WATERWAY ENGINEERING

TBPE&LS Engineering Firm No. F23247

July 24, 2025

Charlie Hastings, PE
Kerr County Engineer
3766 State Highway 27
Kerrville, TX 78028
[redacted]

RE: Hydrologic Assessment of the July 4, 2025 Flooding Event

Dear Mr. Hastings,

Waterway Engineering has conducted a hydrologic assessment of the July 4, 2025 flood event that occurred in the Upper Guadalupe River watershed. The report, provided as an attachment to this letter, outlines the rainfall and riverine conditions experienced in the Upper Guadalupe River watershed during the event. This analysis is based on the best available data as of today. Further data may become available at a later date that will refine the results of this analysis. Regardless, based on this analysis, Waterway Engineering can conclude the following:

- The highest recorded rainfall provided by UGRA produced the 6-hour 688-year (0.15% AEP) event but did not catch the peak rainfall of the event.
- Estimated peak rainfall depths exceeded the 3-hour and 6-hour 1000-year (0.1% AEP) events.
- Gage data show rates of rise in the river that exceeded 20 feet per hour
- The UGRA rainfall gage measured an event that was 57% of the 6-hour tropical PMP event
- The estimated peak rainfall depth produced 70% and 63% tropical PMP for the 3-hour and 6-hour event, respectively.
- Hydraulic modeling data shows the South Fork Guadlupe River flow exceeded the 1,000-year (0.1% AEP) event.

Floodplain modeling results from this data have been provided to both Kerr County and Texas Department of Emergency Management (TDEM). The data has been used by TDEM since 7/13/2025 to more efficiently direct resources for search and recovery efforts.

It has been a pleasure to assist both the County and TDEM in their recovery efforts. If there are any questions or concern please reach out to Michael Pantell, PE at (916) 708-6955.

Sincerely,

[redacted]

Michael G Pantell, PE
Principal Engineer

Attachment:

Guadalupe River Hydrologic Assessment for the July 5, 2025 Flood Event- July 24, 2025

[redacted] [redacted]

GUADALUPE RIVER HYDROLOGIC ASSESSMENT
FOR THE JULY 4, 2025 FLOOD EVENT

July 24, 2025

Prepared For:
Kerr County
3766 State Hwy 27
Kerrville, TX 78028

Prepared By:
Michael Pantell PE, CFM

[redacted]

WATERWAY
ENGINEERING

[redacted]
TBPELS FIRM No.: 23247

Table of Contents

Exhibits

Appendices

Introduction

On the morning of July 4, 2025, an extreme rainfall event caused widespread flooding along the South Fork Guadalupe River and the main stem of the Guadalupe River upstream of Comfort, TX. Waterway Engineering has assisted Kerr County and Texas Department of Emergency Management (TDEM) with the initial emergency response providing real-time hydrologic and hydraulic modeling of the event. The purpose of this report is to summarize the data gathered, outline the modeling methods used to simulate the event, and provide a hydrologic and hydraulic assessment of the event. This report is an initial assessment and may be amended in the future as further information becomes available.

Background

The Upper Guadalupe River watershed is 1,427 square miles and extends from the West end of Kerr County to Canyon Lake. The Guadalupe River is the primary river the flows through the watershed which extends from Hunt, TX 125 miles to Canyon Lake. Upstream of Hunt, the Guadalupe River splits into the North and South Forks. The North Fork watershed is approximately 190 square miles while the South Fork watershed is approximately 97 square miles.

Exhibit 1 provides an overview of the Upper Guadalupe River watershed.

Rainfall

Rainfall data was obtained from United States Geologic Survey (USGS) rainfall gages, Upper Guadalupe River Authority (UGRA) rainfall gages, and National Ocean and Atmospheric Administration (NOAA) Multi-Radar Multi-Sensor (MRMS) data. While the rainfall gages provide the most accurate rainfall data, the availability of gages is sparse in the portion of Upper Guadalupe River watershed where the most intense rainfall occurred. The USGS has only four (4) rainfall gages in the watershed and two (2) that are directly south of the South Fork watershed. The two most centrally located gages in the primary storm area are the Guadalupe River at Hunt and the Johnson Creek at Ingram gages. Rainfall data were obtained from USGS and are provided in Appendix A. A summary of the peak rainfall depths over various time frames are provided in Table 1.

Table 1 Peak Rainfall Depths by Duration at USGS Gages

	Peak Total Rainfall Depth (in)							
Duration:	**5-min**	**10-Min**	**15-Min**	**30-Min**	**60-Min**	**2-Hour**	**3-hour**	**6-Hour**
Johnson Creek Near Ingram	0.25	0.44	0.53	0.98	1.39	2.13	3.40	5.31
Guadalupe River At Hunt	0.48	0.90	1.12	1.90	2.92	4.32	6.64	7.46*

*This station went offline at 4 hours and 35 minutes into the storm

UGRA provided seven (7) rainfall gages in the area with 24-hour total rainfall depths and 6-hour rainfall depths from approximately 11 PM on the 3rd to 5 AM on the 4th. Locations of these gages with the peak 6-hour rainfall depths are provided in Exhibit 2 and shown in Table 2. It is important to note that based on discussion with UGRA, their rainfall gages become less accurate when rainfall intensities exceed 2 inches per hour. It is likely that gages K-7 and K-8 underestimate the 6-hour rainfall depth.

Table 2 UGRA Gage Data

Gage	6-Hour Peak Storm Depth (in)
K-2	2.20
K-3	7.63
K-5	9.92
K-6	8.82
K-7	11.99
K-8	10.40
K-9	2.79

The MRMS data provides hourly radar derived rainfall depths for the entire nation at approximately 1 square kilometer resolution. Exhibits 2 and 3 provide the total maximum 6-hour and 3-hour MRMS rainfall depths, respectively. The maximum hourly rainfall depths from MRMS are provided by in Table 3. Based on the MRMS data, it was determined that between 11 PM on July 3rd and 5 AM July 4th 9.78 inches of rainfall fell. Between 1 AM and 4 AM a maximum of 8.72 inches fell with a peak 1 hour rainfall depth of 4.04 inches.

Table 3 Peak 6-Hour Rainfall Depths by Duration Based on NOAA MRMS

Duration	1-hour	3-hour	6-hour
Depth (in)	4.04	8.72	9.78

Exhibit 2 provides a comparison of the MRMS rainfall 6-hour data to the UGRA gage data captured during that same time period. This comparison shows that the UGRA data did not capture the location of the peak rainfall that occurred. This comparison also shows that the MRMS data underestimates the amount of rainfall depth at each gage location with the underestimation becoming larger as the total depth increases. To estimate the peak rainfall depth at the maximum location, a correction value for the 6-hour rainfall depths was calculated. This correction value, provided in Table 4, was calculated using the average difference between the K-7 and K-8 gages and the MRMS rainfall depths at those locations. From this it was determined that the peak MRMS 6-hour rainfall depths were likely underestimated by 3.57 inches. A 3-hour correction value was estimated by multiplying the 6-hour correction value by 90% which was derived by comparing the 3-hour MRMS depths to the 6-hour MRMS depths. That is to say, approximately 90% of the rainfall fell within a 3-hour period.

Table 4 Average Difference Between UGRA Gage Rainfall and MRMS Depths (6-hour Duration)

Location	Depth (inches)		
	UGRA	MRMS	Difference
K-7	11.99	8.75	3.24
K-8	10.4	6.5	3.90
6-Hour Correction Value			3.57
Estimate 3-hour Correction Value*			3.21

*Assuming 90% of the rainfall fell in 3 hours based on MRMS data

The correction values were then added to the peak 6-hour and 3-hour MRMS rainfall depths shown Table 5. This provides an estimated peak rainfall depth of 13.27 inches and 11.94 inches for the 6-hour and 3-hour events, respectively.

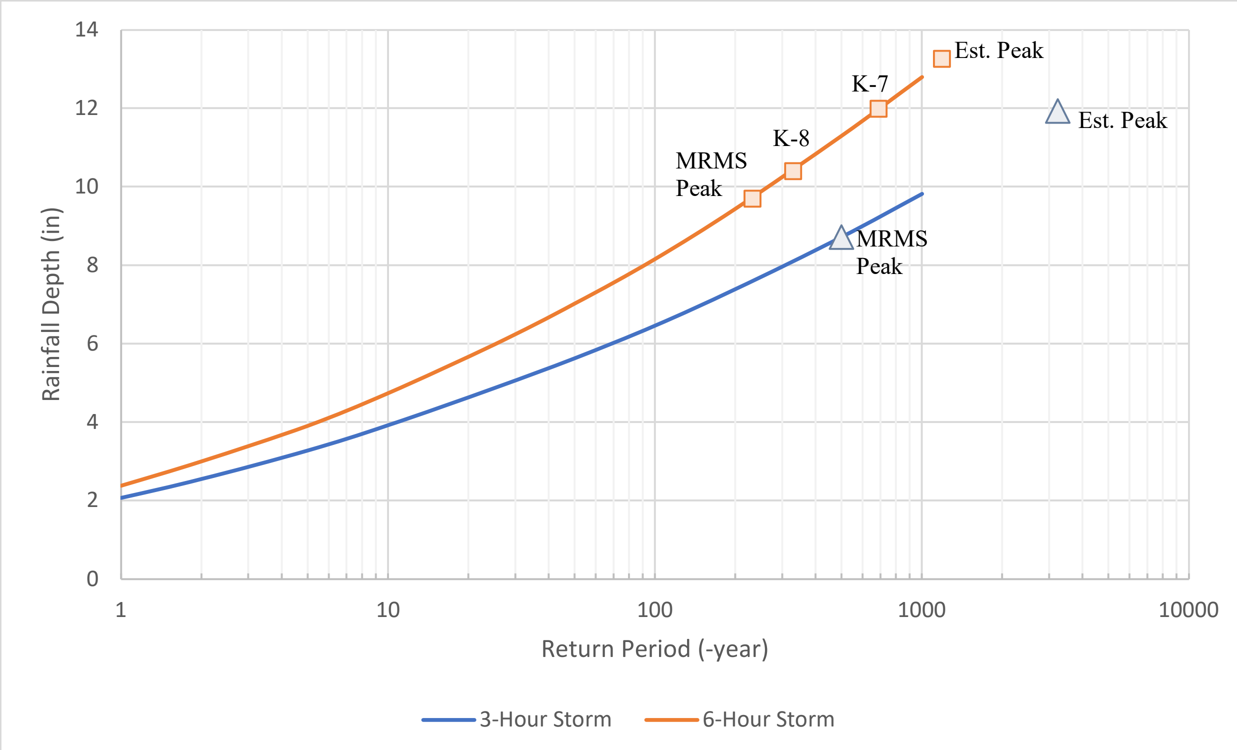
Table 5 Adjusted MRMS Rainfall Depths based on UGRA Gage Data

	Depth (inches)	
Duration:	**6-hour**	**3-Hour**
MRMS Peak	9.7	8.72
Estimated Peak	13.27	11.94

Rainfall Return Period

To determine the return period of this event, NOAA Atlas 14 data was obtained for the South Fork Guadalupe River watershed. The NOAA Atlas 14 rainfall data report is provided in Appendix B. Figure 1 shows the NOAA Atlas 14 3-hour and 6-hour depth-frequency curves with the various rainfall depth points plotted on it. This figure shows that for the 6-hour duration, UGRA measured rainfall depths between the 330- and 688-year (0.3% and 0.15% annual exceedance probability (AEP) events while the MRMS data measured rainfall depths that match the 230-year (0.43% AEP) event. The estimated peak produced a 6-hour rainfall depth well over the 1,000-year (0.1% AEP) event. For the 3-hour event, the MRMS data produced a 500-year (0.2% AEP) event while the MRMS adjusted produced a greater than 1,000-year (0.1% AEP) event.

Figure 1 NOAA Atlas 14 Rainfall Depth-Duration-Freqnuency Curves with Recroded and Esimated Data



Probable Maximum Precipitation

The probable maximum precipitation (PMP) is theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a given location and time. PMP does not have a return period associated with it. For Texas, the PMP was developed for Applied Weather Associates, LLC for the Texas Commission Environmental Quality (TCEQ). This analysis developed PMP depths for a range of durations for three (3) different storm types- General, tropical, and local- at all locations in Texas. TCEQ has developed a tool based on this data to develop the appropriate PMP for a given watershed (Texas PMP Interactive Web Tool). This tool was used to obtain the PMP for the South Fork Guadalupe watershed. Since this storm fits the tropical storm requirements outlined by the PMP analysis, the tropical storm PMP depths are used for this analysis and are provided in Table 6.

Table 6 Tropical Storm PMP

Duration	1-hour	3-hour	6-hour
Depth (in)	10.3	17.1	21.2

The tropical storm PMP values were compared to the various rainfall data collected to determine that percent of the PMP which was experienced. Table 7 provides the results of the PMP analysis. The results show that the K-7 site (the highest recorded rainfall) experienced 57% of the 6-hour tropical PMP. The estimated peak data results in 70% and 63% PMP for the 3-hour and 6-hour events, respectively.

Table 7 Percentage of the PMP

Location	3-hour	6-Hour
K-7	-	57%
K-8	-	49%
MRMS Raw	51%	46%
Estimated Peak	70%	63%

Riverine Conditions

Gage Data

To determine the conditions within the rivers during the storm event, stream gage data was first collected from seven (7) USGS gages along the North Fork Guadalupe and Guadalupe Rivers. The stage and flow graphs are provided in Appendix C. Table 8 provides a summary of the information obtained from the USGS gages. From this it is known that at approximately 2:45 AM the Guadalupe River at Hunt began to rise 12 feet per hour. The flood wave moved downstream through Kerrville arriving at 5:15 AM, rising at a rate of 18 feet per hour and peaking around 7 AM. The wave continued downstream reaching Center Point at 6 AM and peaking at 7:30 AM and reaching Comfort at 9 AM and peaking at 11 AM. The water reached Canyon Lake on July 5th at 3 AM causing the lake to rise at a rate of 0.5 feet per hour until 10 PM.

Table 8 USGS Gage Data

River	Gage	Wave Arrival Time	Peak Recorded Stage (ft)	Peak Recorded Flow (cfs)	Time at Peak	Rate of Rise (ft/hr)
North Fork Guadalupe	Near Hunt	1:45 AM	21.2	28,500[3]	5:30 AM	4.84
Guadalupe	At Hunt	2:45 AM	37.52[1]	120,000[1]	5:10 AM	11.80
	Above Bear Creek At Kerrville	4:45 AM	34.40	86.3[4]	6:30 AM	17.54
	At Kerrville	5:15 AM	34.29	220,000[2]	7:00 AM	18.43
	Near Center Point	6:00 AM	39.61[1]	539[1,4]	7:30 AM	23.30
	At Comfort	9:00 AM	35.64	177,000	11:00 AM	16.25
	At FM474 Near Bergheim	2:30 PM	49.70	111,000	7:15 PM	9.29
	Spring Branch	7/5/25 10:00 PM	30.03	35,000	7/5/2025 4:00 AM	4.72
Canyon Lake		7/5/25 3:00 AM	887.7	-	7/5/25 10:00 PM	0.51

[1]Gage was damaged. No recoded Peak [2]Flow extrapolated from rating curve [3]Peak flow not provided [4]Gage only produces low flow measurements.

Hydraulic Model

While the USGS gage data does provide valuable data at specific locations, information for areas in between these points is lacking. To determine the true floodplain extent, timing, velocities and other hydraulic data, a HEC-RAS 6.6 model was developed. This model was a 2D rain on grid model of the entire Upper Guadalupe River Watershed. The model used 1-meter USGS digital elevation model (DEM) data for the terrain. A mesh was generated of the entire watershed with a base cell size of 250-feet by 250-feet. Breaklines were added along major rivers and creeks with repeating 125 to 250-foot cells added to both sides to align the cell face perpendicular to the flow path. Four (4) structures were added to the model to account for backwater impact through the City of Kerrville. These included the Franciscos-Lemos Bridge, Highway 16, the G-street bridge, and Kerrville Lake Dam. Bridge deck top elevations were derived from LiDAR and pier spacing and sizes, and deck widths were estimated from imagery. Bridges were enforced as breaklines with 20-foot grid cells on either side. Land use was obtained from the National Land Cover Database (NLCD) for the entire watershed and Manning's n value were assigned. These values are provided in Table 9. Additionally, along portions of the channel bottom an override value of 0.035 was used. Exhibit 5 shows the model extent.

Table 9 Manning's n Values used in Model

USGS ID	Description	Base n value
11	Open Water	0.025
21	Developed, Open Space	0.030
22	Developed, Low Intensity	0.040
23	Developed, Medium Intensity	0.050
24	Developed, High Intensity	0.070
31	Barren Land (Rock/Sand/Clay)	0.025
41	Deciduous Forest	0.100
42	Evergreen Forest	0.100
43	Mixed Forest	0.100
52	Shrub/Scrub	0.070
71	Grassland/Herbaceous	0.035
81	Pasture/Hay	0.030
82	Cultivated Crops	0.035
90	Woody Wetlands	0.100
95	Emergent Herbaceous Wetlands	0.070

To determine the flows in the river, a rain-on-grid simulation was performed. This method applies water over the entire model area using MRMS .GRID files provided by the National Weather Service (NWS). The infiltration rates were computed using the deficit and constant method. Hydrologic soil group data was obtained from the National Resource Soil Conservation (NRCS) web soil service. Initial deficits, maximum deficits, and percolation rates were assigned based on the hydrologic soil group. This data is provided in Table 10. As the ground was likely saturated from pervious rainfalls an initial deficit value of 0 inches was used. An overview of the hydrologic data for this model is provided in Exhibit 6.

Table 10 Infiltration Data used in Model

Hydrologic Soil group	Maximum Deficit (in)	Initial Deficit (in)	Potential Percolation Rate (in/hr)
A	2	0	0.350
B	2	0	0.200
C	2	0	0.100
D	2	0	0.025

The model was run from July 3, 2025 at 8 PM to July 5, 2025 at 8 AM.

This model was developed to support emergency management services. As such, assumptions were made, and several structures were left out of the model. The model is considered the best available data for this incident at the point of this report and should not be used for design, development, or establishing finished floor elevations. Further refinement of the model is needed at a later date.

Model Validation

The model results were validated against high water mark (HWM) data provided by the Harris County Flood Control District (HCFCD). The HWM data was collected on both the left and right banks of the North and South Fork Gaudalupe River and the Guadalupe River to a location approximately 6 miles downstream of Comfort. The data was collected between July 7th and July 10th and contained detailed markings, description, and quality rankings. This data was immensely useful in validating the model results. Exhibit 7 provides HWM locations and the difference between the HWM elevations and the model results (negative value indicates locations where model underestimates water surface elevation). A river profile of the results for the South Fork Guadalupe and Guadalupe Rivers are provided in the Appendix D.

Table 11 provides a summary of the HWM results by river reach location.

Table 11 HWM Analysis Results

River	Location	Number of HWM Points	Average Difference (ft)
North Fork Guadalupe	More than 3 miles Upstream Confluence	14	3.27
North Fork Guadalupe	Near Confluence	6	-3.19
South Fork Guadalupe	More than 3 miles Upstream Mystic	10	0.96
South Fork Guadalupe	Near Mystic	13	-1.82
South Fork Guadalupe	Near Confluence	7	-2.74
Guadalupe	Downstream Confluence	11	-2.44
Guadalupe	Near Ingram	12	-1.20
Guadalupe	In Kerrville Upstream of Nimitz	10	0.01
Guadalupe	Between Nimitz and HWY 534	18	0.69
Guadalupe	Between HWY 534 and Center Point	18	-1.10
Guadalupe	Near Center Point	10	0.17
Guadalupe	Between Center Point and Comfort	13	-0.49
Guadalupe	In Comfort	3	-0.25
Guadalupe	Downstream Comfort	4	2.75

The analysis shows that the model's result accuracy varies based on reach location. Generally, the model underestimates the true water surface elevation upstream of Ingram through the confluence to Mystic on the South Fork and 3 miles up the North Fork by 1 to 3 feet. From Kerrville down to Comfort, the model accuracy improves to within 1.1 feet. Downstream of Comfort the model begins to overestimate the true water surface elevation by 2.75 feet.

In addition to the HWM data, the model was compared to the USGS gage data. Where available, the gage stage was translated into elevation (in feet-NAVD88). The comparison hydrographs are provided in Appendix E. The stage results align with the HWM data where available. The USGS gages at Spring Branch and Bergheim show that the model is overestimating water surface elevation downstream of the HWM data by 10 to 20 feet. The flow gage data matches the peak timing and/or peak flows where available upstream of Comfort. In Comfort, the model overestimated the flow by approximately 30,000 cfs and peaks 1 hour and 15 minutes early. This difference between the model and the gage data becomes more extreme as the model proceeds downstream. At Spring Branch, the model overestimates the flow by 140,000 cfs and arrives 4 hours early. This indicates a lack of flood wave attenuation that should be occurring at the lower reaches of the model.

There are several reasons why the model accuracy would vary with location. These include the following:

1. Rainfall data: Based on the Rainfall data, it is known the MRMS data underestimates the high intensities and overestimates the low intensities.
2. Debris loading: The model does not account for debris loading which would increase the HWM water surface elevation.
3. Manning's n value: The Manning's n value may not properly represent the flood condition friction values.
4. Sediment transport: During high flow events, sediment transport can change the terrain of the channel.
5. Model cell resolution: The model cell resolution may not be sufficient to account for all flow impeding structures.
6. Model components: The model only contains bridges within the City of Kerrville. Other bridges are not accounted for and would have an impact on the results.

Further analysis would be required to improve the model downstream of Comfort.

Flow Return Period

The return period of the flow at several locations was estimated using hydrologic data obtained from the Interagency Flood Risk Management (InFRM) analysis of the Guadalupe River. This analysis was developed by the USACE and consisted of a calibrated rainfall-runoff model of the entire Upper Guadalupe River watershed. The analysis provides flow-frequency data from the 2- (50% AEP) to 500-year (0.2% AEP) events. For the South Fork Guadalupe River, the model flows exceeded the 500-year (0.2% AEP) event. The South Fork Guadalupe River watershed basin in the InFRM hydrologic model was modified to include the 1,000-year (0.1% AEP) event. To do this the 500-year (0.2% AEP) model geometry was run with the 1,000-year (0.1% AEP) rainfall provided in Appendix B. This resulted in a 1,000-year (0.1% AEP) flow on the South Fork Guadalupe River of 99,718 cfs.

Flow-frequency curves were plotted and the return period from the model was interpolated from this data. Where available, USGS flow data was also plotted and frequency data computed. Appendix F provides flow-frequency curves and Table 12 provides a summary of the results.

Table 12 Summary of Flow Frequency Results

River	Location	Flow (cfs)		Return Period (-year)	
		Model	USGS Gage	Model	USGS Gage
North Fork	Upstream Confluence	48,538	-	12	-
South Fork	Upstream Confluence	103,589	-	>1,000[2]	-
Guadalupe	Downstream Confluence	148,558	-	59	-
Guadalupe	Downstream Johnson Creek	189,214	-	49	-
Guadalupe	At Kerrville	198,042	220,000[1]	53	74
Guadalupe	At Center Point	206,000	-	44	-
Guadalupe	At Comfort	202,302	177,000	36	27

[1]Extrapolated from rating curve
[2]InFRM did not compute flows above the 500-year (0.2% AEP) event. The updated InFRM model developed in this study was used to compute the 1,000-year (0.1% AEP) event.

The results of this analysis show that the North Fork Guadalupe River experienced a 12-year (8.33% AEP) event while the South Fork exceeded the 1,000-year (0.10% AEP) event. Downstream of the confluence the return period was determined to be between the 49- (2.04 % AEP) and 59-year (1.69% AEP) event through Kerrville. At Center Point the return period decreases to the 44-year (2.27% AEP) event and in Comfort it decreases to the 36-year (2.78% AEP) event. Based on rating curve extrapolated USGS gage flow data, the return period through Kerrville would be the 74-year (1.35% AEP) event. It is worth noting that while the Guadalupe River did not reach the 100-year (1% AEP) event, it reached greater than the 50-year (2% AEP) event in less than 3 hours.

Mapping Results

The final floodplain map is provided in Appendix G. Due to the model error downstream of Comfort the results downstream of Comfort are not provided.

Conclusions

The following conclusions can be drawn from this analysis:

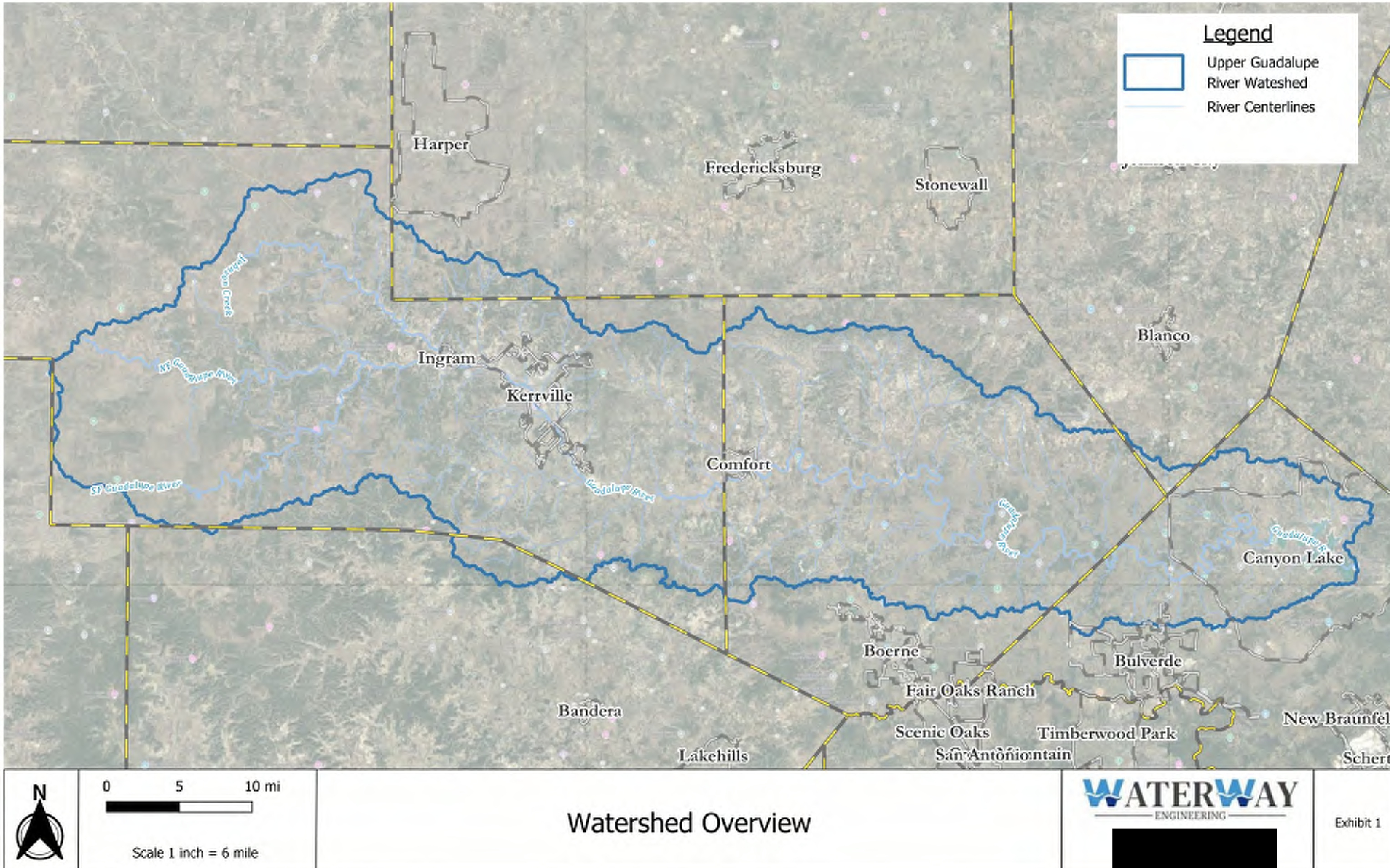
1. The highest recorded rainfall provided by UGRA produced the 6-hour 688-year (0.15% AEP) event.
2. Estimated peak rainfall depths exceeded the 3-hour and 6-hour 1000-year (0.1% AEP) event.
3. The UGRA rainfall gage measured 57% of the 6-hour tropical PMP event.
4. The estimated peak rainfall depth produced 70% and 63% tropical PMP for the 3-hour and 6-hour event, respectively.
5. Gage data show rates of rise in the river that exceeded 20 feet per hour.
6. Hydraulic modeling data shows the South Fork Guadlupe River flow exceeded the 1,000-year (0.1% AEP) event.

Recommendations

This analysis is intended to be an initial hydrologic and hydraulic assessment of the July 4th event. Further data acquisition and analysis should be used to refine the conclusions of this analysis. The following is recommended in future steps:

- Obtain rainfall gage data from other privately owned gages in the South Fork Guadalupe River watershed.
- Obtain high water mark data downstream of Comfort.
- Obtain satellite imagery of the post-flooding debris extents.
- Collect post-incident bathymetric and LiDAR data.
- Update hydraulic model to include bridges, structures, and other physical features.
- Adjust model to better match USGS stage and flow data downstream of Comfort.

Exhibits

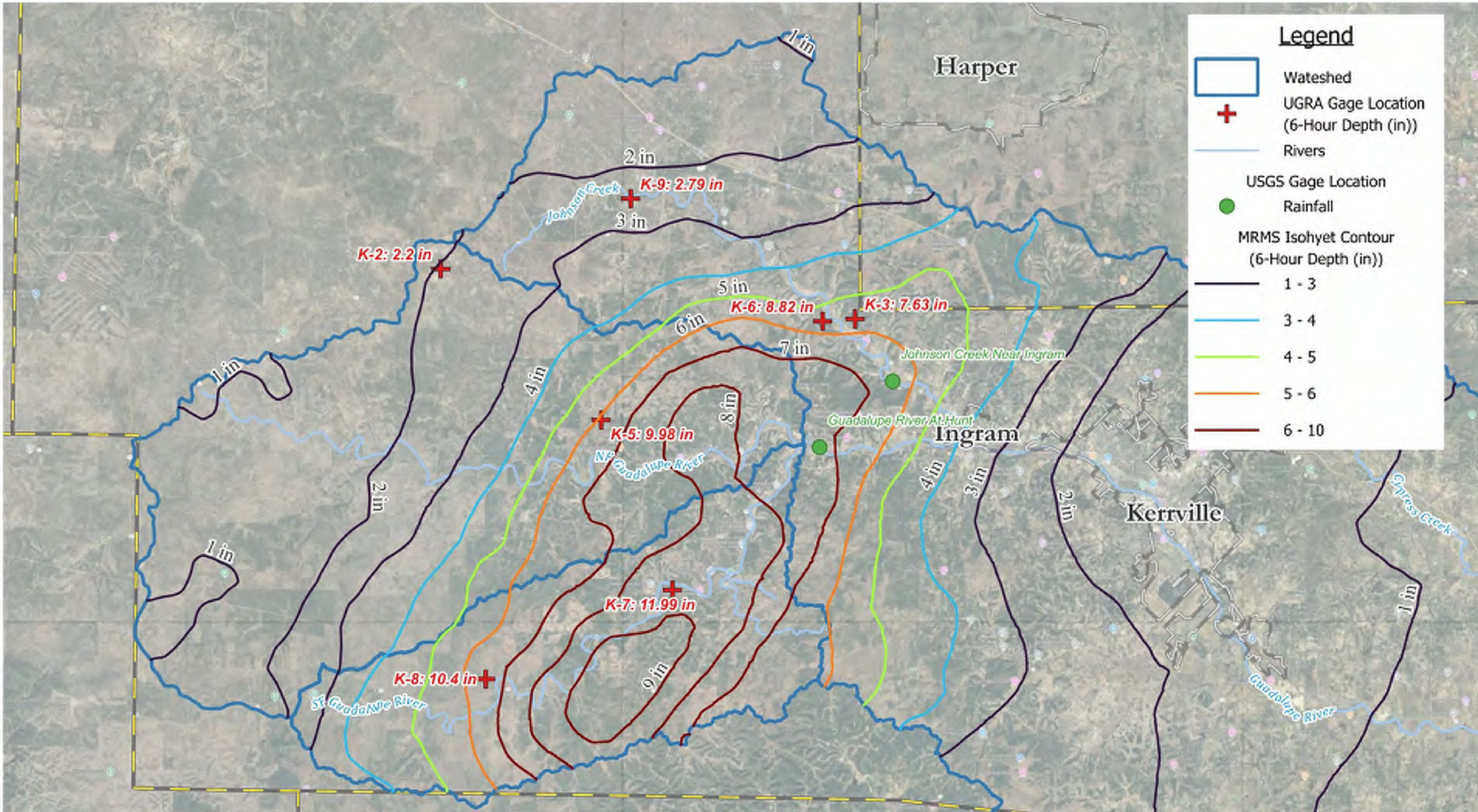


Watershed Overview

WATERWAY ENGINEERING

[redacted]

Exhibit 1



N

0 3 6 mi

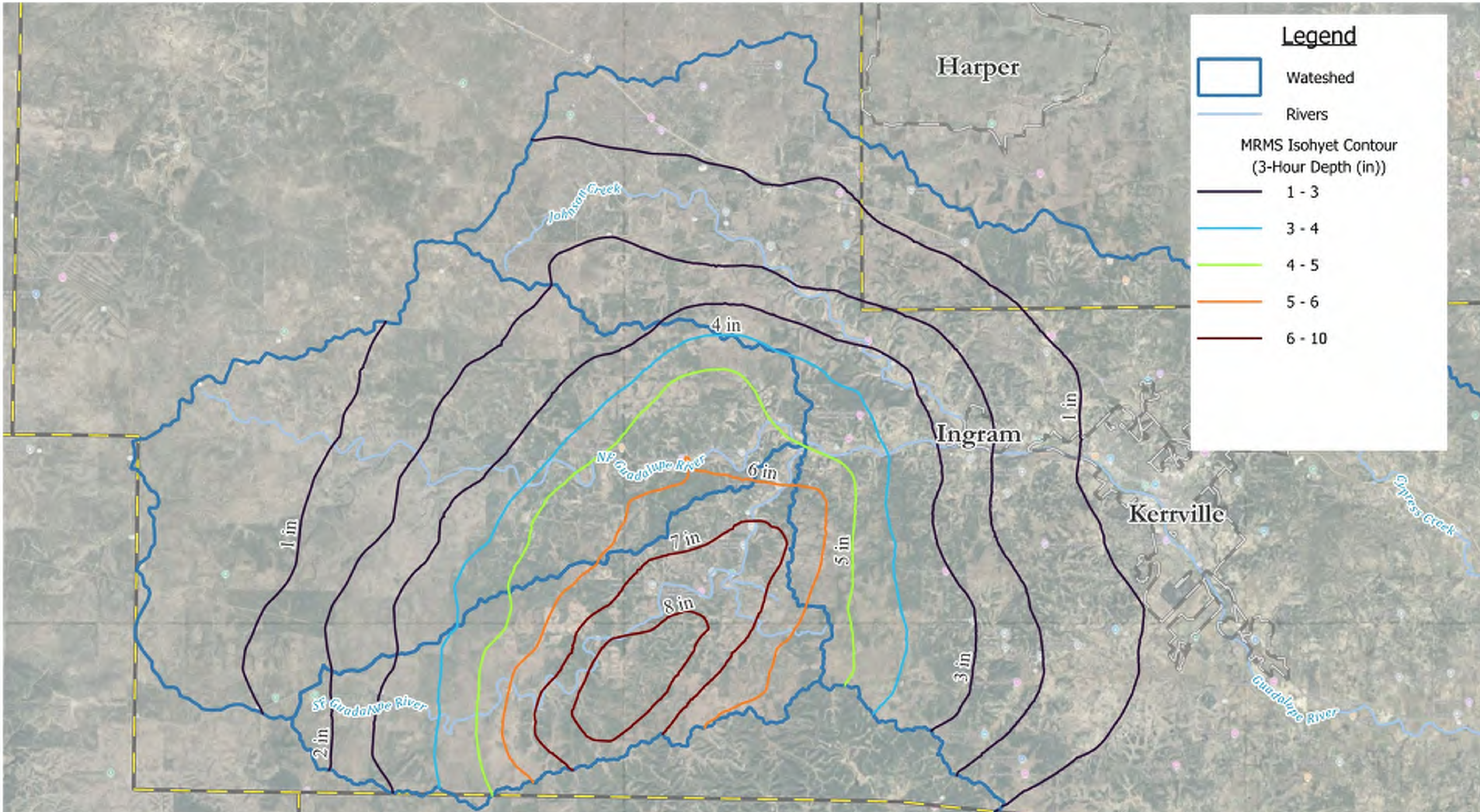
Scale 1 inch = 3 mile

6-Hour Rainfall Overview

WATERWAY ENGINEERING

[redacted]

Exhibit 2



N

0 3 6 mi

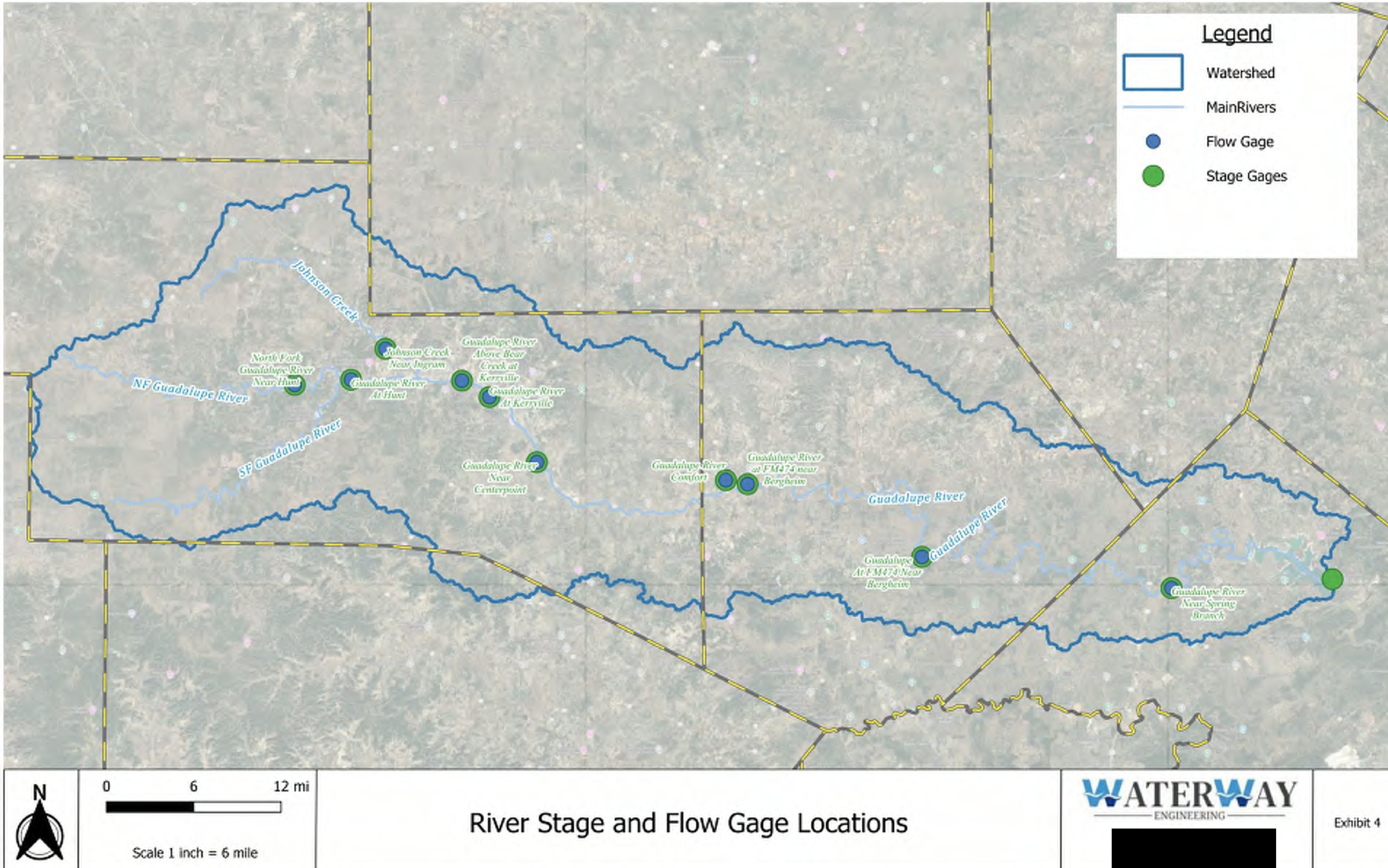
Scale 1 inch = 3 mile

3-Hour Rainfall Overview

WATERWAY ENGINEERING

[redacted]

Exhibit 3

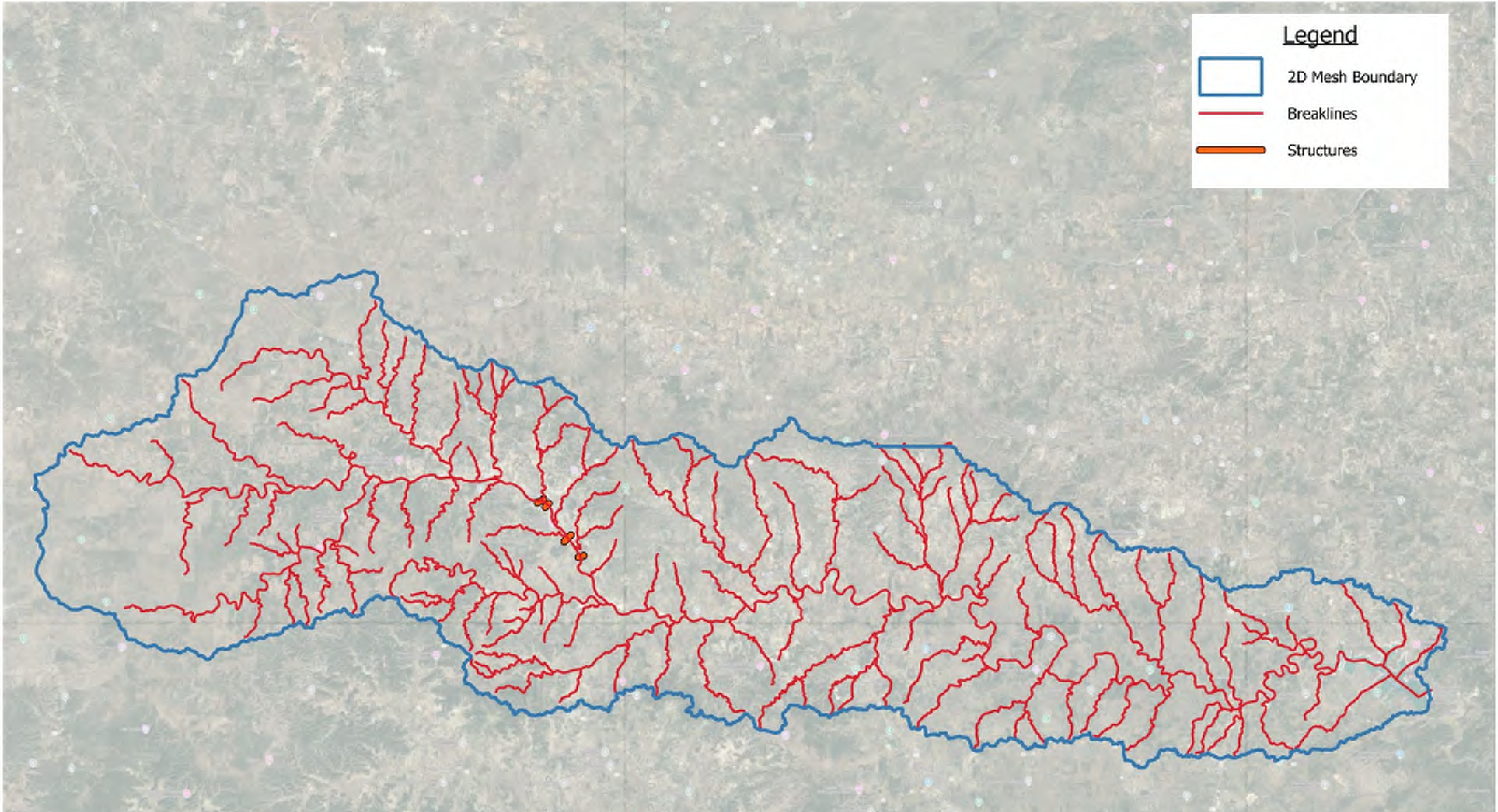


River Stage and Flow Gage Locations

WATERWAY ENGINEERING

[redacted]

Exhibit 4



N

0 6 12 mi

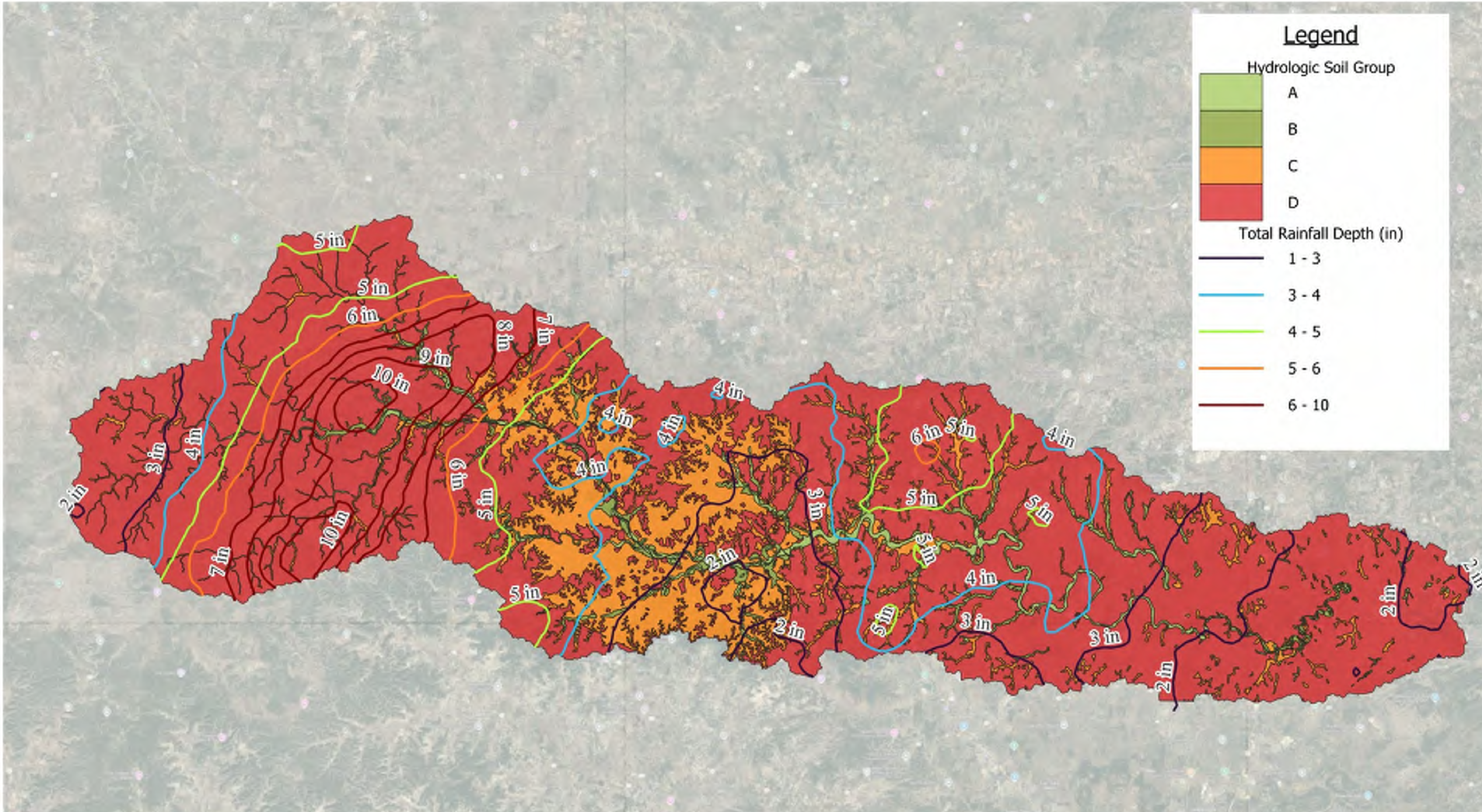
Scale 1 inch = 6 mile

HEC RAS Model Geometry

WATERWAY ENGINEERING

[redacted]

Exhibit 5



N

0 6 12 mi

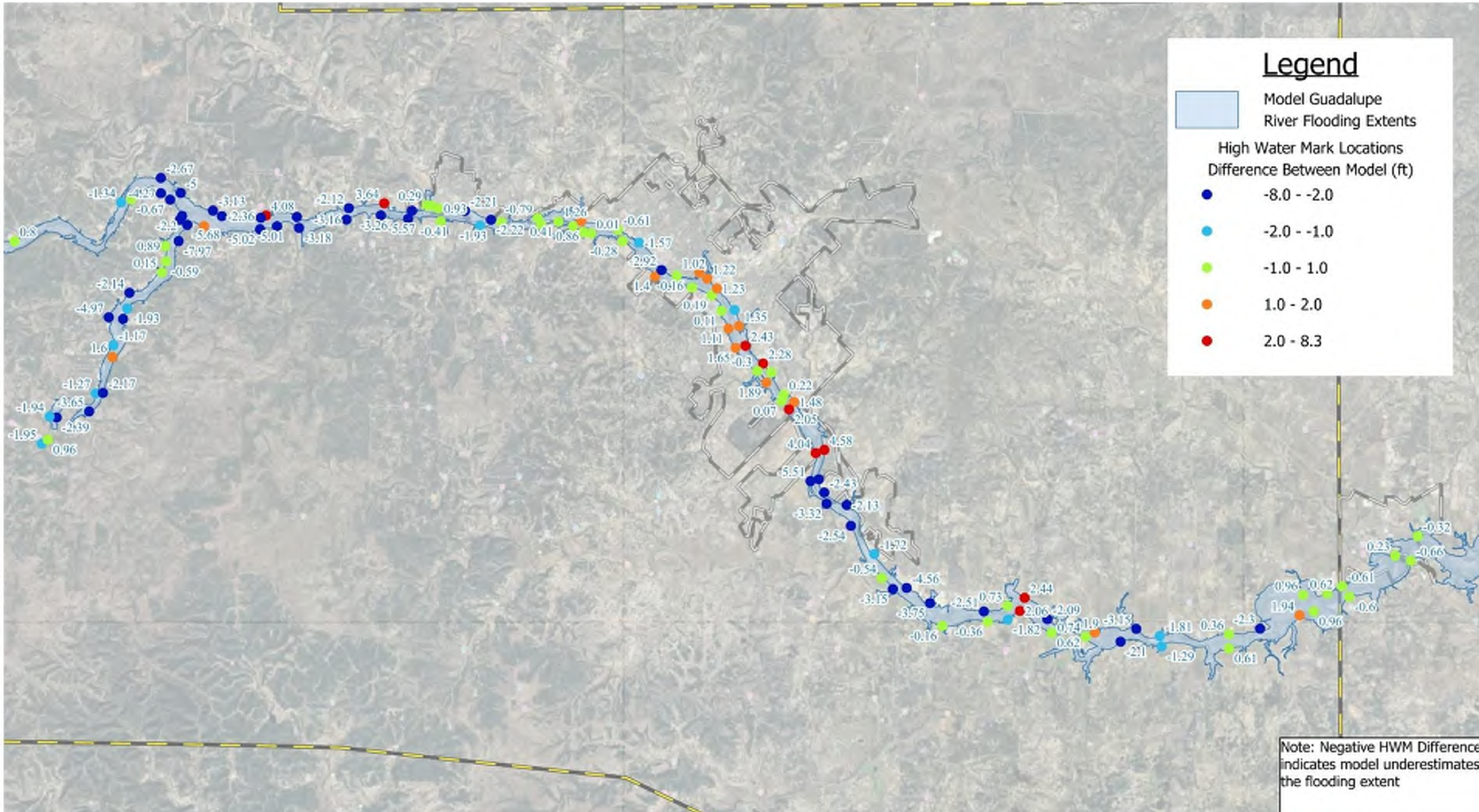
Scale 1 inch = 6 mile

Hydrologic Data

WATERWAY ENGINEERING

[redacted]

Exhibit 6



High Water Mark Validation

WATERWAY ENGINEERING

[redacted]

Exhibit 7