The minimum radius of curvature with normal crown is also included in this analysis. The minimum radius of curvature is crucial for operation with tire friction, lateral acceleration, and as a margin of safety against skidding and vehicle rollover. Superelevation rate is unable to be determined since record plans or topographical survey will be needed for this part of the analysis. The minimum radius of curvature with normal crown for the posted speed of 35 mph is 454 feet per the American Association of State Highway and Transportation Officials (AASHTO) *"A Policy on Geometric Design of Highways and Streets"* (Green Book) Table 3-13b. There are 5 locations within our project limits that do not meet policy (refer to plan and profile exhibit in Appendix A):

1. STA. 31+07 to STA. 34+38: 208’ horizontal curve radius
2. STA. 89+13 to STA. 91+55: 143’ horizontal curve radius
3. STA. 91+55 to STA. 94+85: 358’ horizontal curve radius
4. STA. 94+85 to STA. 97+75: 248’ horizontal curve radius
5. STA. 125+60 to STA. 127+23: 139’ horizontal curve radius

Note that, if present, superelevation may be alleviating these horizontal curve conditions. During a field visit, TERRA observed that superelevation is present on several of the curves. There is a possibility that the listed horizontal curve radii are acceptable if proper superelevation is present. This analysis should be revisited when detailed topographic survey data is available.

Vertical Geometry

Wolfrum Road has rolling terrain. In rolling terrain conditions, natural slopes consistently rise above and fall below the road or street grade, and occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment. The maximum grade for 35 mph is 9% per AASHTO Green Book Table 6-2. There are six locations within the project limits along Wolfrum Road that do not meet policy (refer to plan and profile exhibit in Appendix A):

1. STA. 26+00 to STA. 32+00: 14.6%
2. STA. 40+00 to STA. 43+00: -15.5%
3. STA. 47+00 to STA. 48+50: 9.5%
4. STA. 51+00 to STA. 55+00: 14.0%
5. STA. 82+00 to STA. 85+00: 10.7%
6. STA. 115+00 to STA. 120+00: 11.4%

The crest and sag vertical curves are also taken account for this analysis. The major design control for crest vertical curves is the provision of ample sight distances for the design speed. The rate of change of grade should be kept within tolerable limits. This consideration is most important in sag vertical curves where gravitational and vertical centripetal forces act in opposite directions. Sag vertical curves need to provide sufficient headlight sight distance. To determine the appropriate sight distance, the value of K, or length of vertical curve per percent change in A, the algebraic difference in grade, needs to be determined. Per MoDOT EPG 230.2.8, the appropriate crest vertical curve K value and sag vertical curve K value are 29 and 49 for 35 mph, respectively. The following summary lists the locations of crest and sag vertical curves within the project limits that do not meet the design policy for 35 mph.

Crest vertical curve K value is less than policy value (29):

STA.	K Value
31+66	27
40+50	16
46+97	10
77+97	18
96+10	22
105+50	22
120+41	13
125+50	28

Sag vertical curve K value is less than policy value (49):

STA.	K Value
2+17	33
24+30	24
43+85	16
49+63	17
74+91	17
81+57	15
92+31	28
100+39	13
109+48	8
114+59	11
122+70	7

According to the AASHTO Green Book Table 3-34, the minimum vertical curve length for both crest and sag is 100 feet. Two locations do not meet this policy (refer to plan and profile exhibit in Appendix A):

1. STA. 109+00 to STA. 111+00: 81’ vertical curve length
2. STA. 123+00 to STA. 124+00: 72’ vertical curve length

These horizontal and vertical deficiencies are a possible contributor to crashes on this portion of Wolfrum Road. In some cases, advisory speed warning signs are present to address geometric constraints. The geometric deficiencies also emphasize the significance of the measured speeds that exceed the posted speed limit.

Clear Zone

The "clear zone" concept is the road design principle of providing an unobstructed, traversable area beyond the edge of the traveled way for the recovery of errant vehicles. It is located immediately adjacent to the traveled way.

The MoDOT EPG policy guidance notes that clear zone guidelines should be used when the design speed of the roadway is 45 mph or more. With a posted speed of 35 mph on this portion of Wolfrum Road, the clear zone policy is not strictly applicable. However, the principles of the clear zone concept are always worth considering for driver safety.

Wolfrum Road, within the project limits, has been observed to have a drop off at the edge of pavement due to a lack of shoulder, overlays over the years, and erosion. Errant vehicles may not be able to recover if their wheels fall off the edge. Additionally, the character of this rural section roadway is such that trees have grown to be close to the roadway edge. While this cultivates an aesthetic driving experience, the trees represent hazards within the roadway clear zone, potentially threatening the safety of drivers and passengers of errant vehicles.

The AASHTO Roadside Design Guide (RDG) acknowledges that the most cost-effective improvement that can be made on low-volume roadways is providing adequate signing and marking. However, the RDG defines "low volume" roadways as having less than 400 vehicles per day. As noted in the following section, this portion of Wolfrum Road has over 900 vehicles per day on average. The RDG recommends a clear zone of 10' to 14' from the edge of traveled way, depending on the adjacent foreslope (per RPG Table 3-1). Where feasible and reasonable, Wolfrum Road should be modified to provide a minimum of 10' clear zone.

SECTION IV

TRAFFIC DATA AND OBSERVED SPEEDS

TERRA collected traffic data for the City of Weldon Springs from November 11, 2022, to November 13, 2022, on Wolfrum Road near the 300 Wolfrum Road address at approximately Station 60+00. This section of Wolfrum road is on a straight section of roadway with a moderate slope of around 3%-4% between two curves. The data collected included vehicle volumes and vehicle speeds and were collected over a period of 24 hours on each of the three days for a total of 72 hours of data. Table 1 summarizes the Average Daily Traffic (ADT) measured on Wolfrum Road for each day in each direction and the total volume. The daily totals were summed and divided by three to get an average traffic and it was noted that the ADT was 913 vehicles per day (vpd).

The recording devices utilized also estimated the speeds of each vehicle based on the time that the vehicle spent crossing over the sensor. This included the approximate length of the vehicle and the speed it was travelling. Figure 1, Figure 2, and Figure 3 graphically shows the distribution of vehicle speeds measured on Wolfrum Road. The average speed for all vehicles was 41 miles per hour (mph) with 85% of the recorded vehicles exceeding the posted speed limit of 35 mph. 2.5% of vehicles were traveling in excess of 55 mph. The 85th percentile speed was 47 mph.

TERRA also classified vehicle types during traffic data collection. Of the total classified vehicles, 69% were passenger vehicles, 29% were vans and pickups, 2% were busses and trucks, and 1% were tractor trailers (total is 101% due to rounding).

Table 1 – Average Daily Traffic (ADT) on Wolfrum Road			
	Westbound ADT	Eastbound ADT	Total ADT
Tue 11/8/2022	369	408	777
Wed 11/9/2022	470	499	969
Thur 11/10/2022	453	541	994
Average	**431**	**483**	**913**

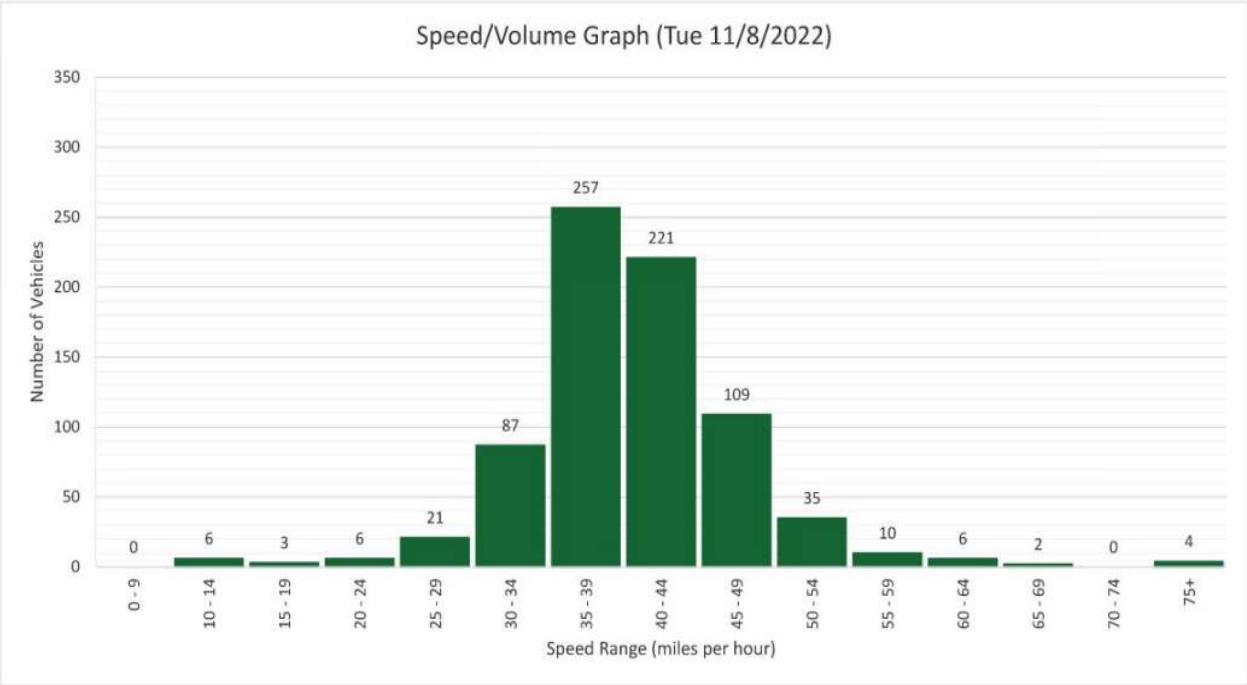


Figure 1 - Speed and volume data for 11/08/2022.

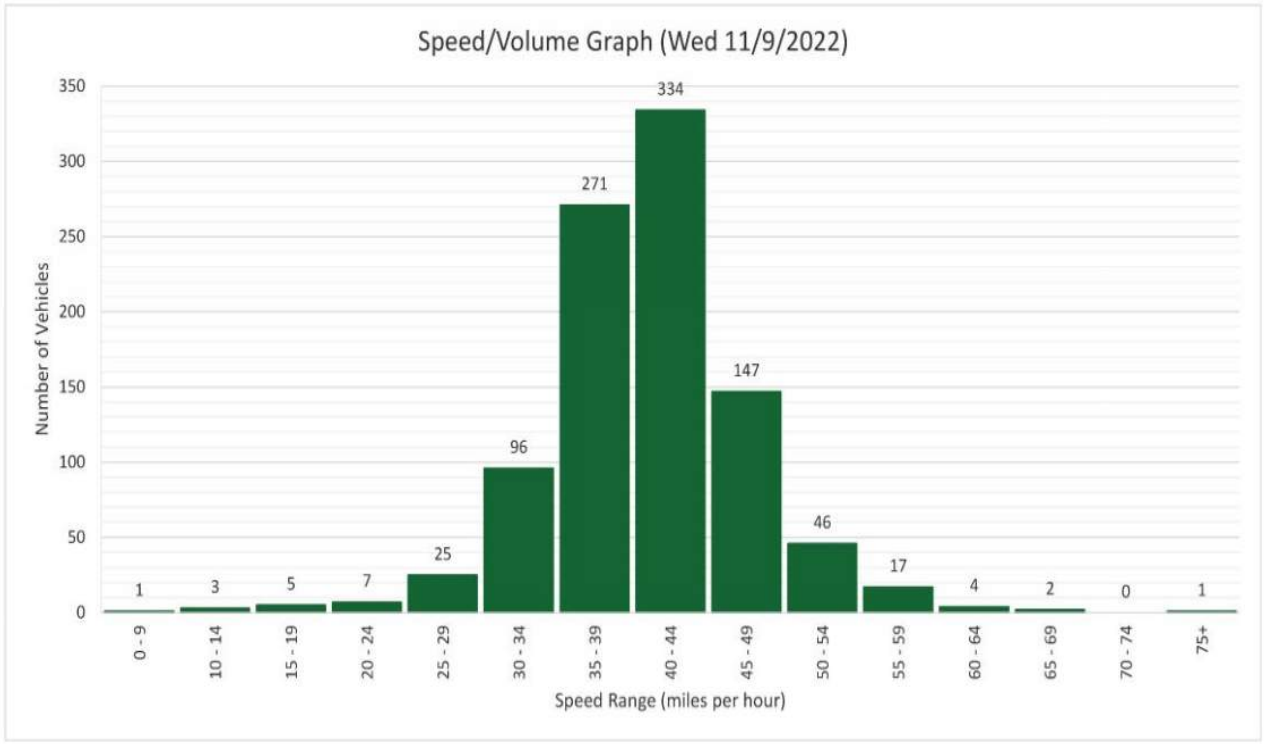


Figure 2 - Speed and volume data for 11/09/2022.

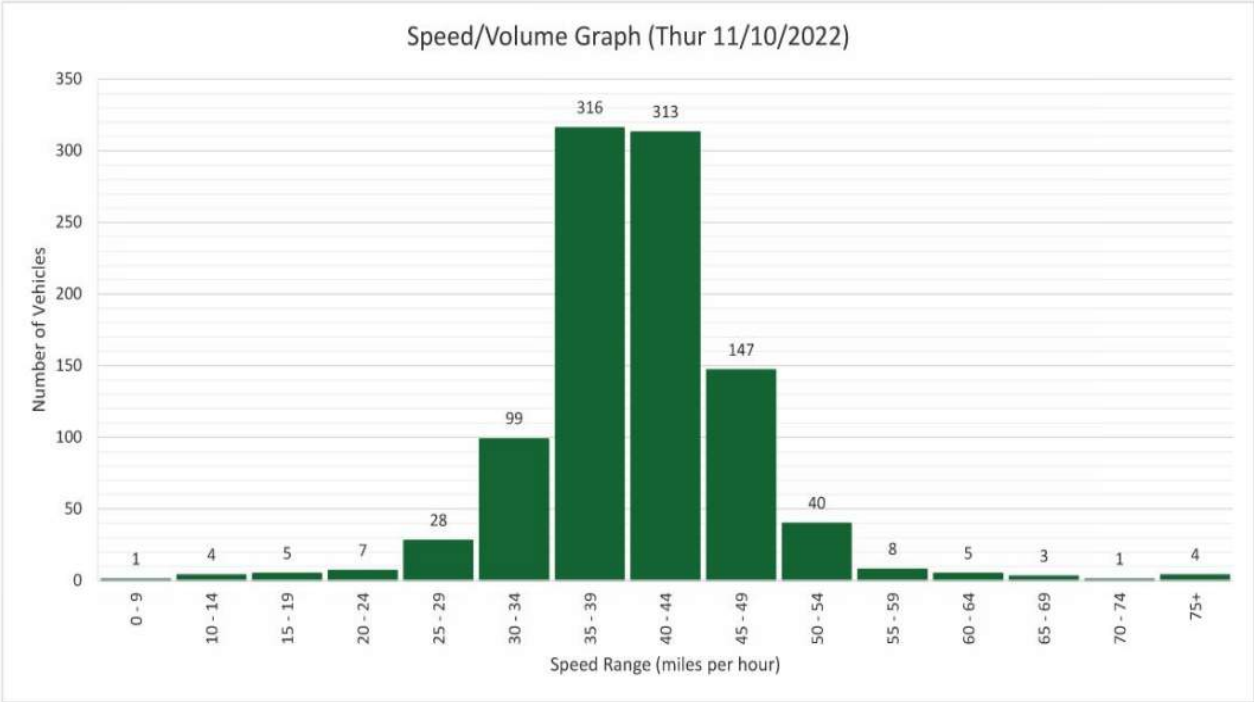


Figure 3 - Speed and volume data for 11/10/2022.

In reviewing the figures, it shows that a majority of the vehicles on each day of observation appear to be traveling within the bars which represent the speeds of 35-45 mph. However, it is also noted that 100-150 vehicles per day are travelling between 45-49 mph which is greater each day than those traveling between 30 mph and 34 mph. Finally, it was observed that around 40 per day are between 50-55 mph, which is an excessive speed for a roadway with approximately 10-11' foot lanes with no shoulders and significant drop-offs at the edge of pavement.

In addition, the City of Weldon Springs also collected speed data for seven (7) days on Wolfrum Road at the speed limit sign near Station 48+00 from September 11, 2023, to September 17, 2023. From the provided speed data, TERRA constructed a histogram of the speeds observed along Wolfrum Road. Figure 6 - Speed/Volume graph for 9/13/2023.Figure 6 through Figure 10 show the number of vehicles in each 5 mile per hour (mph) bins that vehicles drove. Figure 11 shows the measured speeds for the entire duration of the study.

From the data provided by Weldon Springs, 74% of vehicles traveled faster than the speed limit of 35 mph, 41% traveled faster than 40 mph, and 14% traveled faster than 45 mph.

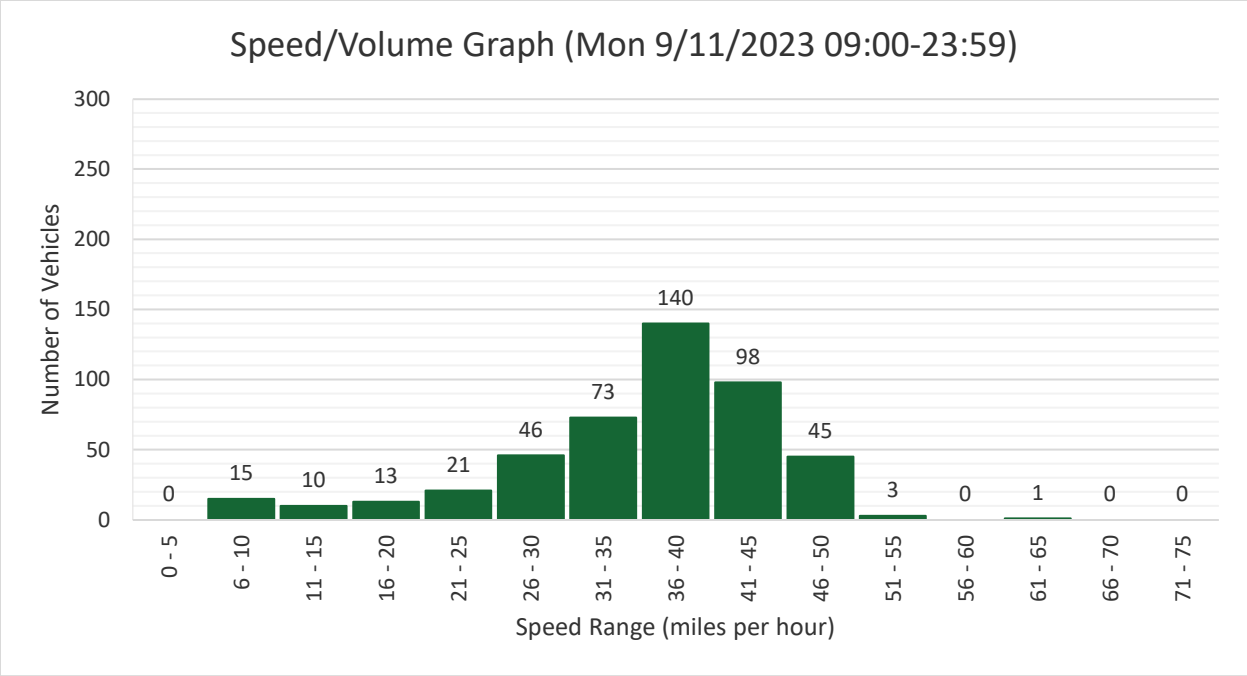


Figure 4 – Speed/Volume graph for 9/11/2023.

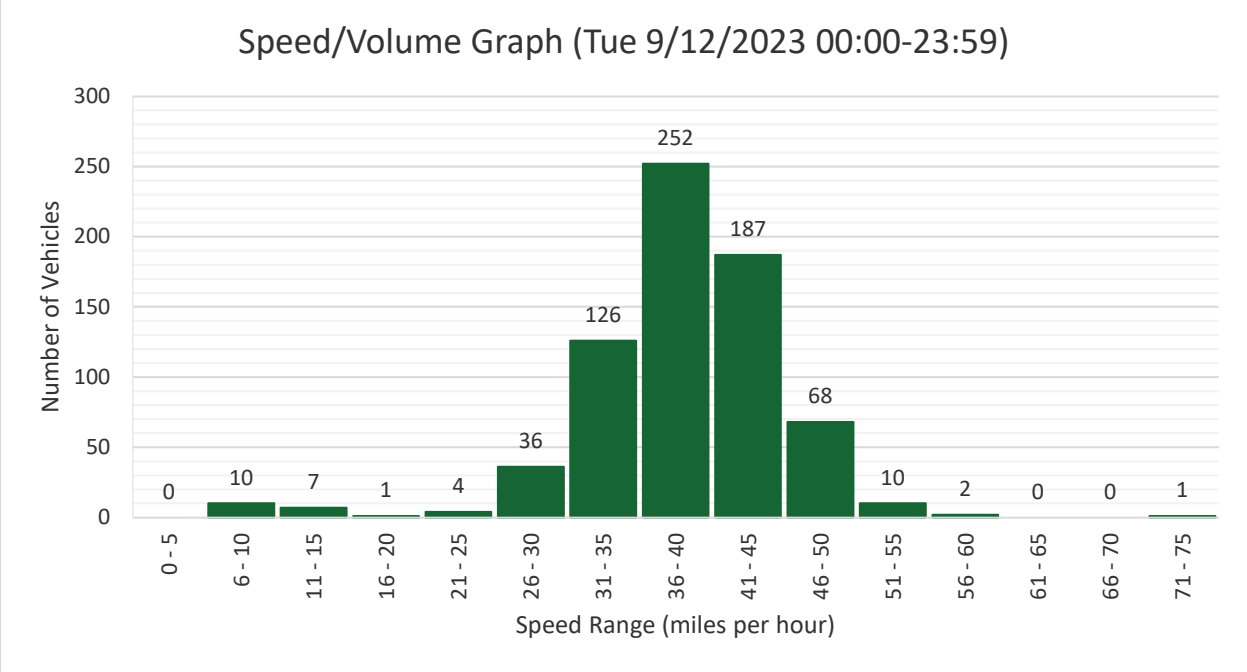


Figure 5 - Speed/Volume graph for 9/12/2023.

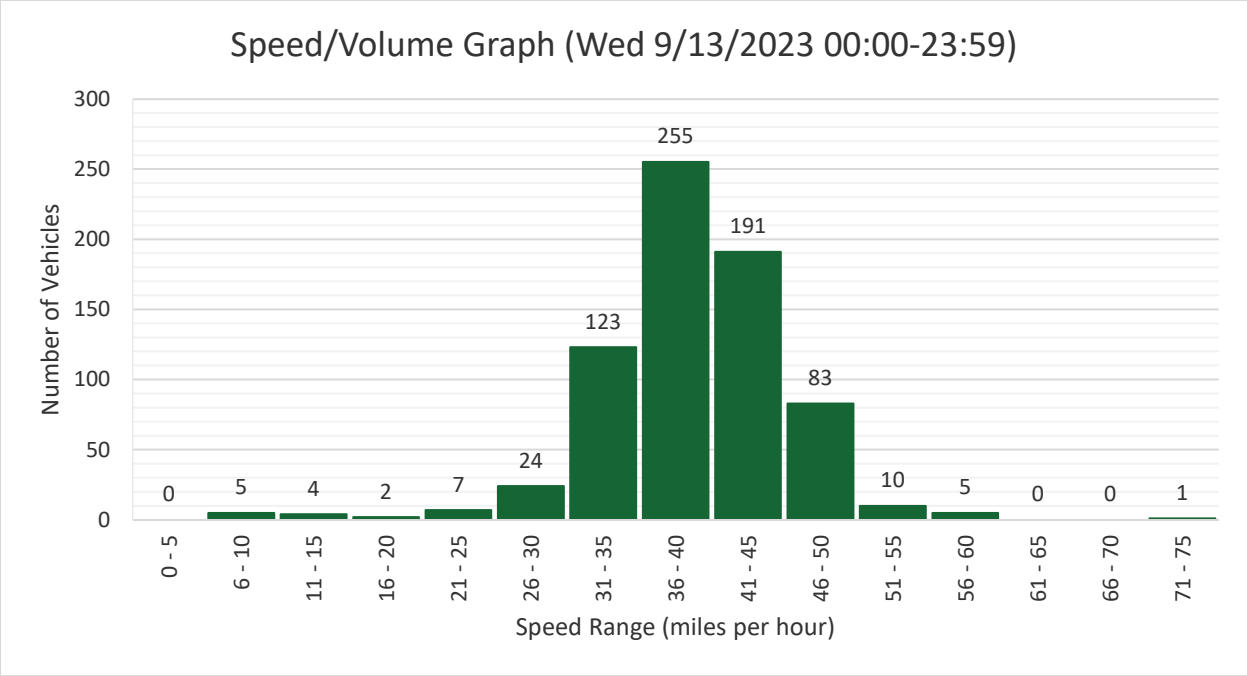


Figure 6 - Speed/Volume graph for 9/13/2023.

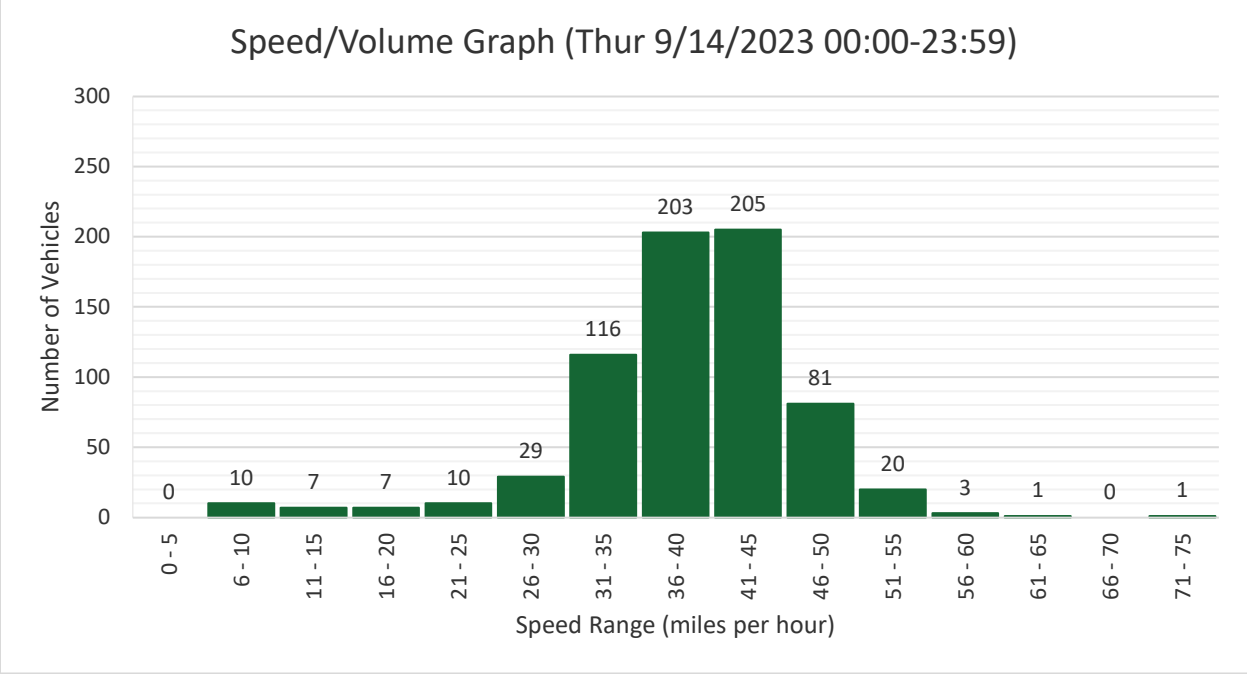


Figure 7 - Speed/Volume graph for 9/14/2023.

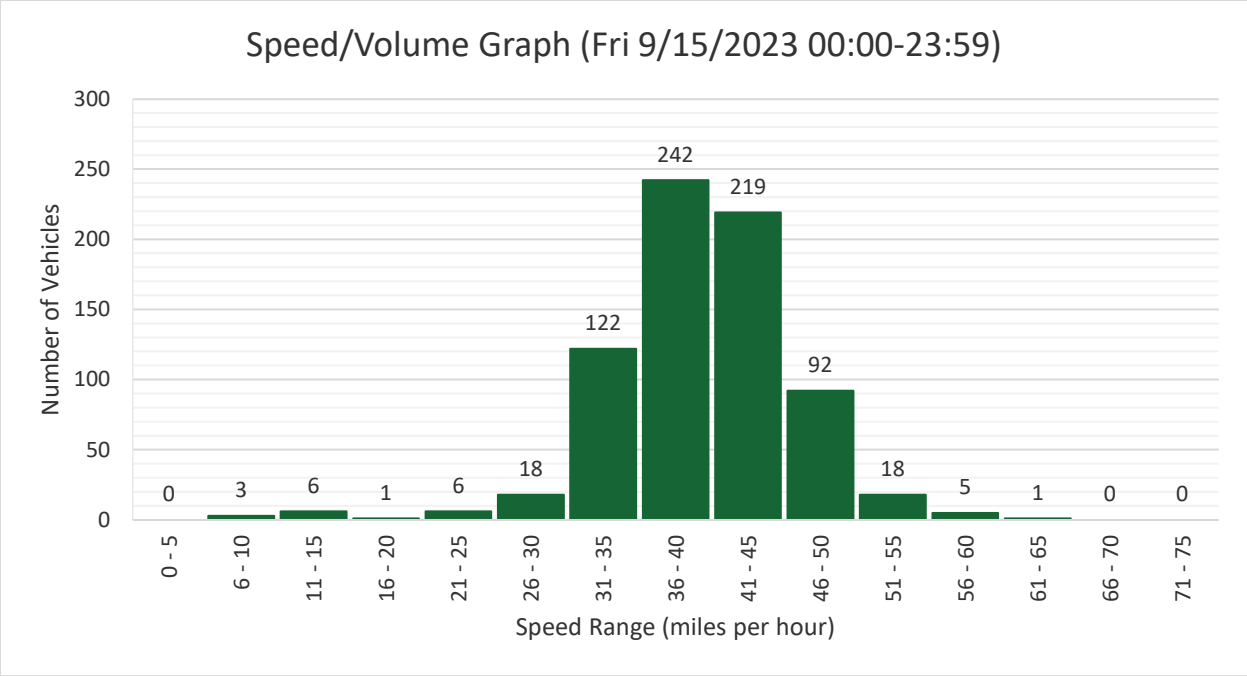


Figure 8 - Speed/Volume graph for 9/15/2023.

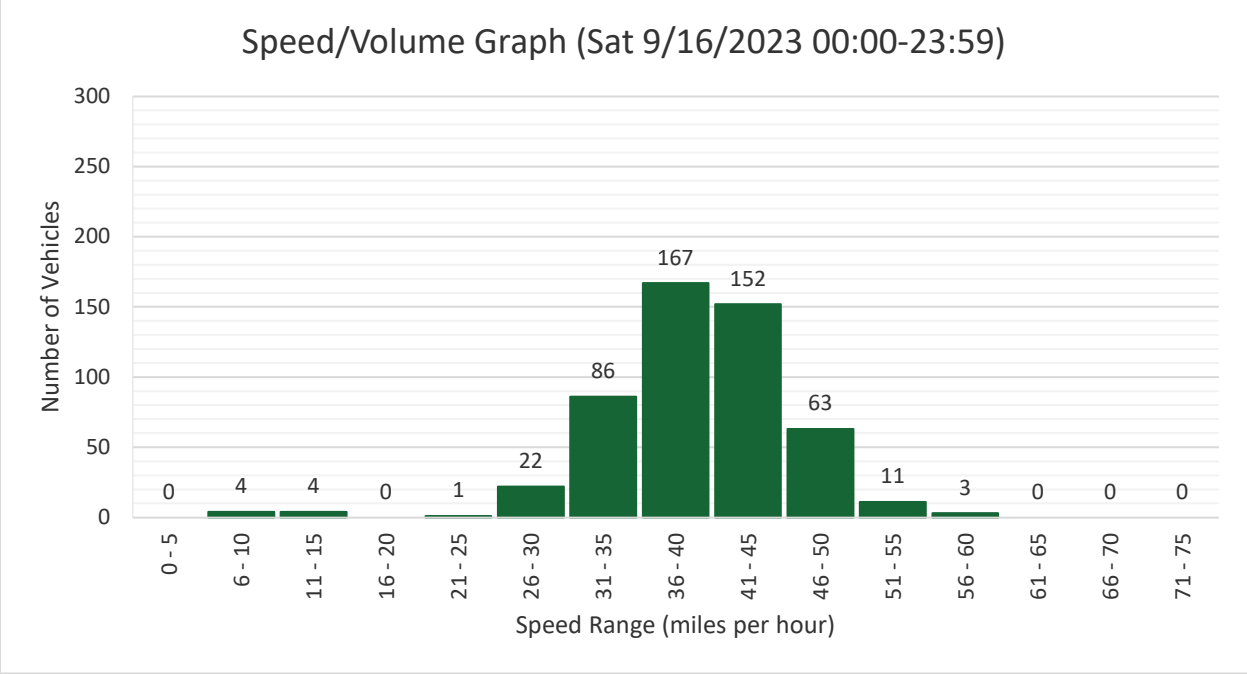


Figure 9 - Speed/Volume graph for 9/16/2023.

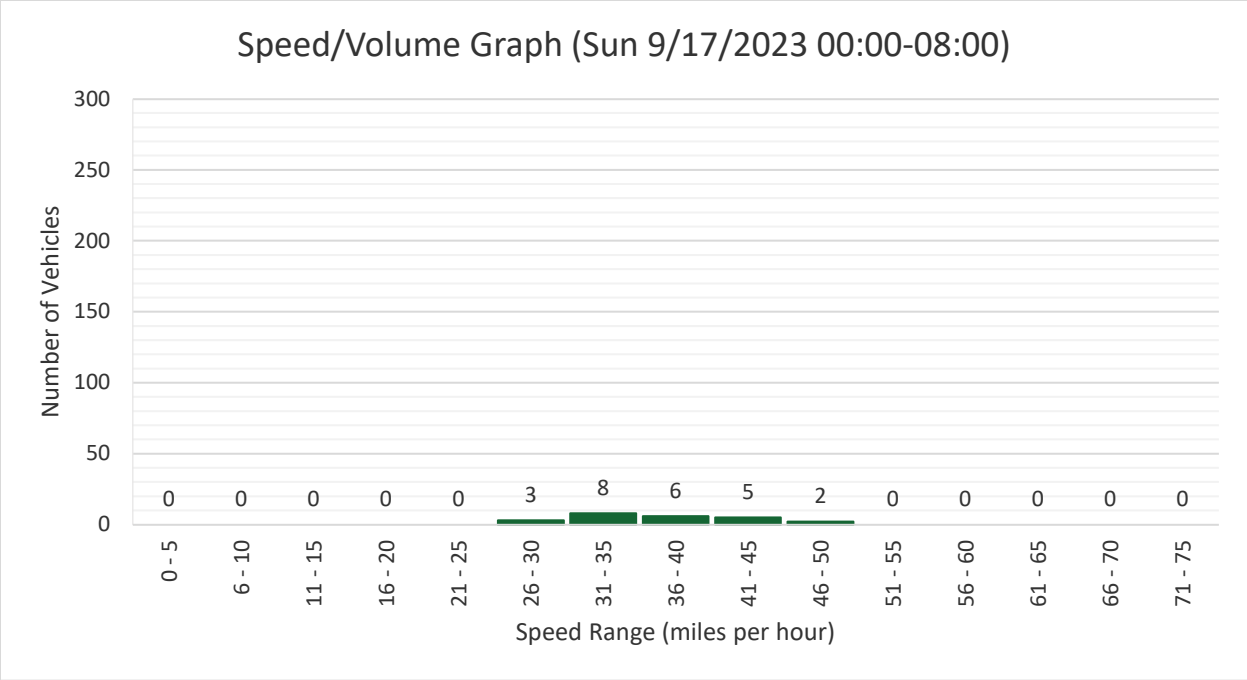


Figure 10 - Speed/volume graph for 11/17/2023

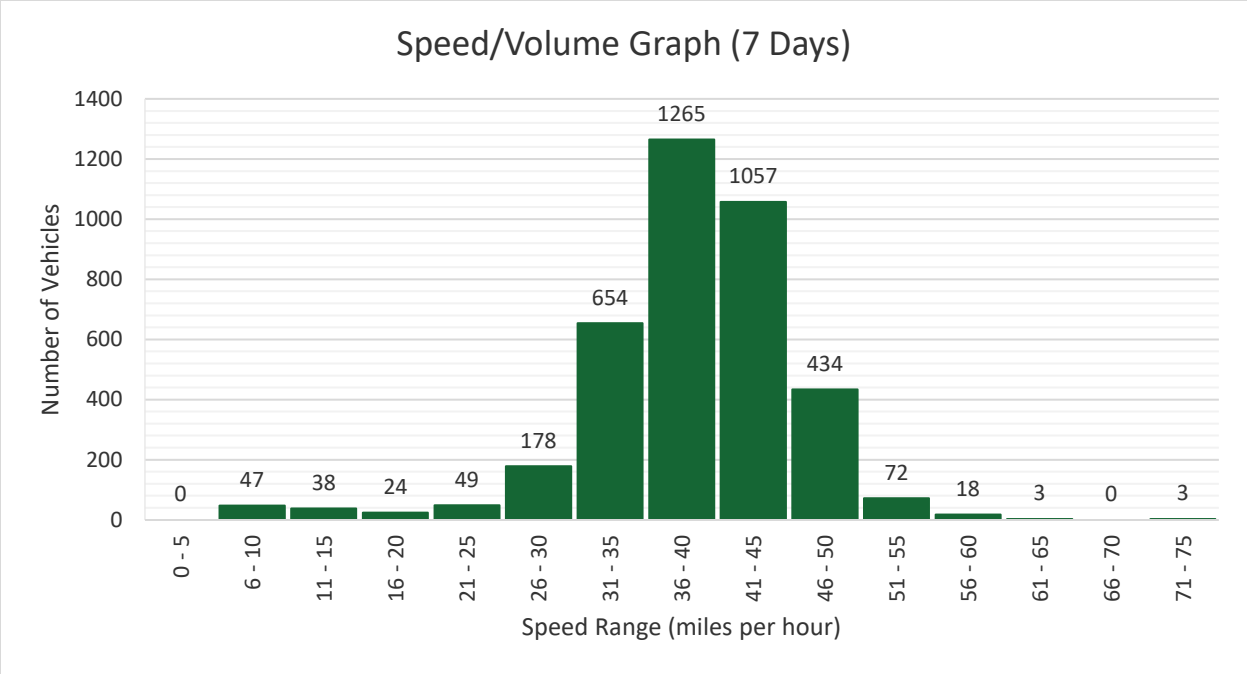


Figure 11 - Speed/Volume graph for entire 7-day data collection duration.

The distribution of the graphs is similar to what TERRA's counts observed with the bulk of the vehicles traveling between 35-45 mph, but a significant number of vehicles traveling in the 45-55 mph range. Although the totals show a higher percentage of drivers in the 31-35 mph range than in the TERRA count, which may be due to the feedback from the radar-controlled speed readout which shows drivers their speed or the location of the count.

SECTION V

CRASH DATA

TERRA Engineering reviewed the information provided in the Missouri State Highway Patrol (MSHP) website for crash reporting data. This data includes all the reported crashes throughout the state which have reported crashes which are recorded in a police record collected by either the State Highway Patrol, County Police, or local police within a jurisdiction. In some locations this may include reports from multiple agencies, however in the case of Wolfrum Road all reports were only provided by St. Charles County Police as the City does not have its own department and the roadway is outside of the area where State Police would respond.

The website allows the user to input the parameters for a specific request within the system to return search results tailored to meet their query. The request submitted by TERRA included the dates of January 1, 2013, through October 30, 2023, to provide the last 10 years of available data. The website containing the crash data is available at www.mshp.dps.missouri.gov/TR15Map/Search. A map showing the query and the crashes within the immediate area of Wolfrum Road is shown in Figure 12.

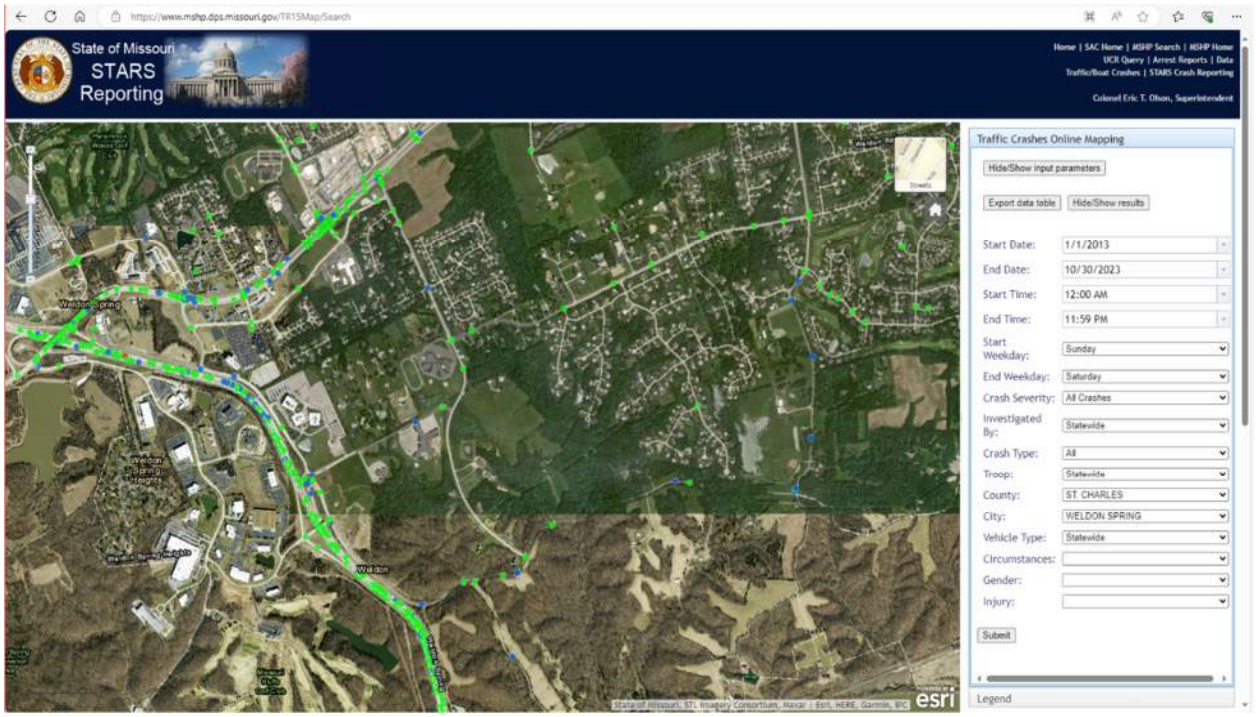


Figure 12 - Screenshot of Crash Query from MSHP website.

It is important to note again that if the police are not contacted then no report is filed, and it would not be reported within the website, therefore the expected crashes which occurred is likely higher than reported. As an example of crashes not being reported, the City of Weldon Spring staff discovered an abandoned car located along the side of Wolfrum Road on November 17, 2023. TERRA staff ran a new query on the MSHP website in December 2023 and there were no reported crashes listed on the website, however this car was significantly disabled and not able to be driven from the site. A photo of this crash is provided in Figure 13.

Figure 13 - Unreported Crash on November 17, 2023.

Investigating the available data, TERRA reviewed the data exported from the MSHP website to find all of the crash reports which detailed crashes which occurred on Wolfrum Road. This initially included all crashes along Wolfrum Road. This data was then cross referenced with the map to develop a list of only the crashes which occurred within the 2.5-mile study area. The list exported from the website was then cut down to only crashes which could be verified within the study area which included a total of 28 crashes which specifically occurred on Wolfrum Road.

The next step in the process was to evaluate the crashes that occurred and to look for potential underlying causes for the crashes which showed trends or patterns which imply that there are deficiencies along the roadway or other contributing factors which need further investigation.

Looking at the total list of crashes, the list shows that three (3) of the crashes occurred with a vehicle striking an animal, five (5) of the crashes involved a vehicle striking another vehicle in motion or on the roadway surface, two (2) vehicles overturned, while the remaining 18 crashes involved vehicles striking fixed objects outside of the roadway surface. It should be noted that both vehicles which overturned also left the roadway surface and one of the vehicles which hit another vehicle continued off the road after crossing the centerline. This brings the total vehicles which left the pavement to 21 of the 28 total accidents or 75% of the overall crashes.

The first evaluation considered the lighting conditions along the roadway. While lighting the entirety of Wolfrum Road would not be something which would be considered, there are other factors affected by the amount of lighting along the roadway, such as the reflectivity of the signs which may need evaluation. The crash reports provide information on whether the road was lighted or dark and this information was pulled from the reports and is shown in Table 2.

Table 2 – Total Crashes based on Lighting Conditions by Year				
Year	Daytime	Night	Day/Night Ratio	Total Crashes
2013	3	2	40%	5
2014	0	1	100%	1
2015	1	7	88%	8
2016	1	0	0%	1
2017	1	0	0%	1
2018	0	2	100%	2
2019	0	1	100%	1
2020	0	2	100%	2
2021	2	1	33%	3
2022	1	1	50%	2
2023	1	1	50%	2
Total	10	18	64%	28

The data shows that overall that 64% of the total crashes occur at night. Looking at the outcomes of the 18 crashes which occurred at night, it appears that two (2) of them were caused by striking an animal, three (3) involved striking other vehicles on the roadway, while the remaining 13 involved drivers leaving the roadway surface on the right or left

side. Of the 10 crashes occurring during the daylight hours, one (1) involved striking an animal while the other nine (9) involved vehicles leaving the roadway surface.

The next evaluation looked at the pavement conditions at the time of the crash. The police reports of the individual crashes include a check box which allows the documenting officer to record the pavement condition at the time of the incident. The results from the crashes based on the pavement condition is provided in Table 3.

Table 3 – Total Crashes based on Pavement Conditions by Year					
Year	Dry	Wet	Snow/Ice	Unknown	Total
2013	2	0	2	1	5
2014	1	0	0	0	1
2015	3	1	4	0	8
2016	0	1	0	0	1
2017	1	0	0	0	1
2018	2	0	0	0	2
2019	0	1	0	0	1
2020	1	0	1	0	2
2021	1	1	1	0	3
2022	2	0	0	0	2
2023	2	0	0	0	2
Total	15	4	8	1	28
%Total	54%	14%	29%	4%	

The results show that over half of the crashes occur during dry conditions where there were no additional frictional causes which could have contributed to the crash. It was noted that only four (4) overall crashes occurred when the pavement was wet, which assumed to only be from rain. There were twice as many crashes, eight (8) which occurred on icy of snow-covered pavement. Descriptions of these crashes revealed that a number of these ice related crashes occurred at the same location on the same day where a crash occurred, and additional vehicles then crashed into the original incident as they slid on the ice which caused the initial crash into the stationary vehicles. Another incident occurred where vehicles got stuck going uphill on one of the steeper slopes and vehicles slid backwards down the hill into the opposing lanes of traffic and hit ither vehicles. It was noted that all crashes which involved motor vehicles crashing into other vehicles occurred on wet or icy pavement.

The next evaluation of the trips looked at the injuries that occurred in the reported crashes. For this evaluation we separated the crashes into those which involved fatalities, crashes with reported injuries and crashes with only property damage without injuries. When fatalities or injuries occurred, the total number of injuries were reported for each crash.

For example, in 2019 there was only one (1) injury crash, but four (4) passengers in the car were injured, so the number of injuries can exceed the number of crashes. The results of the injury evaluation is provided in Table 4.

Table 4 – Injury Crashes by Year							
Year	Fatal Crashes	Number of Fatalities	Personal Injury Crashes	Number of Injuries	Property Damage Only	Total Crashes	Total Injuries
2013	0	0	0	0	5	5	1
2014	0	0	0	0	1	1	0
2015	0	0	1	2	7	8	2
2016	0	0	0	0	1	1	0
2017	0	0	1	1	0	1	1
2018	0	0	2	2	0	2	2
2019	0	0	1	4	0	1	4
2020	1	1	0	0	1	2	1
2021	0	0	2	2	1	3	2
2022	0	0	1	1	1	2	1
2023	0	0	1	1	1	2	1
Total	1	1	9	13	17	28	15

Reviewing the data in the reports, one fatality occurred which was near the intersection of Patriotic Trail and Wolfrum Road which involved a vehicle leaving the roadway at the intersection after failing to make a turn at hitting a tree. It was noted in the report that the other nine (9) crashes which involved an injury of some type, all the vehicles had the wheels leave the roadway surface at some point during the crash and either overturned or struck a fixed object.

Most of the injury crashes were single car accidents with only one occupant of the vehicle, however one crash occurred where four occupants were injured and another had two injuries during the same incident.

Overall, about 32% of the crashes involved an injury of some type during the crash with varying levels of severity.

SECTION VI

ROADWAY SIGNING

TERRA reviewed the signing along the Wolfrum Road corridor to evaluate the existing signing plan and how it performs from a safety perspective. This included both a cursory review of the signs as shown in Google Streetview and then an evaluation in the field to physically observe the signing. An overall exhibit of the signing was prepared for the corridor and is included in Figure 15.

Several items were noted in the field review of the sign conditions and the signing locations. The first thing noted was the number of signs which were damaged or missing.

Working from west to east along Wolfrum Road the first location of concern is on the curve located just west of Wolfrum Road and Patriotic Trail there are several chevron signs (W1-8) in place to denote the curvature in the roadway, however there are two at the beginning of the curve and then a large gap in the signs before reaching the final chevron. This gap is either due to poor sign placement or could be because signs were hit by cars leaving the roadway surface and are no longer in place. As shown in Figure 14 there is a chevron sign in the foreground but then a large gap to the next sign in the background of the picture.

Figure 14 - View along westbound Wolfrum Road approaching Patriotic Trail.

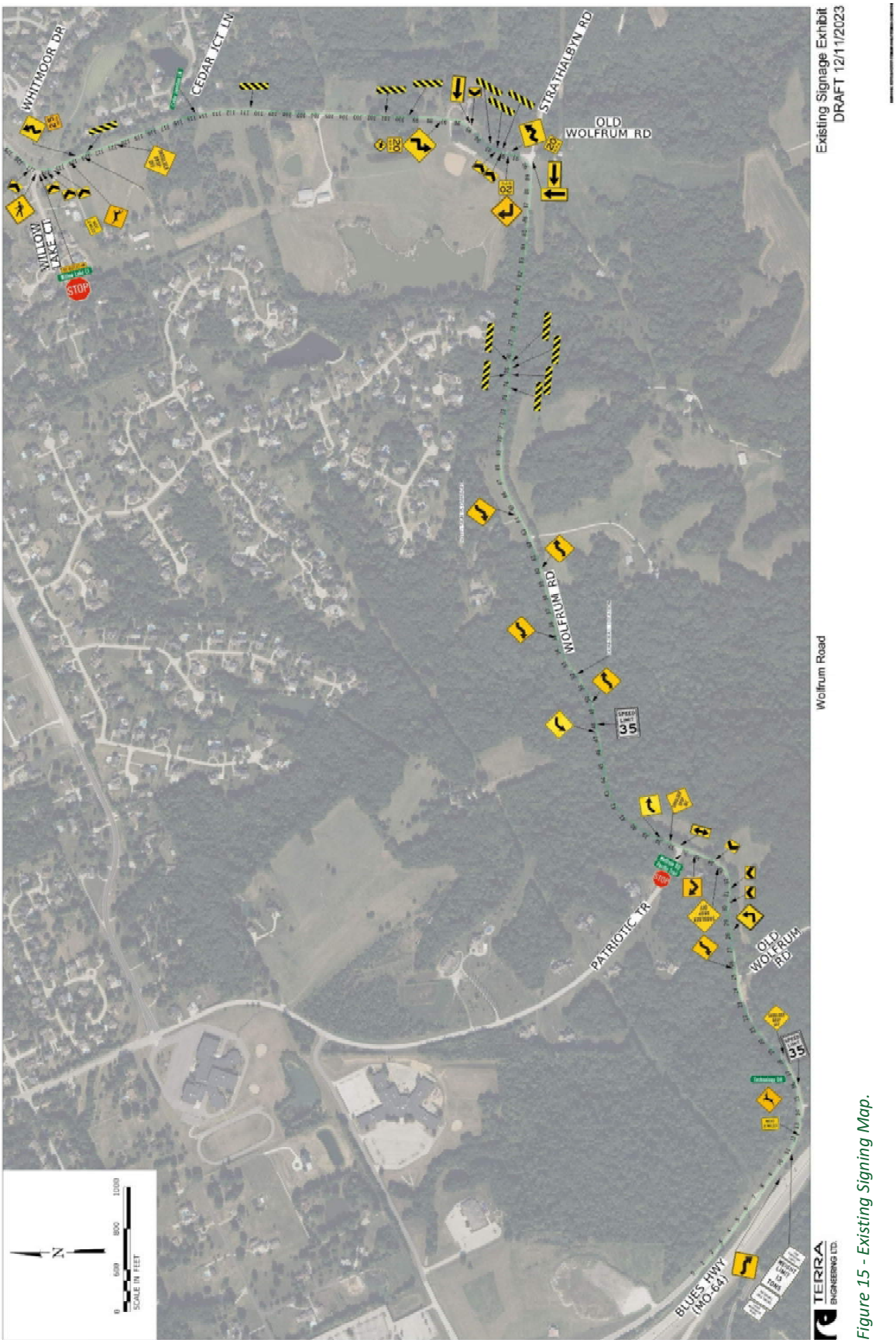


Figure 15 - Existing Signing Map.

TERRA ENGINEERING LTD.

Panning back and looking at the foreground chevron from further away in Figure 16, it is clear that additional chevrons are needed to delineate the curvature in the roadway.

Figure 16 - Another picture approaching the curve traveling westbound.

Figure 17 - Back of westbound facing chevron.

Another thing noted at this curve location is that the chevrons are single sided with the signs only facing westbound and no chevrons providing guidance for eastbound traffic. As noted in Figure 17 the post blocks part of the back of the sign and this particular sign is leaning over slightly as if it has been struck by something. This makes this sign less effective at helping to guide motorists and harder to be seen along the roadway. It was noted that this specific curve was the location of two (2) of the injury crashes which occurred along Wolfrum Road.

The next signing location worth discussing is at the intersection of the Wolfrum Road and Patriotic Trail. The one fatal crash that occurred at this intersection when a car failed to stop or turn and went through the intersection southbound on Patriotic Trail and struck a tree. The sign located at the end of the roadway is the W1-7 sign as shown in **Error! Reference source not found.**.

Figure 18 – Sign W1-7 at end of Patriotic Trail.

This sign is installed at the far side of a T-intersection in line with the view of traffic coming from the stem of the T-intersection. The standard size of this sign is to be 48 inches wide by 24 inches in height, which appears to be the size installed, however larger versions of this sign can be 60 inches wide by 30 inches tall to make the sign more noticeable to drivers. With the gap in the trees which may not indicate the end of the roadway, it might be advisable to install a larger sign at this location if crashes become an issue with vehicles not navigating the turn successfully.

The next section of roadway just to the east of Patriotic Trail leads into a right curve on a steep downgrade which does not meet vertical geometry requirements. There is a W1-2 sign showing the curve in the roadway, but there are no advisory plaques for the horizontal curve or signing for the steep grade. This location was the site of several accidents on the same day in 2015 when ice was present and vehicles coming around the curve were unable to stop on the ice downhill. Another crash report mentions that vehicles coming uphill could not make it up the hill on a different icy day in 2022 when a truck slid down the hill backwards and got stuck blocking the roadway. The sign leading into this curve is shown in Figure 19.

Figure 19 - W1-2 curve sign prior to steep downhill grade.

Coming over the crest of this hill and around the curve it is difficult to see anything that might be around the corner and with the estimated 15.5% downhill grade the lack of sight distance and grade make it more difficult to stop, especially on wet or icy pavement. This may lead to the suggestion of providing additional advisory or warning signs to warn westbound drivers.

To provide an idea of the slope of the roadway Figure 20 shows the view looking back to the east up the hill toward this initial curve from a point partially down the hill. It was also noted in this section while observing the signage that there is a significant drop-off at the pavement edges on both sides of the roadway.

Figure 20 - View looking east back uphill at the curve.

The next location with numerous crashes which likely needs additional signing is near the Strathalbyn Farms and Old Wolfrum Road intersection where Wolfrum road makes a 90-degree curve before continuing in a north-south direction. Vehicles approaching the curve from the west are coming uphill toward the curve and there is a slight crest vertical curve which hides the sharp curvature. A view of the sightline for the driver approaching the curve is shown in Figure 21. From the photo taken, the W1-6 sign is visible in the distance, but the curve itself is not visible at this distance.

At this location there is no advance warning sign when traveling westbound, although it appears that there was an advance warning sign back in May of 2019 in Google Streetview. If this sign was struck by a vehicle leaving the roadway, it was never replaced. The W1-1 sign which had been in place had an advisory plaque (W13-1P) which had a recommended speed of 20 mph.

As shown in Figure 22, the curve is sharp to remain on Wolfrum Road and there is a gravel shoulder that leads to Strathalbyn Farms and Old Wolfrum Road which is positioned lower than the existing pavement and has a sloped drop-off. This could cause some instability to cars rounding the corner which have a tire leave the pavement, but is not as severe as some drop-offs located along the length of the roadway.

Figure 21 - View approaching the 90-degree curve at Strathalbyn Road.

Figure 22 - Curve at the Strathalbyn Farm intersection.

At this sharp curve there are numerous visible signs that cars have difficulty navigating the corner which may be surprising to unfamiliar drivers or hard to navigate on wet or icy pavement or at higher speeds. The Strathalbyn Farms Gun Club has placed large boulders on the far side of the curve as protection for their fence line which appears to have been replaced in sections due to previous damage. The boulders themselves show scrapes and paint marks from being struck by errant vehicles which have gone off the roadway. This is shown in Figure 23. A review of the crash reports and data from this location show that multiple injury crashes have occurred in the area with vehicles leaving the roadway surface due to being unable to successfully navigate the curve.

Figure 23 - Damaged boulder with scrapes and paint transfer.

After rounding the 90-degree curve to the left the driver is presented with a reverse curve to the right and then back to the left with an advisory speed of 20 mph. This section of roadway has the W1-3 sign denoting the reverse curve with the advisory plaque, several chevron (W1-8) signs and several Type 3 object marker signs to designate the steep drop off along the side of the roadway. This location is shown in Figure 24.

The object markers were in place to denote the steep drop which also contains a drainage structure and outfall along the side of the roadway partially down the slope from the edge of pavement. It was noted that several of these signs are leaning to the side, implying they have been clipped by vehicles traveling around the curve along Wolfrum. Additionally, there are chevron signs for the opposite direction of travel which have the back side facing the eastbound/northbound traffic.

Figure 24 - Signage denoting reverse curve north of Starthalbyn Dr.

In the opposite direction of travel, heading south and west along Wolfrum Road, it was noted that there is a curve advisory sign (W1-1) with a speed advisory plaque at the 90-degree curve. Upon closer investigation, it was also noted that there may have been another version of this sign or another type of sign placed near which had been struck and knocked down as the base of the sign post was still visible in the ground as shown in Figure 25. The sign that remains also appears to be darkened and obscured with dirt and a dark residue of some type on the sign. This dirt reduces the retroreflectivity of the sign when viewed and especially at night when headlights are supposed illuminate the sign. This may make it harder to see and reduces the effectiveness of warning motorists about the upcoming curve, although after having just navigated the reverse curve section drivers have hopefully already slowed their speed entering the 90-degree curve. The less reflective sign is shown in Figure 26.

Moving along the curve to the north and looking back toward the Strathalbyn Rd intersection to the south, drivers can see the reverse curves in Figure 27. Heading southbound toward the intersection, there is a W1-6 sign which denotes the first curve and again there is an uphill stretch leading into the curve which makes it hard to see for drivers approaching the curve. There is an advance warning sign of the upcoming reverse curve heading southbound (W1-3) with a speed advisory plaque of 20 mph. There is also a small horse crossing sign posted on the bottom of the sign which does not appear to meet the minimum size criteria for the official crossing sign per the MUTCD. These conditions on the approach can be seen in Figure 28.

Figure 25 - Broken sign post foundation.

Figure 26 - Dirty sign with reduced retroreflectivity at night.

Figure 27 - Reverse curves looking to the south along Wolfrum Road.

Figure 28 - Advance curve warning sign and approach to first turn heading southbound.

The remainder of the corridor to the north is a relatively straight section of roadway when compared to the previous sections. There are fewer signs in this northern section consisting mostly of Type 3 object markers to identify roadside hazards which are typically near culverts placed under the road. At the north end of study area, there is a northbound advance warning sign for the reverse curve (W1-3) with an advisory speed plaque for a 25-mph speed. There are also chevron signs for southbound traffic delineating the curve near Willow Lake Ct. which are facing southbound traffic. It was noted that in Google Streetview there were three (3) chevron signs in March 2022, but a fourth chevron had been added toward the end of the curve in November 2022.

Overall, the signs are appropriate at many of the locations along the corridor, however several locations need to have signing replaced or augmented to improve the overall safety of the corridor. It will also be important for the City of Weldon Spring to perform regular sign maintenance to replace damaged signs and ensure that the existing signs are kept up to desired standards.

SECTION VII

LANE WIDTH AND EDGE DROP OFF

TERRA also completed some spot measurements of the roadway in the field. This included using a measuring wheel to estimate the lane widths along Wolfrum Road and to visually look at some of the roadway pavement edges.

First TERRA completed roadway width measurements in the area near Wolfrum Road and Patriotic Trail. Lane width measurements were taken on both the east and west side of the Patriotic Trail intersection and on both sides of the intersection the overall roadway width was measured to be around 20-21 feet in width. This equates to roughly 10-foot lanes in each direction which is less than the standard lane width of 12 feet. It appears that the lane widths may widen slightly around some of the roadway curves to allow for slightly larger lanes. There are no shoulders anywhere within this study area, so there are no areas along the roadway for a disabled or vehicle to pull out of the lane safely, so any breakdowns or incidents are likely to remain within the driving lane.

The City of Weldon Spring has discussed with TERRA that the pavement has been overlaid multiple times with new asphalt which has raised the top of pavement elevation, however the elevation of the ground adjacent to the pavement was not necessarily raised along with the pavement height. With no shoulders or safety edge along the outside edge, when a tire goes off of the edge of pavement there is a drop almost straight down which often leads to

the frame of the car scraping on the edge of pavement and provides no room for the driver to recover their vehicle because the tire may be in the air or has nothing to gain traction on. It was noted in reading the crash reports that a number of vehicles did have a tire go off the right edge of pavement and then turned the steering wheel to the left to try to get back onto the pavement which resulted in them losing control of the vehicle, crossing the centerline and leaving the left side of the pavement. An example of one drop-off observed is shown in Figure 29. As shown in the photo there are numerous scrape marks along the edge of the pavement from vehicle frames hitting the edge and the asphalt edge has broken off the edge in some places.

Figure 29 - Pavement edge drop-off east of Patriotic Trail

Further down the roadway it was noted that there were similar edge drop-off concerns at the edge of pavement throughout the length of the corridor. Another example from the area near Strathalbyn Farms is provided in Figure 30. Again, there are numerous scrapes observed on the edge of pavement near the lane in this area and the drop-off from the edge of pavement is severe, as is typical throughout the length of Wolfrum Road. This edge drop-off makes it very difficult for vehicles going off the road to recover back onto the pavement should they have a wheel go over the edge. This may mean that some types of edge treatments such as rumble stripes, narrow shoulders or some other treatment might need to be considered to improve safety throughout the study area.

Figure 30 - Another edge drop-off near Strathalbyn Farms

SECTION VIII

SUMMARY AND CONCLUSIONS

TERRA reviewed the Wolfrum Road corridor to look at the safety concerns of the roadway. This included evaluating the traffic volumes, speeds, horizontal and vertical geometry, roadway width, edge drop-off, curve treatments, and signing along the route. These factors were looked at along with the crashes reported along the corridor to evaluate the possible causes and to determine what contributing factors may be present.

In evaluating the crash data, it was noted that many of the crashes which occur along Wolfrum Road involve vehicles leaving the pavement surface at some point during the crash and often this vehicle strikes a fixed object near the roadway, which is often a tree due to the proximity of the tree line to the edge of pavement, and the inability of vehicles that leave the pavement to recover and get back onto the pavement without crossing over the centerline or possibly going off of the left side of the roadway after crossing the other lane of traffic. There is a tight tree canopy along the entire roadway which increases the likelihood of having cars strike a fixed object/tree. It is important to the community to maintain the trees and overall feel of the roadway, so it may be important to consider

options to keep vehicles on the pavement surface where there are trees or other obstacles near the roadway edge.

While crashes occur along the entire length of the roadway it was noted that many of the crashes occurring happen near the 90-degree curve at Strathalbyn Rd and near the curves on either side of the intersection with Patriotic Trail. The data shows that 22 of the 28 crashes occurred on a curved section of roadway. This could be due to several roadway geometry factors including poor superelevation, deficient radii, narrow lanes and vertical slopes. Other potential deficiencies at curves could include inadequate signing, pavement edge drop-offs, poor curve delineation and inadequate pavement friction.

The crash reports offer various descriptions of the circumstances that led to the different crashes. In some cases, it was wet or icy pavement, others speeding may have been a factor, a couple of deer were hit on the road, but many had drivers leaving the roadway edge either because of encroachment on their lane, inattentiveness or other factors.

While there are no perfect treatments to prevent all crashes, there are measures which can be implemented to reduce the potential for crashes and severity of the crashes which do occur.

Many of these are low-cost treatments which can be implemented strategically throughout the corridor or can be applied to the entire length of the roadway. As many of the crashes which do occur involve roadway departures, this should be an area of focus in the potential strategies. There are several proven treatments which are recommended by the Federal Highway Administration (FHWA) for treating roadway departure accidents. These include:

1. Enhanced Delineation and Friction for Horizontal Curves
2. Longitudinal Rumble Strips and Stripes
3. Safety Edge Treatments
4. Roadside Design Improvements at Curves

Evaluation of safety improvements often include both a site analysis component and a systemic component. The site analysis strategy often involves treatments of specific locations where clear safety problems exist. These treatments are often reactive and come at a higher cost. A systemic approach looks to solve particular types of severe crashes and are deployed throughout the corridor at a number of locations and often are considered more proactive.

Additional guidance can be found in numerous publications including from the FHWA which provides safety publications including the publication on “Low-Cost Treatments for Horizontal Curve Safety” which in discussing safety improvement programs states:

> *“How a safety program and data analyses are focused—severe crashes versus total crashes—influences the degree to which a particular safety problem is addressed with*

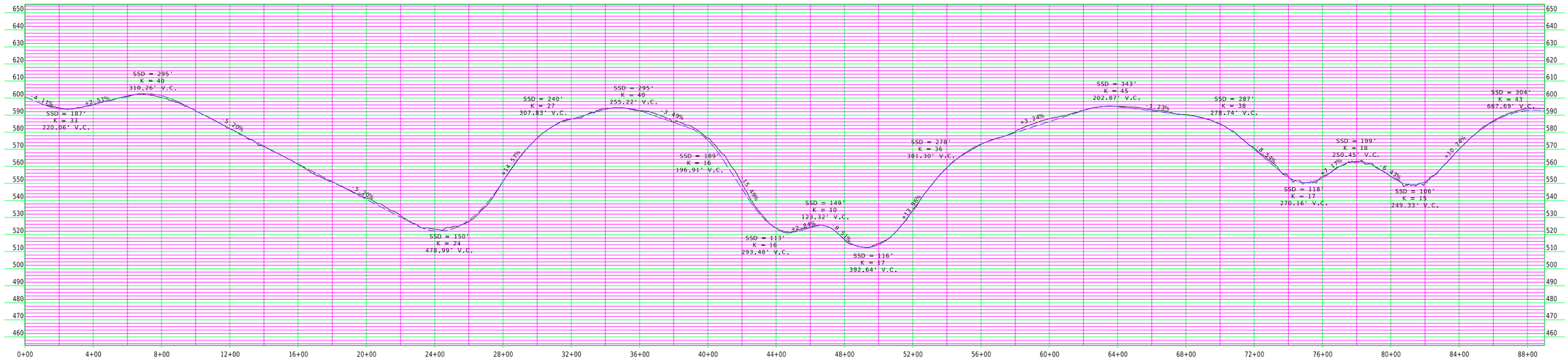
the systemic approach versus the more traditional site analysis approach. With a program where all crashes are used as the performance measure, high crash locations will be more prevalent and treatment strategies will tilt more heavily toward addressing high crash locations. In contrast, a program that uses severe crashes as the performance measure will use a stronger systemic component as severe crash locations are not as concentrated.

This is particularly true for severe roadway departure crashes, which tend to be highly scattered across the rural and local roads system. This does not mean that severe crashes are random. They tend to be overrepresented at locations with high risk characteristics, horizontal curvature being one of those.

A safety improvement process should include both components: treating high severe crash locations where they exist as well as systemically addressing locations or segments at higher risk. Both components will provide optimal results with good data and data analysis."

With this in mind, based on the results of TERRA's review of the corridor we would suggest that the City of Weldon Spring consider multiple different strategies to address the roadway deficiencies along Wolfrum Road. There are both specific locations which have higher crash occurrences which need improvements and overall system wide improvements which should be considered.

APPENDIX A
PLAN AND PROFILE SHEETS, SIGNING PLAN, AND CRASH DIAGRAM



MODEL: $MODELNAME$
FILE NAME: $FILE$

TERRA ENGINEERING LTD.

USER NAME = $USER$	DESIGNED -	REVISED -
	DRAWN -	REVISED -
PLOT SCALE = $SCALE$	CHECKED -	REVISED -
PLOT DATE = $DATE$	DATE -	REVISED -

CITY OF WELDON SPRINGS
DEPARTMENT OF PUBLIC WORKS

PLAN AND PROFILE
WOLFRUM ROAD

SCALE:

SHEET 1 OF 2 SHEETS STA. TO STA.

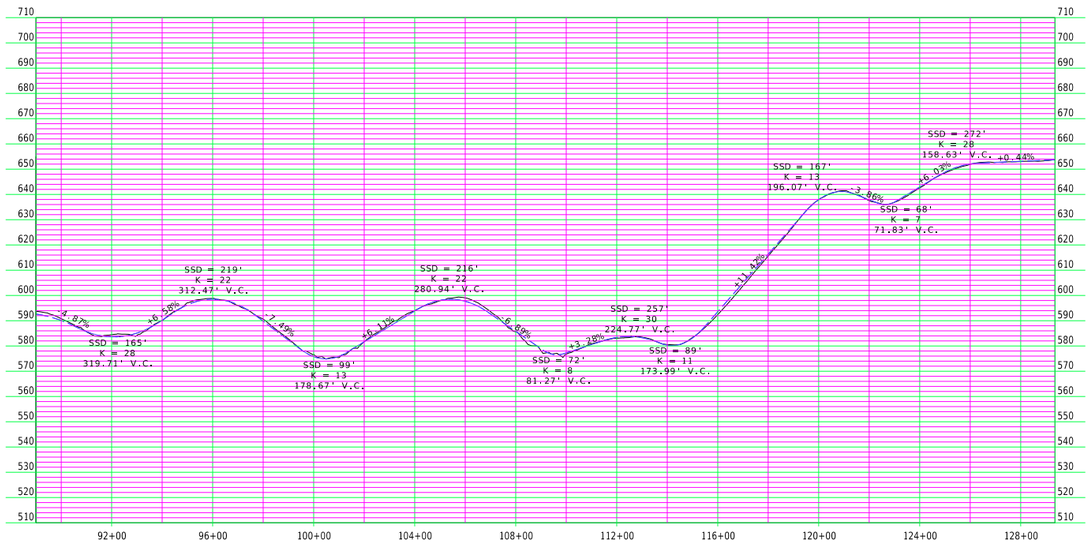
F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.

CONTRACT NO.

MISSOURI FED. AID PROJECT

N

0 300 600 900
SCALE IN FEET



MODEL: $MODELNAME$
FILE NAME: $FILE$

TERRA ENGINEERING LTD.

USER NAME = $USER$	DESIGNED -	REVISED -	
	DRAWN -	REVISED -	
PLOT SCALE = $SCALE$	CHECKED -	REVISED -	
PLOT DATE = $DATE$	DATE -	REVISED -	

CITY OF WELDON SPRINGS
DEPARTMENT OF PUBLIC WORKS

PLAN AND PROFILE
WOLFRUM ROAD

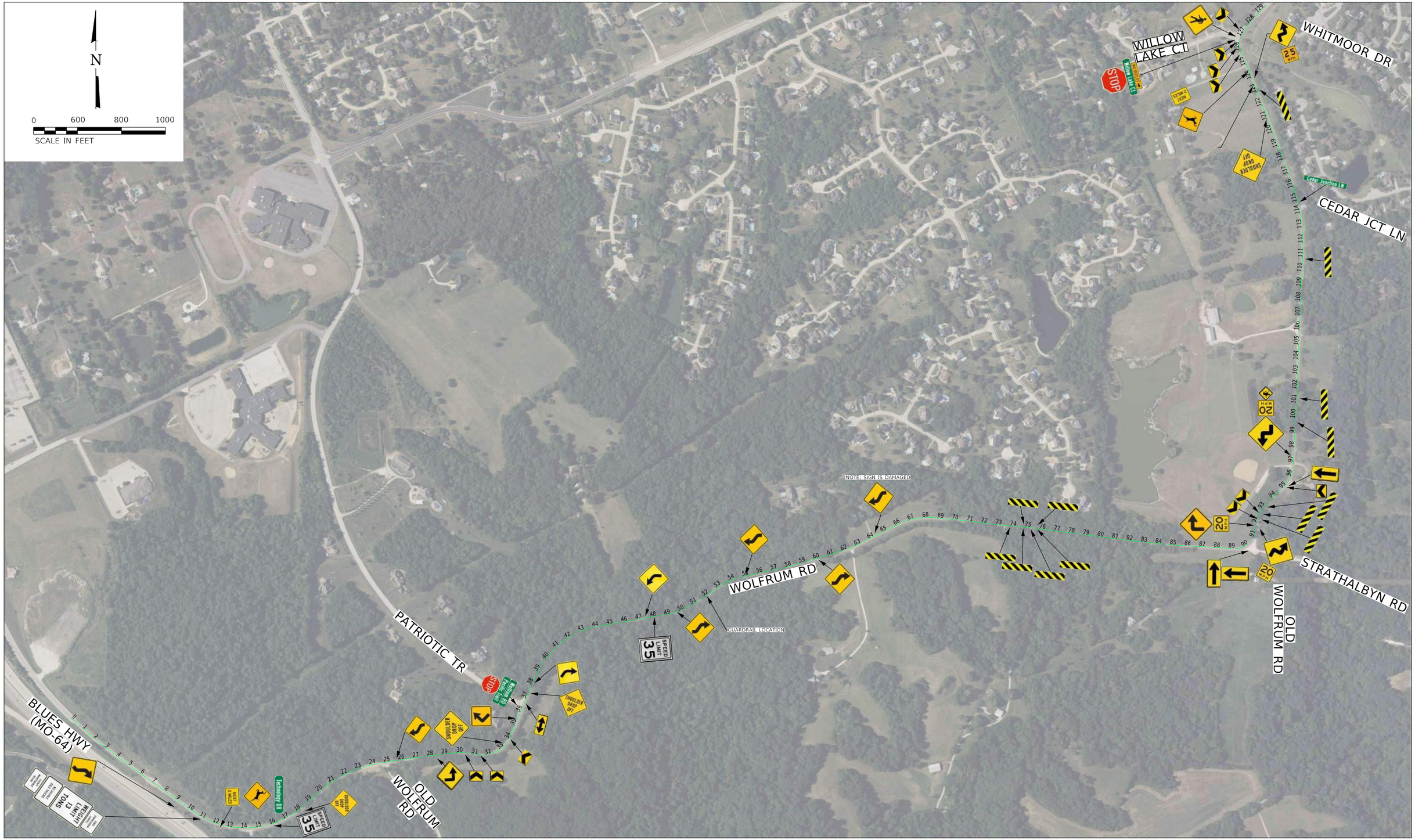
SCALE:

SHEET 2 OF 2 SHEETS STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.

CONTRACT NO.

MISSOURI FED. AID PROJECT



TERRA ENGINEERING LTD.

Wolfrum Road

Existing Signage Exhibit
DRAFT 12/11/2023

N

0 600 800 1000

SCALE IN FEET

LEGEND

- FIXED OBJECT, PROPERTY DAMAGE
- FIXED OBJECT, PERSONAL INJURY
- FIXED OBJECT, FATAL
- OTHER OBJECT, PROPERTY DAMAGE
- MOTOR VEHICLE IN TRANSPORT, PROPERTY DAMAGE
- OVERTURN, PERSONAL INJURY
- ANIMAL, PROPERTY DAMAGE

NOTE:
DUE TO THE LACK OF INFORMATION, 3 FIXED OBJECT CRASHES AND 1 ANIMAL CRASH ALONG WOLFRUM ROAD ARE NOT MAPPED ON THIS EXHIBIT.

TERRA ENGINEERING LTD.

Wolfrum Road

Existing Signage Exhibit
DRAFT 11/07/2023