



KC ENGINEERING, INC.

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February 5, 2018

Mr. Joe Don Dockery
Burnet County Commissioner
Precinct 4
Burnet County, Texas

Re: Speed Limit Review of CR 413
From: SH 71
To: CR 404

Commissioner Dockery,

K.C. Engineering, Inc. (KCE) has performed a review of Burnet County Road No. 413 (CR 413) for the purposes of issuing a preliminary opinion if the existing roadway geometry would be conducive to increasing the currently posted prima facie speed limit of 35 miles per hour (mph) to 45 mph (the opinion).

The opinion has been prepared without the benefit of on-the-ground survey and its accuracy is limited to the publicly available information with which it was prepared. However, it is probable that on-the-ground survey data would likely not change the outcome of the opinion. The opinion is based upon criteria published by the Federal Highway Administration (FHWA), the Texas Department of Transportation (TxDOT) Roadway Design Manual, Revised October 2014 (RDM), the Procedures for Establishing Speed Zones Manual, Revised August 2015 (SZM), and the 2014 Texas Manual on Uniform Traffic Control Devices, Revision 2 (TMUTCD). All references cited herein are from the FHWA, RDM, SZM and TMUTCD.

The SZM provides multiple methods for determining speed zones and the traffic control devices used in speed zones. For the opinion, the Design Method was used. Since design files or as-built plans were unavailable, alignment geometry was “best-fitted” using aerial imagery and LiDAR elevation data to relatively closely approximate the existing roadway geometry.

The Design Method requires three (3) steps and all were performed:

1. Obtain Curve Geometry
2. Determine Advisory Speed
3. Confirm Speed for Conditions (using Step 3 from the Direct Method)

Additional guidance for the opinion was obtained from the FHWA publication “Report No. FHWA-SA-11-22: Procedures for Setting Advisory Speeds on Curves”. Curve Advisory Speed (CAS) software published and/or provided by the FHWA was used to develop the type and placement of warning signs and the results of the calculations are attached hereto.

KCE reviewed crash data obtained from the TxDOT Crash Records Information System (CRIS) for the period of 2013 – 2017 and found two recorded accidents: one in 2015 and one in 2016 and there were no reported injuries in either accident. Both accidents were intersection-related: 1) at the intersection of SH 71, and 2) at the intersection of CR 404. The Crash Map is attached hereto.

Factors considered in the opinion are the pavement cross-section, horizontal geometry, and vertical geometry. Since on-the-ground survey data or as-built construction plans are unavailable, roadway cross-slope (a component of the roadway configuration) and roadway super-elevation were unavailable. It is important to note that both components play a major role in the determination of design speed and should be influential in determining a roadway's speed limit. For the purposes of the opinion, an on-the-ground inspection appears to indicate that little or no super-elevation is present, so a conservative value of "0" (no super-elevation) was assumed for the calculations. Negative super-elevation was not observed.

Horizontal Geometry

Based upon the existing horizontal geometry, the procedure described in the SZM using the CAS software was utilized for calculating the advisory speed and appropriate warning signs and their placement.

Using publicly-available information, KCE developed a visual, best-fit of the horizontal alignment to approximate horizontal geometry. KCE applied what is referred to as "centerline stationing" to the alignment as a method to locate alignment features. The point where CR 413 intersects State Highway No. 71 is Station 0+00. The end of CR 413 for the purposes of the opinion is approximately the end of the horizontal curve at the intersection of CR 413 and CR 404. The station of the end of CR 413 is approximately 49+95. The length of CR 413 for the opinion is 4,995'.

The data below was entered into the CAS software with the appropriate deflection angle, radius, and proposed speed limit (refer to Exhibits A – C):

CURVE DATA				
CURVE NUMBER	STATION	SPEED LIMIT	RADIUS	DEFLECTION ANGLE
1	15+91	45 MPH	2,402'	3°
2	21+19	45 MPH	369'	31°
3	48+65	45 MPH	295'	55°

The results of the CAS software calculations are:

Curve 1

- It is not recommended to place curve warning signs at Curve 1

Curve 2

- Advisory speed: 30 mph
- Recommended advance placement distance of warning sign is 100'
- Advisory Speed Plaque (W13-1P) is required
- Chevrons (W1-8) and/or One Direction Large Arrow (W1-6) is required
- Spacing of Chevron Alignment Signs is 80'

Curve 3

- Advisory speed 30 mph
- Recommended advance placement distance of warning sign is 100'
- Advisory Speed Plaque (W13-1P) is required
- Chevrons (W1-8) and/or One Direction Large Arrow (W1-6) is required
- Spacing of Chevron Alignment Signs is 80'

From the CAS software, *"This equation is calibrated for speed limits in the range of 50 to 75 mph. It can be used to estimate the 85th percentile tangent speed when the speed limit is outside this range; however, judgment should be used to confirm the accuracy of the estimate"*. For the purposes of the opinion, judgment indicates that the results of the software's calculations for 45 MPH appear to be reasonable.

The CAS software requires the use of one of the W1-10 curve signs. However, the TMUTCD Section 2C.07 states, *"A Turn (W1-1) sign shall be used instead of a curve sign in advance of curves that have advisory speeds of 30 mph or less."* Therefore, the TMUTCD prevails and the Turn (W1-1) sign shall be used.

The CAS software and Table 2C-5 of the TMUTCD require an Advisory Speed Plaque (W13-1P) and Chevrons (W1-8) and/or One Direction Large Arrow (W1-6) for a difference between speed limit and an advisory speed of 15 mph.

Vertical Geometry

Based upon the existing vertical geometry, the RDM was used to determine approximate sight distance at vertical curves.

There are two general factors to consider for vertical geometry: 1) Grade; and 2) Vertical Curves. Because of the relatively flat grades on each end of the vertical curves, grade was not evaluated in the opinion.

There are two types of vertical curves: 1) Crest; and 2) Sag. Generally, sight distance must be maintained at crest vertical curves so that a vehicle can stop or take evasive maneuvers if an obstacle is observed in the roadway by a driver. The general control for sag vertical curves is headlight distance so that a driver can see an obstacle in his path at night and stop or take evasive maneuvers to avoid the obstacle. To simplify relatively complex mathematics, engineers use a factor that is referred to as a vertical curve's "K" value that combines constants in the equations:

<u>Curve Type</u>	<u>Speed</u>	<u>"K" value</u>
Crest	35 MPH	29
Crest	45 MPH	61

RDM Figure 2-5

<u>Curve Type</u>	<u>Speed</u>	<u>"K" value</u>
Sag	35 MPH	49
Sag	45 MPH	79

RDM Figure 2-6

The crest vertical curvature at Station 21+19 does not meet minimum criteria for 45 MPH. KCE, using LiDAR data obtained from the TNRIS, created a triangular-irregular network (TIN) surface from the data and placed a reasonable, best-fit, vertical profile to approximate the existing vertical curves (Exhibit D). Vertical curve alignment data was interpolated to approximate the curve's "K" value using symmetrical parabolic curves. The approximate "K" value for the crest vertical curve is 35. As shown above, the minimum "K" value for a crest vertical curve at 35 MPH is 29 and for 45 MPH is 61. The vertical curve appears to meet the minimum "K" value for 35 MPH but not for 45 MPH.

If the speed limit is increased to 45 MPH, it is recommended to place the sign "HILL BLOCKS VIEW" (W7-6) on both approaches to the hill. The sign "LIMITED SIGHT DISTANCE" was once used but it has since been removed from the TMUTCD.

From Section 2C.18 of the TMUTCD:

A HILL BLOCKS VIEW (W7-6) sign may be used in advance of a crest vertical curve to advise road users to reduce speed as they approach and traverse the hill as only limited stopping sight distance is available.

The sag vertical curve at Station 16+29 does not meet minimum criteria for 45 MPH. The approximate "K" value for the sag vertical curve is 19. As shown above, the minimum "K" value for a sag vertical curve at 35 MPH is 49 and for 45 MPH is 79. The vertical curve does not appear to meet the minimum "K" value for either 35 MPH or 45 MPH. Based upon RDM Figure 2-6, the sag vertical curve appears to have a design speed of approximately 20 MPH.

KCE was unable to locate guidance combining the use of curve advisory signs and the "HILL BLOCKS VIEW" sign. It is the opinion of KCE that if curve advisory signs with the appropriate Advisory Speed Plaque are posted that it would provide adequate warning for the crest vertical curve condition. However, since the sag vertical curve does not meet even 35 MPH, then it appears appropriate to install the "HILL BLOCKS VIEW" signs on each approach to the curve.

Curve 3 is at the end of CR 413 at its intersection with CR 404. Considering the intersection configuration, the installation of curve warning signs as described herein may be problematic (the signs may require locating within the intersection). Therefore, it is recommended that the

contemplated speed zone's northern regulatory limit be approximately at the beginning of the horizontal curve at Station 47+12. Section 2C.38 of the TMUTCD states, "*A Reduced Speed Limit Ahead Sign (W3-5) should be used to inform road users of a reduced speed zone where the speed limit is being reduced by more than 10 mph, or where engineering judgment indicates the need for advance notice to comply with the posted speed limit ahead.*" Engineering judgment suggests that there is a need to comply with the posted speed limit ahead because of the geometric limitations of the horizontal curve at Station 48+65. It is important that drivers traverse the curve at the existing, posted, prima facia speed limit of 35 mph and therefore, sign W3-5 is warranted.

Attached are exhibits of each curve and the recommended type and placement of warning signs.

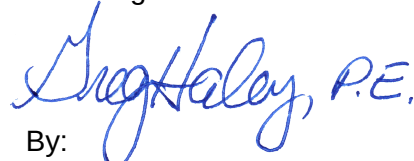
In accordance with the Design Method, Step 3: Confirm Speed for Conditions (using Step 3 from the Direct Method), the roadway was driven at 45 mph – the proposed speed limit and travel speed at Curve 2 was reduced to the advisory speed (30 mph) to evaluate the factors listed. Provided that speed limit sign and warning signs are placed as indicated herein and drivers adhere to the posted speed limit and obey the curve warning signs, increasing the prima facia speed limit to 45 mph appears reasonable.

KCE is available at any time to discuss the opinion. Please feel free to contact us at 830-693-5635.

This document is released for the purpose of interim review under the authority of Greg Haley, P.E. 52292 of K.C. Engineering, Inc., Firm Registration #F-977, on February 5, 2018. It is not to be used for any other purpose.

Sincerely,

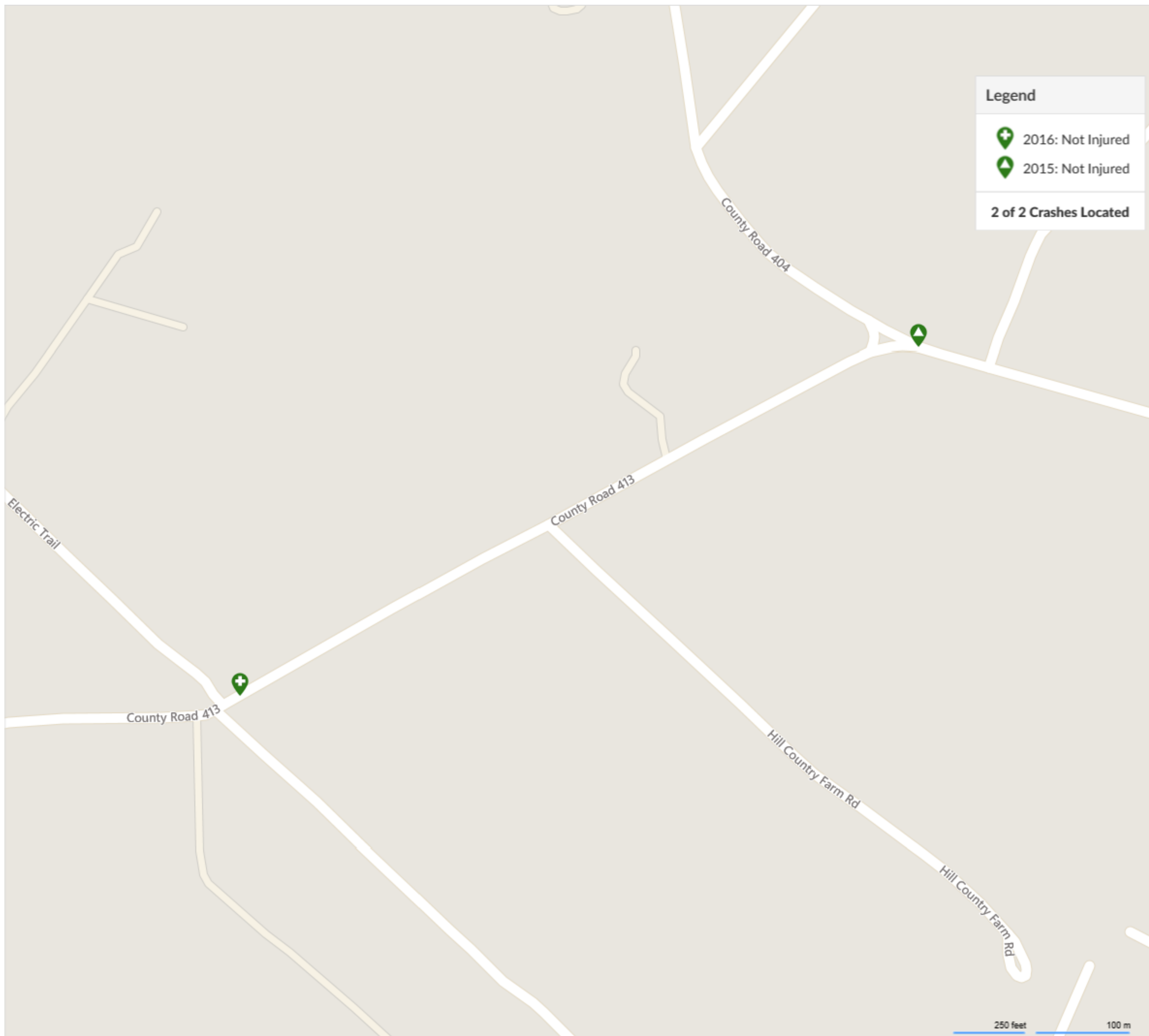
K.C. Engineering, Inc.
Firm Registration #: F-977

A handwritten signature in blue ink that reads "Greg Haley, P.E." with a stylized flourish at the end.

By:
Greg Haley, P. E.
President

Attachments:

Crash Map
CAS Worksheet
Exhibits A - D



CURVE ADVISORY SPEED WORKSHEET						
General Information						
District:	Burnet County Precinct 4	Curve Data Source:	Date: February 4, 2018			
Highway:	County Road 413	Design	Analyst: Greg Haley, P.E.			
Input Data						
Data Description	Curve Identification Number					
	1	2	3	4	5	6
Curve deflection, left or right	Right	Left	Left	Left	Left	Left
Compass heading 1, degrees						
BBI reading of superelevation, degrees						
Deflection of ball for superelevation reading, left or right	Right	Left	Left	Right	Right	Left
Speed when recording the BBI reading of superelevation, mph						
Curve length, ft						
Compass heading 2, degrees						
Survey method (partial or full)	Partial	Partial	Partial	Partial	Partial	Partial
Regulatory speed limit, mph	45	45	45			
Estimate of 85th% tangent speed, mph	57	54	52			
Caution, speed limit outside equation range.	See note.	See note.	See note.			
Alternate Input Data (if data are entered here, they will be used instead of estimates from the data above)						
85th% tangent speed, mph						
Total curve deflection angle, degrees	3	31	55			
Curve deflection angle, degrees						
Superelevation rate, percent	0.0	0.0	0.0			
Curve radius, ft	2402	369	295			
Max of Speed limit & 85th% speed	45	45	45	0	0	0
Two adjacent reversed curves separated by <= 600' (Yes or No)	No	No	No	No	No	No
Three or more adjacent reversed curves separated by <= 600' (Yes or No)	No	No	No	No	No	No
Intersection occurs within or immediately adjacent to a curve (Yes or No)	No	Yes	Yes	No	No	No
Freeway/expressway ramp (Yes or No)	No	No	No	No	No	No
Advisory Speed						
Survey method (partial or full)						
Total deflection angle, degrees	3	31	55	0	0	0
Curve deflection angle, degrees	0.0	0.0	0.0	0.0	0.0	0.0
Curve radius, ft	2402	369	295			
Degree of curvature, degrees	2.4	15.5	19.4			
Curve path radius, ft	11157	451	322			
Superelevation rate, percent	0.0	0.0	0.0			
Average tangent speed, mph	50	47	46			
Unrounded advisory speed, mph	50	34	30			
Rounded advisory speed, mph	50	30	30			
Advisory Speed from other source						
Advisory Speed	50	30	30			

CURVE ADVISORY SPEED WORKSHEET							
General Information							
District:	Burnet County Precinct 4	Curve Data Source:	Date: February 4, 2018				
Highway:	County Road 413	Design	Analyst: Greg Haley, P.E.				
Input Data							
Data Description		Curve Identification Number					
		1	2	3	4	5	6
Traffic Control Device Guidance							
Curve Warning Signs (for AADT>1000, the following standards shall be used; for AADT<1000, the following standards may be used.)							
Recommended advance placement distance of warning signs (ft.)		-	100	100			
Turn (W1-1)							
Combination Turn/Advisory Speed (W1-1a)							
Curve (W1-2)							
Combination Curve/Advisory Speed (W1-2a)							
Reverse Turn (W1-3)							
Reverse Curve (W1-4)							
Winding Road (W1-5)							
Combination Horizontal Alignment/Intersection (W1-10 series with turn/reverse turn arrow)			Required	Required			
Combination Horizontal Alignment/Intersection (W1-10 series with curve/reverse curve arrow)							
Hairpin Curve (W1-11)							
270-degree Loop (W1-15)							
Advisory Speed Plaque (W13-1P)			Required	Required			
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)			Required	Required			
Spacing of Chevron Alignment Signs (ft.)			80	80			
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp							
Combination Horizontal Alignment/Exit and Ramp Speed (W13-6, W13-7)							

CALIBRATION PARAMETERS						
Lateral shift in lane, ft	3	Side Friction Demand Increase Thresholds, g				
Ratio of average to 85th% speed	0.90		A	0.00	D	0.13
Ratio of truck speed to car speed	0.97		B	0.03	E	0.16
			C	0.08		

INTERMEDIATE CALCULATIONS						
Speed conversion factor (mph to fps):	1.47					
BBI reading adjusted for ball deflection:	0	0	0	0	0	0
Unrounded advisory speed, mph	50	34	30			
Rounded advisory speed, mph	50	30	30			
Equivalent ball-bank reading, deg:	1	11	12			
Average side friction demand, g	0.02	0.17	0.18			
Side friction demand increase (85th %), g	0.00	0.10	0.11			

Date: Feb 05, 2018, 7:51am User ID: gregh
File: K:\17-105 Burnet CR 413 Speed Limit Review\MP 17-105.dwg

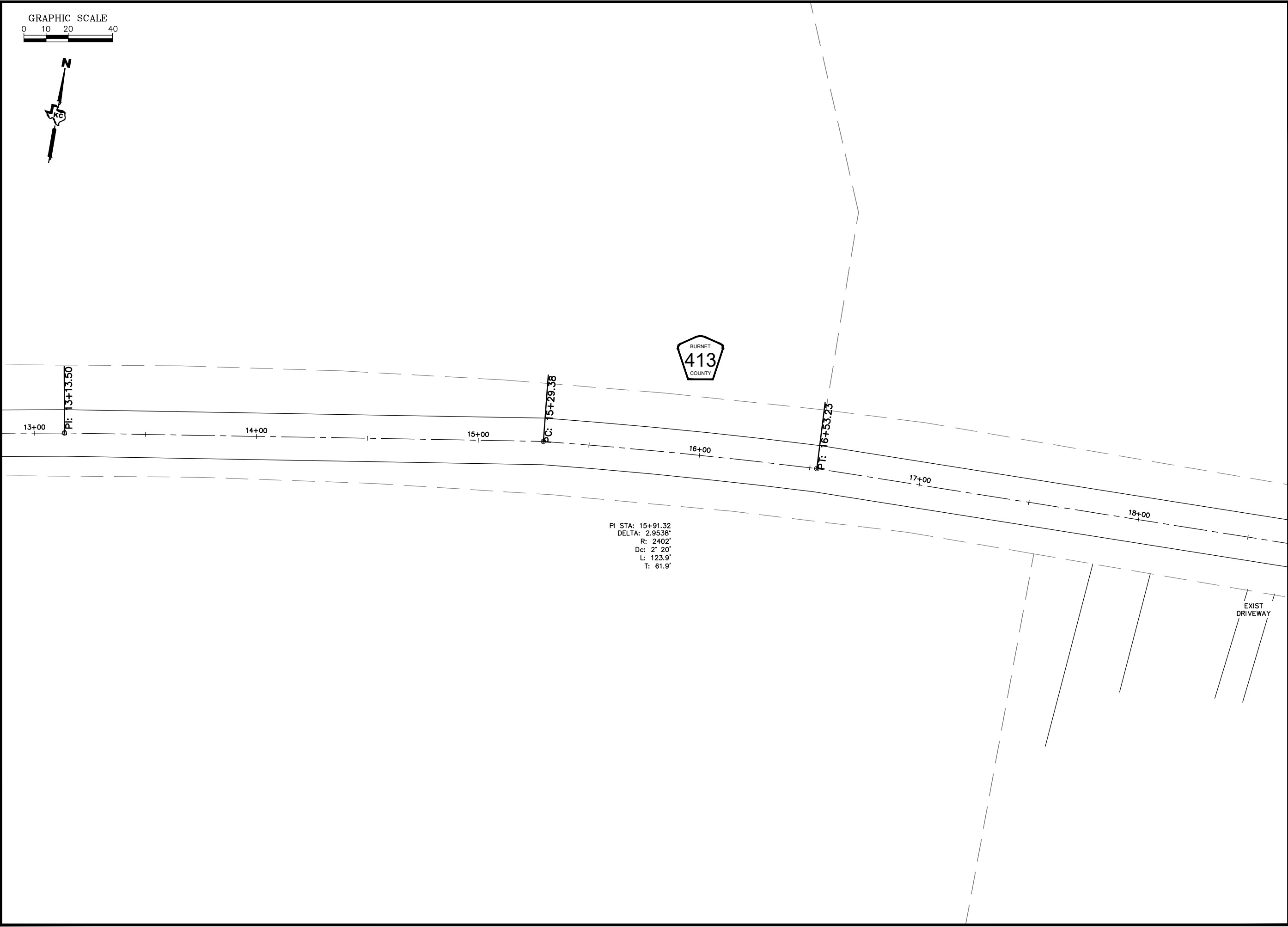


EXHIBIT
A

File: 17-105 Burnet CR 413 Speed Limit Review\MP 17-105.dwg			
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Date: 02/03/18	Checked By:	Drawn By: GK	
Rev. No.	Date	Remarks	
1			
2			
3			
4			

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Greg Haley, P.E. 52292
on FEB 3, 2018
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CURVE 1
CURVE ADVISORY ANALYSIS
COUNTY ROAD 413
BURNET COUNTY, TEXAS



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Date: Feb 05, 2018, 5:03pm User ID: gregh
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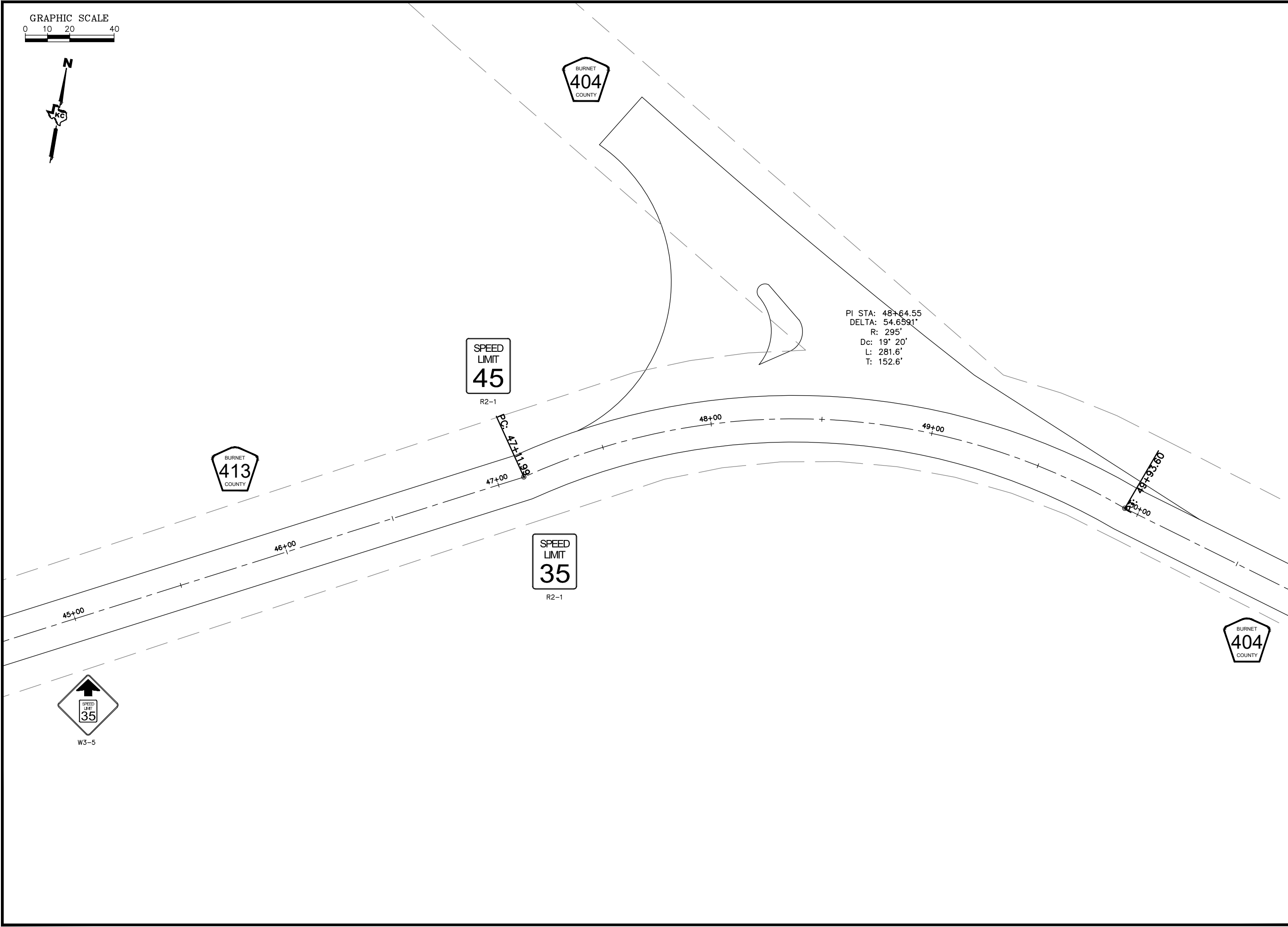


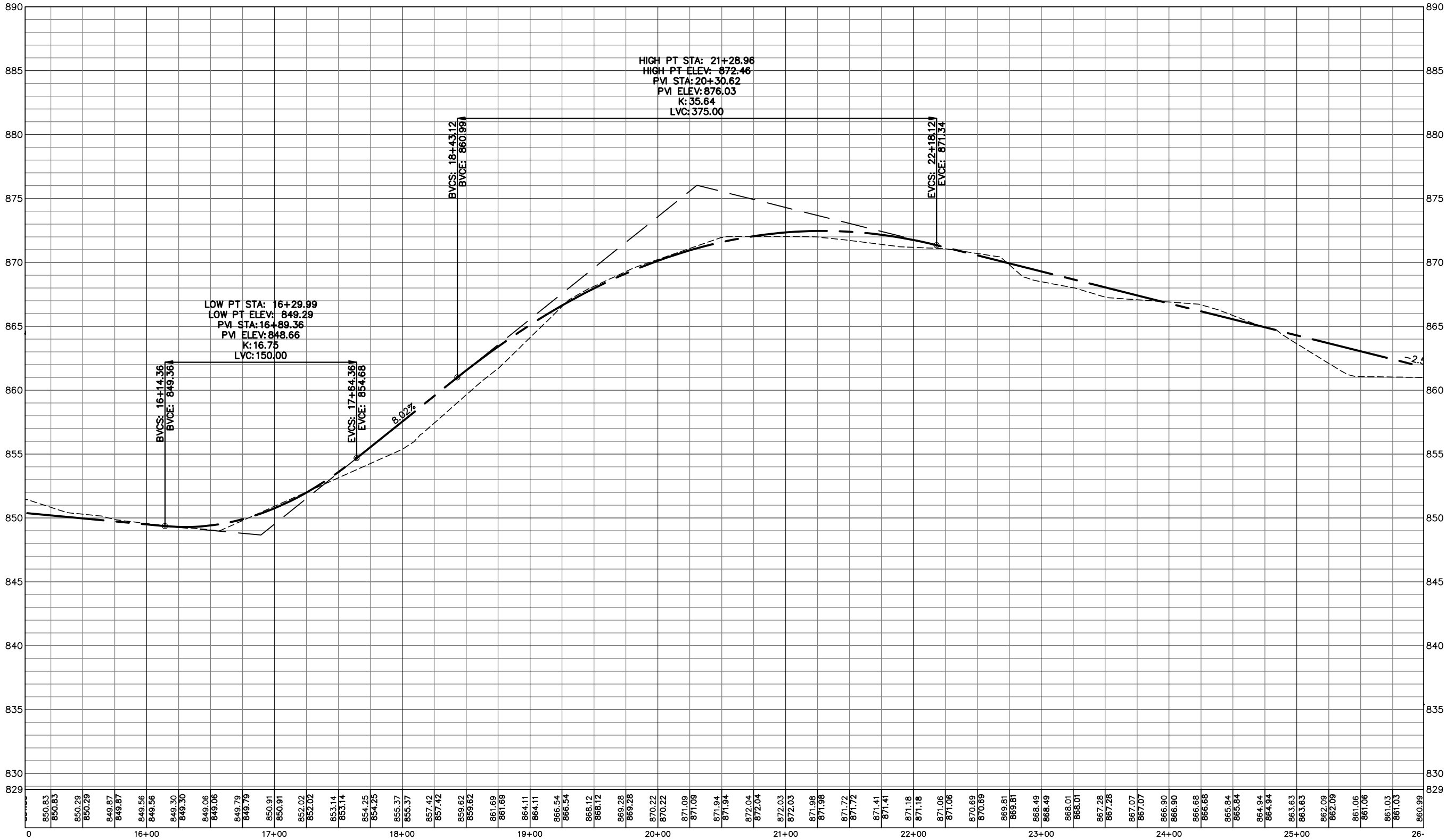
EXHIBIT			
C			

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CURVE 3
CURVE ADVISORY ANALYSIS
COUNTY ROAD 413
BURNET COUNTY, TEXAS



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FIRM REGISTRATION # F-977



Job No.		Scale (Hor.):	AS SHOWN
17-105		Scale (Vert.):	N/A
Date:	02/03/18	Checked By:	Drawn By: GK
Rev. No.	Date	Remarks	
1			
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3			
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PROFILE
CURVE ADVISORY ANALYSIS
COUNTY ROAD 413
BURNET COUNTY, TEXAS

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