Final Report: North Bosque River Watershed FIF Study

Texas Water Development Board Contract #40051

Prepared for:

Texas Water Development Board

Prepared by:

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City of Stephenville

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Engineering Seal

This report documents the work of the following Licensed Texas Engineers:

05/03/2024

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F-2144

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Executive summary

The City of Stephenville, in collaboration with Erath County, the City of Dublin, and the Cross Timbers Soil and Water Conservation District, was awarded a grant under the newly created Flood Infrastructure Fund (FIF) to develop a watershed study of the Green Creek-North Bosque River Watershed (Hydrologic Unit Code 1206020401), also referred to as the North Bosque River Watershed FIF. The City of Stephenville, located within Erath County, is located approximately 65 miles southwest of the Fort Worth metropolitan area, in central Texas and represents the highest flood risk within the study area.

The Green Creek-North Bosque River watershed covers much of the southwest portion of the county and includes the City of Stephenville and part of the City of Dublin. Streams flow through the watershed from northwest to southeast. Previous drainage master studies were completed for the City of Stephenville in 2001 and 2020, and in 2017, a culvert evaluation was done for Erath County. This watershed study adds to these prior evaluations by conducting a screening assessment for the entire watershed, detailed hydrologic and hydraulic modeling for a study area around the City of Stephenville, a critical flood hazard alternatives analysis to generate potential future project for construction, and a dam safety assessment to assess current conditions of high-risk National Resources Conservation Service (NRCS) dams. A separate report was developed for the dam safety assessment.

To identify flood prone areas in the screening assessment, a 2D “Rain-on-Mesh” (ROM) model was developed using the United States Army Corps of Engineer’s Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.0. Hot spots were determined based on roadway overtopping, public safety, and building inundation criteria. Hot spots were evaluated based on several metrics and then ranked, producing a list of 28 hot spots in categories for high, medium, and low priorities.

A hydrologic model was developed using the U.S. Army Corps of Engineer’s Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) version 4.8. The study area for the hydrologic analysis includes the entire Green Creek-North Bosque River HUC10 watershed, with additional evaluation detail within the City of Stephenville city limits. Synthetic storm models were created for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year 24-hour return periods.

A detailed hydraulic model was developed using the U.S. Army Corps of Engineer’s HEC-RAS version 5.0.7. The study area for this analysis generally includes only tributaries located within the City of Stephenville. For the 1D steady-state analysis, the peak discharges under existing and ultimate conditions from the HEC-HMS model were utilized. Hydraulic results indicate that the FIF study peak water surface elevations (WSELs) range from 5.7 feet lower to 6.54 feet higher than the effective Federal Emergency Management Agency (FEMA) WSELs. The changes in the computed WSELs can be attributed to updated topographic data and more detailed hydraulic modeling and methodology as compared to dated FEMA modeling and mapping. Updated detailed hydrologic modeling also account for these hydraulic differences.

Based on the results and discussions with City staff, the study focused on five areas of concern and completed alternative analyses to alleviate the hazards at these sites. The evaluations included modeling analysis, exhibits, Opinions of Probable Construction Cost (OPCCs), Benefit-Cost Ratios (BCRs), and no negative impact assessments. All analyses were evaluated, and the recommended alternative for each project site was selected. Project sites were then ranked against each other based on BCR, prioritization in the hot spot analysis, and City interest. Each project location and drainage area can be seen in Exhibit D-2.

The highest ranked project is at Prairie Wind Boulevard, located in the northwestern side of Stephenville in a residential neighborhood. Prairie Wind Boulevard crosses a Tributary to the North Bosque River just upstream of the confluence to the North Bosque River. The flooding that occurs at this crossing is a known issue to the City and currently has a less than 2-year level of service (LOS), creating frequent disruptions for residents. The existing culverts include (3) 60” corrugated metal pipes (CMPs) and twelve buildings are inundated greater than 0.5 foot in the 100-year storm event. The recommended alternative for this site is Alternative 2 (FMP ID 83001298), which allows for a 100-year level of service (LOS). It involves channel grading upstream of the crossing, realigning the existing channel from the crossing to the North Bosque River, and replacing the culverts with (5) 10’x6’ reinforced concrete box (RCB). The OPCC is $11,030,000 and the BCR is 0.1.

This Prairie Wind Boulevard alternative was evaluated further as part of supplemental Task 6, and a conceptual schematic was developed as part of the evaluation. This additional analysis is provided in Appendix E and the project area location can be seen in Exhibit D-2 in Appendix D. The City of Stephenville will directly benefit from this project.

The next recommended project is at Morgan Mill Road, which is in northeastern Stephenville and crosses over the Tributary to Dry Branch. Several structures, including both residences and businesses, are inundated around the crossing a 100-year event. The existing crossing provides a 2-year LOS with (5) 6’x7’ RCB. The recommended alternative is Alternative 1 (FMP ID 83001301), which recommends grading around the road and replacing the existing culverts with (6) 12’x7’ RCB. This allows for a 100-year LOS at the road and removes 13 structures from the 100-year flood extents. The OPCC is $2,661,000 and the BCR is 1.8.

The third ranked project is at Long Street, which is located near central Stephenville and crosses over the North Bosque River. The existing culverts of (4) 60” CMP provide a less than 2-year LOS and is considered a low water crossing. Depth across the crossing during a 100-year storm exceeds 15 feet and is considered high hazard. The recommended alternative is Alternative 1 (FMP ID 83001302), which constructs a bridge across the river. The OPCC is $8,993,000 and the BCR is 0.1.

The fourth ranked project is at Lingleville Road, which is located upstream of Prairie Wind Boulevard. The existing crossing has (2) 5’x5’ RCB culverts and provides a 2-year LOS. The recommended alternative is Alternative 2 (FMP ID 83001299), which allows for a 100-year LOS and involves replacing the existing culverts with (4) 10’x6’ RCB and upstream grading to mitigate upstream WSEL rises. The OPCC is $2,014,000 and the BCR is 1.1.

The final project is at County Road 256, which is located southwest of Stephenville, outside of the city center. Future development is anticipated in this area, which makes it of interest for a proactive mitigation project. The current crossing over Town Creek of (3) 42" CMP culverts provides a less than 2-year LOS, and several nearby structures are inundated in the 100-year storm event. The recommended alternative is Alternative 1 (FMP ID 83001300), which grades the creek to deepen and widen it and installs (7)10'x9' RCB. This produces a 5-year LOS at the road crossing and removes 2 buildings from the 100-year flood extent. The OPCC is $4,145,000 and the BCR is 0.54.

All alternatives have been developed for inclusion into the Regional Flood Plan, which will provide opportunities for funding for the stakeholders (City of Stephenville, Erath County, etc.). It is recommended to pursue funding through this route.

1 Introduction

The City of Stephenville, in collaboration with Erath County, the City of Dublin, and the Cross Timbers Soil and Water Conservation District, was awarded a grant under the newly created Flood Infrastructure Fund (FIF) to develop a watershed study of the Green Creek-North Bosque River Watershed (Hydrologic Unit Code 1206020401) also referred to as the North Bosque River Watershed FIF. The FIF study is managed by the Texas Water Development Board (TWDB) and was created to assist in the financing of drainage, flood mitigation and flood control projects.

The watershed study includes the development of hydrologic and hydraulic models that serve as planning tools to define flood hazard risks for private properties and public infrastructure. The models also provide a platform for developing and evaluating improvements that will mitigate flood hazards in the area. A dam safety assessment of NRCS dam structures was also performed and includes visual condition assessments and breach analyses. A project location map of the Green Creek-North Bosque River Watershed can be found in Exhibit A-1.

The following report describes the methodology and findings resulting from the study.

1.1 Tasks in scope of work

Within the scope of work, there were eight tasks to be completed, as listed below:

- Task 1: Project Management and Meetings
- Task 2: Public Outreach
- Task 3: Data Collection
- Task 4: Screening Assessment
- Task 5: Flood Risk Analysis
- Task 6: Critical Flood Hazard Alternatives Analysis
    - Supplemental Task 6 Scope of Work Amendment:
        - Identify single preferred alternative from those previously prepared through discussions with the City of Stephenville.
        - Develop conceptual layout and grading of the design elements in CAD.
        - Identify utility conflicts the project elements needed to relocate the conflicting utilities.
        - Define additional cost components such as erosion control elements.
        - Identify property acquisition needs.
        - Confirm no negative impacts.
        - Confirm Opinion of Probable Construction Cost and Benefit Cost Ratio
        - Review permitting requirements and strategy for identified project
- Task 7: Dam Safety Assessment
    - Compiled in a separate report.
- Task 8: North Bosque River Watershed Study – Technical Report

2 Public outreach

A web survey was created and shared on the City of Stephenville website. Through this survey, residents could share information about flood prone areas.

Two public meetings were conducted over the course of the study. The first was held on October 7th, 2021 on Zoom to provide information about the study, answer questions, and gather public input. The second was held on November 8th, 2022 at Stephenville City Hall to discuss study results and answer questions.

3 Background

Erath County is located approximately 65 miles southwest of the Fort Worth metropolitan area, in central Texas. The county population was 42,545 in 2020, according to the U.S. Census, and the two incorporated communities are Stephenville (population 20,897) and Dublin (population 3,359) (U.S. Department of Commerce, 2020). The Green Creek-North Bosque River watershed covers much of the southwest portion of the county and includes the City of Stephenville and part of the City of Dublin. Streams flow through the watershed from northwest to southeast, ultimately travelling towards the Gulf of Mexico as a part of the Lower Brazos River Basin, or Region 8 in the Regional Flood Plan. The size of the HUC10 watershed is approximately 301 square miles. Several previously completed studies were reviewed by FNI as a part of the study.

3.1 Erath County flood insurance study (FIS)

FEMA conducted a flood insurance study (FIS) for Erath County and incorporated areas (cities of Dublin and Stephenville) in November 2011. The hydrologic method in the FIS uses the USGS regional regression equation to determine peak discharges, which were then used to compute water surface elevations within HEC-RAS version 4.1.0 (Federal Emergency Management Agency, 2019).

Erath County is generally mapped as Special Flood Hazard Area (SFHA) Zone A with Stephenville mapped as Zone AE (FIRM Panel 48143C0430D). The effective mapping, especially within the City of Stephenville city limits, was created based on low detail analyses and dated topographic information. Several areas throughout the city have SFHAs that appear to be incorrect and no longer align with the channel.

3.2 Stephenville master drainage plans

In 2001, Carter Burgess, Inc. reevaluated a previous Drainage Master Plan, completed in 1990. Major concerns of the city were changes to federal and state regulatory constraints, development and redevelopment in the city limits, and flooding complaints (Carter Burgess, 2001). The study evaluated seven drainage areas, including one containing Lingleville Road and Prairie Wind Boulevard, to identify improvements and cost estimates. For the Lingleville Road and Prairie Wind Boulevard project area, two phases of construction were proposed with a total cost of $1,662,200 in 2001 dollars.

In 2020, Freese and Nichols, Inc. created a citywide rain-on-mesh model to identify 28 individual CIPs in 11 potential project areas, including cost estimates (Freese and Nichols, Inc., 2020). The focus was mainly on localized drainage issues within the City of Stephenville and did not evaluate the larger flooding sources. After project identification, they were ranked based on known flooding history, project cost, modeled structure flooding, and road overtopping. A total of 28 projects were identified including two projects at Prairie Wind Boulevard, with a combined cost of $1,160,000 in 2020 dollars.

3.3 2017 Erath County culvert replacement assessment

In response to flooding in May 2016, Freese and Nichols, Inc. provided an engineering assessment of seven damaged culvert crossings in Erath County to propose replacements and determine adverse impacts (Freese and Nichols, Inc., 2017). All proposed culvert sizes were found to provide a level of service of <2-year or 2-year. Four proposed culverts had no upstream or downstream impacts, and three had impacts due to raising the road elevation. impacted areas were largely undeveloped, and waivers could be obtained from affected property owners to address concerns.

4 Screening assessment

As part of the North Bosque River Watershed FIF, a screening assessment was completed to identify flood prone areas, or hot spots, for the entirety of the Green Creek-North Bosque River HUC10 Watershed. Hot spots were determined based on roadway overtopping, public safety, and structure damage criteria, which is discussed in the paragraphs below.

4.1 Methodology

To identify flood prone areas, a “Rain-on-Mesh” (ROM) model was developed using the United States Army Corps of Engineer’s Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.0. The modeling software has the capability to simulate a storm event by applying a rainfall hyetograph to the 2D area, which covers the entire Green Creek-North Bosque watershed. Excess rainfall is then dynamically routed along the surface to simulate runoff as discharges travel to open channel systems. The model considers infiltration using the SCS Curve Number method. Model results obtained from this analysis provided information about roadway flooding/overtopping, structure flooding, and other drainage concerns. Additional details regarding the ROM methodology are provided below.

4.1.1 Precipitation

Flow Hydrographs were developed for standard design storms including the 2-, 5-, 10-, 25-, 50-, and 100-year events (24-hr duration). Rainfall input data was obtained from Atlas 14 (U.S. Department of Commerce, 2017).

Table 4-1: Atlas 14 Precipitation (in) Depths.

Duration	**Frequency (Return Period)**					
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
5 min	0.487	0.600	0.694	0.823	0.923	1.02
15 min	0.971	1.19	1.38	1.64	1.83	2.03
1 hr	1.76	2.17	2.51	2.98	3.33	3.70
2 hr	2.17	2.72	3.18	3.83	4.32	4.84
3 hr	2.42	3.06	3.61	4.38	4.97	5.60
6 hr	2.84	3.65	4.35	5.33	6.10	6.92
12 hr	3.26	4.22	5.06	6.26	7.21	8.24
24 hr	3.73	4.84	5.81	7.20	8.32	9.52

4.1.2 2D mesh

For the development of the 2D mesh, Brazos River Basin LiDAR (2016) and Middle Brazos-Lake Whitney Watershed LiDAR (2016) were obtained from Texas Natural Resources Information System (TNRIS). The Brazos River Basin LiDAR data was acquired from November 17, 2016, to May 28, 2018, at 70 cm resolution (United States Geological Survey (USGS), 2016). The Middle Brazos-Lake Whitney Watershed LiDAR was acquired from March 1, 2016, to March 21, 2016, at 70 cm resolution (United States Geological Survey (USGS), 2016).

4.1.3 Infiltration

Runoff was calculated using the SCS Curve Number method. This method uses a combination of land use and soil type to calculate runoff values. This was done for both current, or existing, land use conditions and predicted future, or ultimate, land use conditions. Current land use data was obtained from the North Central Texas Council of Governments (NCTCOG), and future land use data was obtained from the 2019 Stephenville Future Land Use Map. Exhibit A-2 shows existing land use conditions, and Exhibit A-3 shows future land use conditions for the watershed. For both ultimate and existing conditions, land use was intersected with soil data from the Natural Resources Conservation Service's (NRCS) Soil Survey Geographic database (SSURGO). Exhibit A-4 shows the hydrologic soils map for the watershed. Based on land use and soil data, curve numbers were assigned using guidance from the Technical Release 55 (TR-55). The abstraction ratio was assumed to be 0.5. No minimum infiltration rate was used.

4.1.4 Other model elements

The HEC-RAS version 6.0 ROM model only models surface flow and does not represent any existing storm drain systems or culverts. To properly evaluate the overland flow and channel conveyance within the system, several model elements, such as break lines and terrain modifications, were used to reduce obstructions where culvert conveyance exists but is not captured within the LiDAR and to minimize artificial depths. Exhibit A-5 shows the model elements that were developed.

Break lines

To capture critical topographic features in the ROM model, break lines were created along dams, major roadway centerlines, main channel breaks, and flow centerlines and banks. This creates cell faces along linear features to better direct water through the 2D model, allowing for more accurate definitions along critical points, such as high ground.

Terrain modifications

Where the initial terrain model insufficiently represented the ground surface or conveyance area, terrain modifications within HEC-RAS were used. For example, since the approach of this ROM analysis was to not model culverts as 2D connections, where roadway embankments do not accurately show bridge or culvert openings, a terrain modification was incorporated to represent conveyance through the roadway similar to that of the existing culvert. To maintain a stable and efficient 2D model, terrain modifications were used to allow flow to pass through these openings, rather than using 2D connections with culverts or bridge data. The terrain modification dimensions were estimated based on adjacent ground characteristics, aerial imagery, and Google Street View.

Cell resolutions

A 100 ft x 100 ft cell resolution was used for the entire 2D area.

Rating curves for NRCS dams

NRCS dam releases upstream of Stephenville were modeled using 2D connection rating curves. Elevation discharge curves were created using NRCS watershed and dam assessment software SITES based on the geometry of the spillway systems, as described in the as-builts plans. The dams this was done for are Upper Bosque (UB) 2, UB 3, UB 4, UB 5, UB 6, UB 7, UB 12, UB 13, UB 14, and UB 15. These dams were selected due to their distance from population centers. By using rating curves, this allows for increased accuracy in released discharges. Further information is available in the separate Dam Safety Assessment Report.

Boundary condition

At the downstream end of the watershed, a normal depth boundary condition was assigned using the slope of the terrain.

4.2 Criteria for prioritization

Results were evaluated and hot spot locations were determined based on two main criteria: structure, or building, flooding, and roadway overtopping. Ten hot spots were identified based on inundated structures and 18 were identified based on overtopped roadways. Structure hot spots were identified by examining areas with high numbers of inundated structures throughout the watershed. Roadway hot spots were identified by intersecting the ROM depth and hazard results with road centerlines to find areas of dangerous overtopping.

To prioritize hot spots, a scoring system was developed. The 28 hot spots were evaluated differently based on if they had structure flooding or roadway flooding.

4.2.1 *Structure flooding*

For structure inundation locations, the number of affected structures was used to sort the hot spots into high, medium, and low priorities.

Table 4-2: Points per Number of Inundated Structures.

Number of Structures Inundated > 1 ft	Points
0	0
0-10	5
10-20	10
20-30	15
30-40	18
40-50	20
50-60	22
60-70	26
70+	30

4.2.2 *Roadway flooding*

For road overtopping locations, hazard was determined using a Flood Hazard Vulnerability Graph developed by the U.S. Army Corps of Engineers (USACE), which compares velocity and depth to find the associated hazard level for each hot spot during a flood event. This hazard value is a metric to describe how dangerous flooding conditions are, as described in the legend at the bottom of the graph.

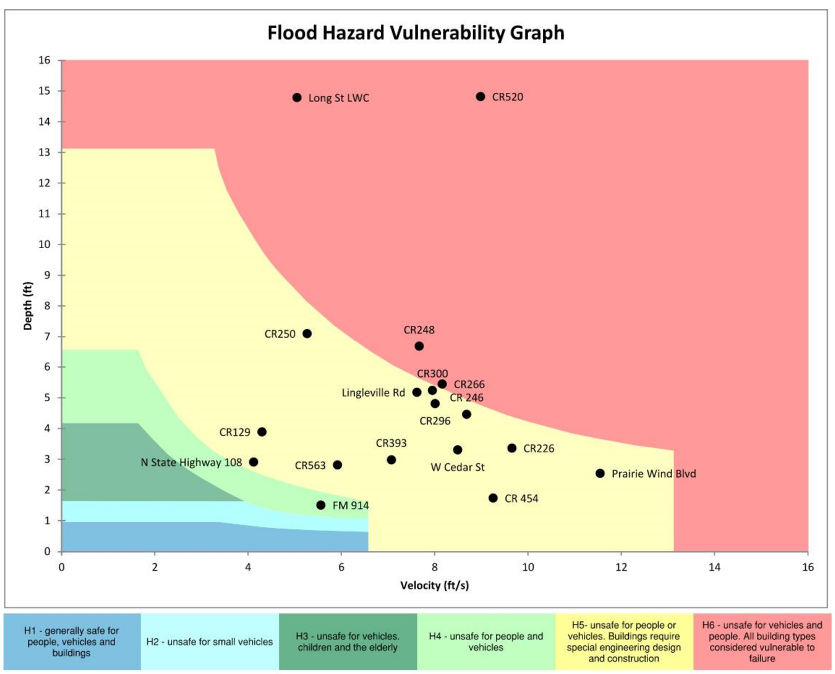

Figure 4-1: Roadway hot spots shown on the Flood Hazard Vulnerability Graph.

Using the hazard value generated from the graph, points were assigned as shown below.

Table 4-3: Points for Hazard Values.

Hazard Value	Points
0	0
1	2
2	4
3	8
4	10
5	12
6	15

Annual average daily traffic (AADT) counts from the Texas Department of Transportation (TxDOT) were used for each road to assign further points. For locations with no traffic counts available, 0 points were given as those were in residential or rural areas where low traffic counts are expected.

Table 4-4: Points for Average Annual Daily Traffic (AADT).

Traffic Count	Points
0	0
0-100	1
100-200	3
200-300	5
300-400	7
400-1,000	9
1,000-5,000	11
5,000-10,000	13
10,000+	15

Based on the points for each hot spots, they were sorted into high, medium, and low priority at the ranges below.

Table 4-5: Points Per Priority Level.

Score	Priority Level
<15	Low
15-20	Medium
20+	High

Once structure and roadway hot spot points were assigned, each hot spot location was individually examined. Hot spot rankings were then reassigned, if necessary, based on historical flooding information, flooding depth, local knowledge, and City input.

4.2.3 Hot spot ranking

Hot spots were ranked and compiled in Table 4-6. Exhibit A-6 shows these hot spots spatially throughout the watershed, while Exhibit A-7 shows a close-up of hot spots within Stephenville, where most of the hot spots are located.

Table 4-6: Ranked Hot Spots.

Rank	Name	Description	Waterway	Flooding Issue	Depth (ft)	Hazard	Traffic Count	Structures	Priority
1	Lingleville Rd	High hazard flooding at Lingleville Rd between N Bates Ave and CR 518	North Bosque River	Roadway	5.2	5	12,688	-	High
2	Railroad between W Washington St and W Tarleton St	Flooding impacts a high number of buildings upstream of the culvert passing under the railway near the intersection of W Washington St and N Clinton Ave	Methodist Branch Storm Drain Overflow	Structures	-	-	-	55	High
3	Long St Low Water Crossing	High hazard flooding at a low water crossing with few warning markers between S Minter Ave and S Lennox Ave	North Bosque River	Roadway	14.8	6	244	-	High
4	South Town Creek d/s of the intersection of W Washington St and W South Loop	Inundation impacting many buildings along the creek between the railroad and W Washington Street	Town Creek	Structures	-	-	-	52	High
5	North Town Creek u/s of the intersection of W Washington St and W South Loop	Flooding upstream of the culvert crossing under Walgreens - impacts many buildings, including a pedestrian bridge	Town Creek	Structures	-	-	-	42	High
6	N State Highway 108	Road floods on section parallel to creek around the intersection of FM 2303	North Fork North Bosque River	Roadway	2.9	5	4,260	-	High
7	CR 454	High hazard flooding on relatively high traffic rural road between CR 221 and Private Road 1196	Town Creek	Roadway	1.7	5	474	-	High
8	North HWY 377	Flooding of several structures up and downstream of HWY 377, a major road outside of Stephenville city limits	Alarm Creek	Structures	-	-	-	70	High
9	N Graham Ave	Several structures inundated near the intersection of N Graham Ave and E Elm St	Small tributary near N Graham St and the Railroad	Structures	-	-	-	20	Medium
10	Storm Drain between Long and College	Several structures inundated alongside the creek stretching from College St to Long St	College St Branch	Structures	-	-	-	39	Medium
11	W Cedar St/CR 256	Road overtopping close to the city limits boundary	Town Creek	Roadway	3.3	5	336	-	Medium
12	FM 914	Road overtopping south of the community of Alexander	Green Creek	Roadway	1.5	4	355	-	Medium
13	CR248	Road overtopping close to the intersection with HWY 6	North Bosque River	Roadway	6.7	6	113	-	Medium
14	CR250	Flooding on CR 250 between the railroad CR 249	Bell Branch	Roadway	7.1	5	124	-	Medium
15	CR520	Significant inundation depth south of the community of Harbin, upstream of a dam	Bell Branch	Roadway	14.8	6	84	-	Medium
16	Prairie Wind Blvd at Tributary	Road overtopping in residential area containing a tributary to the main creek	Tributary to the North Bosque River	Roadway	2.5	5	0	-	Medium
17	Heritage Way Neighborhood	Several structures inundated alongside the creek in the Heritage Way Neighborhood	Town Creek	Structures	-	-	-	10	Low
18	CR 246	Road flooding between CR 245 and CR 247	North Bosque River	Roadway	4.5	5	102	-	Low
19	CR266	Flooding on the road south of the community of Clairette	Green Creek	Roadway	5.4	6	78	-	Low
20	CR300	Roadway inundation east of CR 300's intersection with the railroad	Green Creek	Roadway	5.2	5	62	-	Low
21	CR296	Road overtopping between Private Road 1636 and Private Road 1443	North Fork Little Green Creek	Roadway	4.8	5	57	-	Low
22	CR226	Roadway inundation upstream of the intersection with US HWY 281	Tributary to Indian Creek	Roadway	3.4	5	46	-	Low
23	Morgan Mill Rd and Dry Branch	Inundated structures where Morgan Mill Rd crosses Dry Branch	Tributary to Dry Branch	Structures	-	-	-	16	Low
24	South HWY 377	Several structures inundated between CR 516 and CR 379 on HWY 377	Tributary to Green Creek	Structures	-	-	-	5	Low
25	CR129	Roadway inundation close to CR 129's intersection with N State Highway 108	Tributary to North Fork North Bosque River	Roadway	3.9	5	0	-	Low
26	CR393	Flooding on CR 393 between W FM 8 and Private Road 1022	South Fork North Bosque River	Roadway	3.0	5	0	-	Low
27	CR563	Roadway inundation at the end of CR 563	Tributary to South Fork North Bosque River	Roadway	2.8	5	0	-	Low
28	N Floral Ave	Some structure flooding near the intersection of E Washington St and N Floral Ave	Small tributary near Washington Street and Floral Ave	Structures	-	-	-	8	Low

5 Flood risk analysis

Hydrologic and hydraulic models were developed for the North Bosque River and its tributaries. The hydrologic study area is approximately 100 square miles of the Green Creek-North Bosque River watershed, including the area around and upstream of the City of Stephenville, and the hydraulic analysis includes the sections of the North Bosque River, Town Creek, Dry Branch, and their tributaries within the City of Stephenville.

5.1 Hydrologic analysis

A hydrologic model was developed using the United States Army Corps of Engineer's Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) version 4.8 (U.S. Army Corps of Engineers Hydrologic Engineering Center, 2021). The study area for the hydrologic analysis includes area around and upstream of Stephenville, which is the northern section of the Green Creek-North Bosque River watershed. Drainage areas and other model components were assessed at additional detail within the City of Stephenville city limits.

5.1.1 Precipitation

Synthetic storm models were created for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year 24-hour return periods. Rainfall input data was obtained from Atlas 14 (U.S. Department of Commerce, 2017). Table 5-1 shows the rainfall depths used to develop the frequency storms in HEC-HMS.

Table 5-1: Atlas 14 Precipitation (in) Depths.

Duration	**Frequency (Return Period)**						
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**500-yr**
5 min	0.487	0.600	0.694	0.823	0.923	1.02	1.25
15 min	0.971	1.19	1.38	1.64	1.83	2.03	2.48
1 hr	1.76	2.17	2.51	2.98	3.33	3.70	4.59
2 hr	2.17	2.72	3.18	3.83	4.32	4.84	6.18
3 hr	2.42	3.06	3.61	4.38	4.97	5.60	7.27
6 hr	2.84	3.65	4.35	5.33	6.10	6.92	9.15
12 hr	3.26	4.22	5.06	6.26	7.21	8.24	11.0
24 hr	3.73	4.84	5.81	7.20	8.32	9.52	12.7

5.1.2 Drainage area delineation

The Green Creek-North Bosque Watershed subbasins were delineated based on the latest available topographic data, storm sewer infrastructure data obtained from the city and aerial photography (Esri, 2021). Brazos River Basin LiDAR (2016) and Middle Brazos-Lake Whitney Watershed LiDAR (2016) were obtained and utilized for all of Erath County from Texas Natural Resources Information System (TNRIS). The area within Stephenville city limits, where detailed hydraulic modeling was completed, was hydrologically evaluated with more detail.

Drainage areas were delineated at selected design points such as road crossings and stream confluences. A total of 64 drainage areas were delineated for the entire watershed, 38 of which are for the detailed study area around Stephenville. The average subbasin is 1.83 square miles, and within the detailed study area, the average subbasin is 0.76 square miles. Exhibit B-1 shows the Drainage Area Map for the watershed.

5.1.3 Infiltration losses

Runoff for each subbasin was determined through use of the Soil Conservation Service (SCS) Curve Number method. A land use dataset was developed for existing conditions based on land use data provided by North Central Texas Council of Governments (NCTCOG, 2015). Existing land use data was confirmed and updated using 2015 ESRI aerials. Exhibit B-2 shows the Existing Land Use Map for the watershed with delineated drainage areas. Future conditions were obtained from the 2019 Stephenville Future Land Use Map and are shown with drainage areas in Exhibit B-3. The future land use data provides information within the City of Stephenville ETJ. Future growth may cause continued increases in discharges, especially for the North Bosque River.

Hydrologic soil types for the watershed were determined from data obtained from Natural Resources Conservation Service (NRCS). Hydrologic soil types are classified as A, B, C, or D with Soil Type A being sandy with high infiltration rates and Soil Type D being clayey with low infiltration rates (USDA, 2018). Exhibit B-4 shows the Hydrologic Soils Map for the watershed with drainage areas.

Composite curve numbers for each drainage area were calculated from the soil types and land use classifications in accordance with the TR-55 methodology (USDA, 1986), as shown in Table 5-2.

Table 5-2: TR-55 Curve Numbers.

Land Use	Soil CN A	Soil CN B	Soil CN C	Soil CN D
Commercial	89	92	94	95
High Density Residential	77	85	90	92
Industrial	81	88	91	93
Low Density Residential 2 Acres	46	65	77	82
Medium Density Residential Quarter	61	75	83	87
Open Space - Fair	49	69	79	84
Open Space - Good	39	61	74	80
Pasture - Fair	49	69	79	84
Paved Parking Lots	98	98	98	98
Paved Streets and Roads	98	98	98	98
Water	100	100	100	100
Woods - Good	30	55	70	77

Table 5-3 located in the following section, provides curve numbers for each drainage area.

5.1.4 Unit hydrograph method

The runoff hydrograph for each drainage area was developed using the SCS Unit Hydrograph method. The times of concentration were determined according to the United States Department of Agriculture TR-55 methodology (USDA, 1986). The time of concentration (Tc) is calculated by the summation of the travel times of the storm flow over different segments of the basin and can be used to estimate the lag time (0.6*Tc). There are three types of flow conditions considered for time of concentration: 1) sheet flow, 2) shallow concentrated flow, and 3) concentrated flow. The latter is broken into channel, swale, and pipe flow. Several standard assumptions were implemented in the time of concentration calculations.

Sheet flow takes place in the most upstream portion of the drainage area. Sheet flow is where flow travels across the surface in wide sheets but has not yet formed into a concentrated flow. Per industry standards, sheet flow path lengths were limited to 300 ft in rural, undeveloped parts of the study area, 100 ft for areas with natural cover in urban areas, and 50 ft for smooth surfaces, such as concrete. Shallow concentrated flow starts to collect into defined flow paths after sheet flow. The shallow concentrated flow travel time is calculated from the velocity and distance of travel. The velocity is determined based on the slope and surface over which the water travels. Once the flow path reaches a channel, swale or pipe, the flow becomes concentrated flow. The flow path alignments were determined by contours, aerials, and storm drain GIS information. For the concentrated portion of a flow path, average velocities of 3 ft/s, 6 ft/s, and 8 ft/s were assumed, per industry standards, for swales, channels, and pipes, respectively.

Several assumptions were made for ultimate conditions. For basins changing from undeveloped to industrial/commercial, it was assumed that there would be 50 feet of sheet flow and then there would be paved shallow concentrated flow. Table 5-3 located below provides the hydrologic parameters for each drainage area.

Table 5-3: Hydrologic Parameters.

Sub-Basin Name	Area (acre)	Existing CN	Ultimate CN	Existing TC (min)	Ultimate TC (min)
NB_D05	255	85	89	36.8	36.8
NB_D04	152	85	94	35.7	21.2
NB_D01	77	81	85	28.3	28.3
NB_D02	540	73	80	40.2	40.2
NB_D03	352	82	86	32.7	32.7
NB_D06	565	78	88	48.1	38.9
NB_D07	540	73	87	48.5	35.2
NB_D08	507	73	83	49.4	49.4

Sub-Basin Name	Area (acre)	Existing CN	Ultimate CN	Existing TC (min)	Ultimate TC (min)
NB_D09	528	82	87	55.6	55.6
NB_D10	526	67	77	56.2	56.2
NB_D11	201	81	86	45.9	45.9
NB_D12	407	77	81	65.9	65.9
NB_09	298	87	87	38.3	38.3
NB_B01	99	89	92	24.9	24.9
NB_A01	2676	77	77	122.0	122.0
NB_A02	716	79	80	65.3	65.3
NB_A03	1775	78	83	87.3	87.3
NB_A04	121	78	89	24.8	24.8
NB_A05	931	79	87	77.4	77.4
NB_A06	143	83	90	27.3	27.3
NB_05	44	74	86	36.1	36.1
NB_N02	3709	76	76	114.9	114.9
NB_N01	2920	76	76	125.1	125.1
NB_N04	3832	76	76	121.3	121.3
NB_N03	1152	76	76	81.6	81.6
NB_N05	2400	76	76	110.9	110.9
NB_N07	1245	76	76	72.2	72.2
NB_N06	1663	77	77	93.9	93.9
NB_S16	316	83	85	35.0	35.0
NB_S17	309	81	83	36.7	36.7
NB_S18	76	82	83	22.8	22.8
NB_S10	2921	74	74	121.3	121.3
NB_S08	2534	75	75	104.8	104.8
NB_S02	6285	76	76	134.0	134.0
NB_S01	2340	75	75	99.1	99.1
NB_S04	3565	76	76	98.3	98.3
NB_S06	3508	74	74	108.6	108.6
NB_S05	709	75	75	68.9	68.9
NB_S03	2896	73	73	140.4	140.4
NB_S07	671	74	74	73.6	73.6
NB_S09	984	74	74	81.0	81.0
NB_S11	457	74	74	69.7	69.7
NB_S12	1621	69	72	98.7	98.7
NB_S13	944	71	78	63.1	63.1
NB_S14	189	80	88	55.2	55.2
NB_S15	971	72	81	55.5	55.5
NB_S19	514	77	82	35.2	35.2

Sub-Basin Name	Area (acre)	Existing CN	Ultimate CN	Existing TC (min)	Ultimate TC (min)
NB_N08	4620	74	75	133.8	133.8
NB_S20	218	73	80	45.1	45.1
NB_01	196	78	83	50.4	50.4
NB_02	146	90	90[1]	31.2	31.2
NB_04	219	88	89	26.0	26.0
NB_03	237	84	87	18.4	18.4
NB_06	520	85	92	54.7	37.1
NB_07	174	83	89	14.4	14.4
NB_08	145	81	82	29.5	29.5
NB_10	341	82	85	30.0	30.0
NB_11	605	79	89	37.6	37.6
NB_12	412	83	90	36.2	36.2
NB_C01	2779	79	82	93.6	93.6
NB_C02	1049	75	85	77.9	53.8
NB_13	204	74	83	58.8	58.8
NB_14	81	67	67	26.6	26.6
NB_E01	2858	73	74	113.8	113.8

5.1.5 Flow routing

The hydrologic model accounts for the attenuation and timing of hydrographs as they travel downstream through the use of flow routing. Using discharge-volume information from the hydraulic model where possible, the Modified Puls routing method was used within the detailed study area around Stephenville. Outside of the detailed study area where hydraulic models were not developed, three different types of routing were considered: lag routing using velocities from the Rain-on-Mesh model, Muskingum-Cunge, and lag routing assuming a standard channel velocity of six feet per second. After evaluating the peak discharges and shapes of the hydrographs for each of these methods, lag routing using velocities from the ROM model was determined to best suit the model.

5.1.6 Diversions

In order to account for the Methodist Branch storm drain system, a diversion was placed for NB_09. The pipe capacity of 791 CFS was determined based on the Infoworks ICM 9.0 rain-on-mesh model developed during the 2020 Master Drainage Plan. The flow is assumed to travel through the storm drain system and then passes through NB_B01_R before joining with the other flows at NB_08_J. Any flow that exceeds the capacity of the storm drain travels beneath the railroad to NB_B01.

[1] The ultimate CN value was less than the existing CN value, due to generalization of areas in the future land use plan. Therefore, the ultimate CN value was defaulted back to the existing CN value.

5.1.7 Results

A summary table of the existing condition discharges is included below in Table 5-4 and ultimate condition discharges are show in Table 5-5. A Hydrologic Workmap, Exhibit B-5, with HEC-HMS elements depicted on the map can be found in Appendix B. Output tables for existing and ultimate 100-year conditions are included in Exhibit C-3.

Table 5-4: Summary of Existing Conditions Discharges.

Stream	Location	HMS Element	Drainage Area (mi^2)	Existing Flow Rate (cfs)						
				2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
North Bosque River	Confluence with Town Creek	NB_13B_J	105.41	5965	9465	12842	17369	21624	27071	41181.6
North Bosque River	Confluence of Pole Hollow Branch and the North Bosque River	NB_12_J	105.28	5737	9023	12113	16490	20008	24230	36895.3
North Bosque River	Crossing at US 377/W South Loop	NB_09_J	97.4	5622	8842	11876	16180	19621	23602	35683.9
North Bosque River	Confluence with the Methodist Branch Storm Drain and College St Branch	NB_08_J	96.91	5610	8821	11852	16149	19580	23598	35590.5
North Bosque River	Confluence with Dry Branch at E Washington St	NB_04_J	94.94	5557	8738	11727	16037	19397	23292	34925.5
North Bosque River	Crossing at the Fort Worth and Western Railroad	NB_03_J	84.23	5297	8255	11087	15198	18448	21924	31038.1
North Bosque River	Crossing at FM 8/E Lingleville Rd	NB_02_J	84	5299	8240	11072	15179	18426	21895	31017.3
North Bosque River	Confluence with the North Fork North Bosque River downstream of N SH 108/Graham Ave	NB_01_J	83.69	5312	8230	11063	15161	18415	21869	30940.1
North Bosque River	Confluence with Tributary to the North Bosque River	NB_S12_J	48.89	3051	4786	6359	8613	10417	12334	17528.8
North Bosque River	14,000 ft upstream of Graham St bridge	NB_S10_J	46.28	2935	4579	6047	8158	9842	11623	16264.5
Dry Branch	Confluence with East Fork Dry Branch	NB_A03_J	9.93	2037	3054	3934	5120	5938	6871	9191.3
Dry Branch	Confluence with Tributary to Dry Branch	NB_A02_J	8.07	1959	2924	3762	4942	5841	6784	9090.8
Dry Branch	Downstream of UB6	NB_A01_J	4.18	51	56	60	64	66	69	287.1

Stream	Location	HMS Element	Drainage Area (mi^2)	Existing Flow Rate (cfs)						
				2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Tributary to Dry Branch	700 ft upstream of Smith Springs Rd	NB_A03_J	2.77	1322	1980	2553	3364	3983	4633	6231.9
East Fork Dry Branch	Downstream of UB7	NB_A04_J	1.45	26	28	30	32	33	34	125.8
Tributary to the North Bosque River	Crossing at Prairie Wind Blvd	NB_S13A_J	1.09	1060	1486	1867	2369	2751	3154	4111.4
Tributary to the North Bosque River	Crossing at Lingleville Rd	NB_S13_J	0.97	971	1376	1721	2195	2550	2918	3778.5
Tributary to the North Bosque River	600 ft upstream of Lingleville Rd	NB_S16_J	0.49	518	726	903	1146	1326	1513	1949.1
College St Branch	220 ft upstream of College St	NB_B01_J	0.66	237	312	376	502	687	880	1333.5
Pole Hollow Branch	Downstream of UB15	NB_C01_J	4.34	55	58	60	63	64	66	652
Town Creek	Confluence with Tributary to Town Creek 1 at County Road 454	NB_D07_J	6.62	2161	3734	4983	7154	8960	10708	16197.9
Town Creek	Confluence with Tributary to Town Creek 2	NB_D05_J	4.66	2250	3636	4842	6445	7679	8973	12107.3
Town Creek	Confluence with Tributary to Town Creek 3 at Fort Worth and Western Railroad	NB_D03_J	2.15	1429	2064	2556	3207	3872	4540	6011.6
Town Creek	Crossing at W Frey St	NB_D02_J	0.96	637	991	1304	1748	2087	2444	3295.1
Town Creek	Crossing at NW Loop	NB_D01_J	0.12	131	187	236	302	352	403	522.5
Tributary to Town Creek 1	Downstream of D10_Dam	NB_D08_J	0.82	0	16	99	438	795	1209	2012.3
Tributary to Town Creek 2	6300 ft upstream of County Road 256	NB_D06_J	0.84	456	722	960	1299	1561	1837	2504
Tributary to Town Creek 3	150 ft upstream of Lockhart Rd	NB_D04_J	0.24	271	373	458	575	662	752	961

Table 5-5: Summary of Ultimate Conditions Discharges.

Stream	Location	HMS Element	Drainage Area (mi^2)	Existing Flow Rate (cfs)						
				2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
North Bosque River	Confluence with Town Creek	NB_13B_J	105.41	6598	9905	13549	18600	23379	28306	42593.3
North Bosque River	Confluence of Pole Hollow Branch and the North Bosque River	NB_12_J	105.28	5921	9233	12351	16769	20976	25411	38193.8
North Bosque River	Crossing at US 377/W South Loop	NB_09_J	97.4	5795	9036	12095	16413	20643	24739	36950.4
North Bosque River	Confluence with the Methodist Branch Storm Drain and College St Branch	NB_08_J	96.91	5777	9015	12071	16379	20745	24744	36855
North Bosque River	Confluence with Dry Branch at E Washington St	NB_04_J	94.94	5688	8940	11946	16263	20837	24400	36268.6
North Bosque River	Crossing at the Fort Worth and Western Railroad	NB_03_J	84.23	5401	8414	11262	15386	18649	22126	31229.8
North Bosque River	Crossing at FM 8/E Lingleville Rd	NB_02_J	84	5401	8403	11247	15366	18628	22101	31227.7
North Bosque River	Confluence with the North Fork North Bosque River downstream of N SH 108/Graham Ave	NB_01_J	83.69	5410	8396	11236	15348	18606	22055	31138.8
North Bosque River	Confluence with Tributary to the North Bosque River	NB_S12_J	48.89	3125	4868	6453	8716	10525	12508	17711.7
North Bosque River	14,000 ft upstream of Graham St bridge	NB_S10_J	46.28	2983	4631	6106	8223	9909	11692	16335.9
Dry Branch	Confluence with East Fork Dry Branch	NB_A03_J	9.93	2433	3480	4364	5514	6337	7271	9560.8
Dry Branch	Confluence with Tributary to Dry Branch	NB_A02_J	8.07	2320	3321	4175	5361	6254	7188	9458.4
Dry Branch	Downstream of UB6	NB_A01_J	4.18	51	56	60	64	66	69	287.1
Tributary to Dry Branch	700 ft upstream of Smith Springs Rd	NB_A03_J	2.77	1650	2339	2925	3740	4354	4995	6560

Stream	Location	HMS Element	Drainage Area (mi^2)	Existing Flow Rate (cfs)						
				2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
East Fork Dry Branch	Downstream of UB7	NB_A04_J	1.45	28	30	31	33	34	35	263.6
Tributary to the North Bosque River	Crossing at Prairie Wind Blvd	NB_S13A_J	1.09	1145	1574	1956	2453	2834	3235	4179.1
Tributary to the North Bosque River	Crossing at Lingleville Rd	NB_S13_J	0.97	1053	1461	1806	2279	2630	2994	3843.3
Tributary to the North Bosque River	600 ft upstream of Lingleville Rd	NB_S16_J	0.49	560	769	946	1187	1365	1550	1980.7
College St Branch	220 ft upstream of College St	NB_B01_J	0.66	259	333	395	506	691	883	1336.5
Pole Hollow Branch	Downstream of UB15	NB_C01_J	4.34	56	59	61	63	65	66	773.8
Town Creek	Confluence with Tributary to Town Creek 1 at County Road 454	NB_D07_J	6.62	3294	5043	6941	9457	11298	14149	18797.1
Town Creek	Confluence with Tributary to Town Creek 2	NB_D05_J	4.66	3376	5136	6453	8270	9575	10931	14069.9
Town Creek	Confluence with Tributary to Town Creek 3 at the Fort Worth and Western Railroad	NB_D03_J	2.15	1935	2600	3135	3834	4314	4874	6463.8
Town Creek	Crossing at W Frey St	NB_D02_J	0.96	870	1255	1581	2034	2372	2724	3552.7
Town Creek	Crossing at NW Loop	NB_D01_J	0.12	154	211	259	325	374	424	540.5
Tributary to Town Creek 1	Downstream of D10_Dam	NB_D08_J	0.82	0	142	448	984	1376	1711	2338.9
Tributary to Town Creek 2	6300 ft upstream of County Road 256	NB_D06_J	0.84	1029	1388	1688	2096	2397	2709	3435
Tributary to Town Creek 3	150 ft upstream of Lockhart Rd	NB_D04_J	0.24	471	596	700	842	946	1054	1302.7

Comparison to FEMA FIS discharges

Discharges were compared to the 2011 Erath County FEMA FIS (Table 5-6). There were a limited number of locations that could be compared against the model due to sparse FIS data coverage in Erath County. It should be noted that the FEMA flows for the Bosque River do not increase downstream as contributing area is added, which may indicate that flow from additional drainage areas along the river aren't being considered in the FEMA hydraulic model. Therefore, peak discharges are assumed to be not accurate or comparable to the revised detailed discharges.

Table 5-6: FIS Comparison.

Location	Waterway	FEMA Discharge (cfs)	FIF Discharge (cfs)	Comparison (%)
North Bosque River	North Bosque River	15,500	12,334(US) – 28,538 (DS)	-20% - 84%
Immediately downstream of Prairie Wind Blvd	Tributary to N Bosque River	2,019	3,154.3	56%
Immediately downstream of FM 8	Tributary to N Bosque River	1,713	1,512.8	-12%
Town Creek	Town Creek	2,000	2,443.5	22%

5.2 Hydraulic analysis

A new detailed hydraulic model was created for the North Bosque River Watershed FIF Study. The study area for this analysis was in and around the City of Stephenville, extending downstream until the confluence of Town Creek and the North Bosque River. The methodology utilized to create the steady state 1D models is described in the following sections.

5.2.1 Modeling software

FNI developed the hydraulic models using the United States Army Corps of Engineer's Hydrologic Engineering Center River Analysis System (HEC-RAS) version 5.0.7 software. HEC-RAS is an industry standard modeling software and the City of Stephenville's preferred software. Version 6.0 was originally used, but bugs present in the lateral structure optimization process necessitated the shift to version 5.0.7. Hydraulic modeling techniques, consistent with the HEC-RAS Hydraulic Reference Manual Version 5.0, were used (U.S. Army Corps of Engineers Hydrologic Engineering Center, 2018). RAS Mapper, ArcGIS Pro, and ArcMap were used to create model components, such as cross sections, flow paths, manning n assignments and junctions, and delineate floodplains based on the water surface elevations computed by HEC-RAS.

5.2.2 Topography

The grid surfaces (DEMs) used for this study were created with LiDAR obtained from TNRIS. Two different datasets were obtained, as both cover different portions of the county. The two datasets, the Brazos River Basin LiDAR, and Middle Brazos-Lake Whitney Watershed LiDAR, were both captured in 2016 with 70 cm resolutions (United States Geological Survey (USGS), 2016).

Since conventional LiDAR does not penetrate water bodies, the channel topography below the water level was not captured. To address this limitation, channel data was captured by field survey (1519 Surveying, LLC) in October 2021 at hydraulic structures and select locations. This data was then integrated into the LiDAR grid surface for modeling and mapping purposes. A total of 28 structures and 32 channel cross-sections were field surveyed. This survey data is included in Appendix F. Additional structures were examined by FNI in the field. A map of locations surveyed or examined in the FNI field visit are shown in Exhibit B-6.

5.2.3 Cross sections

Cross sections were placed at regular intervals along the streams and were spaced so that the channel geometry and hydraulic roughness between adjacent cross sections varied gradually and could be assumed as linear. Cross sections were placed directly upstream and downstream of hydraulic structures, in areas where the channel geometry greatly varied, and at or near FEMA lettered cross section locations. Elevations from surveyed cross sections were used whenever applicable.

The main stem of the North Bosque River, Town Creek and its three tributaries, Dry Branch and its two tributaries, and three additional tributaries off the North Bosque River (Tributary to North Bosque River, Pole Hollow Branch, and College St Branch) were studied in detail, including field survey. The model includes 625 cross sections, 28 surveyed bridge and culvert crossings, and 15 bridge and culvert crossings with approximate geometry. A Hydraulic Workmap, Exhibit B-7, with HEC-RAS elements depicted on the map can be found in Appendix B.

5.2.4 Roughness values

Manning’s roughness values were assigned based on aerial photography, field observations, and land use information. For channels, Manning’s roughness values generally range from 0.015 for concrete lined channels to 0.8 for dense vegetation. For overbanks, Manning’s roughness values range from 0.015 for paved streets and parking lots, to 0.45 for natural grass, and 0.1 was used for obstructions such as existing homes or structures. The full list of Manning’s n values used is shown in Table 5-7.

Table 5-7: Manning's N Values for 1D Hydraulic Model.

Land Cover	Manning's n value
Paved Parking Lots/Paved Streets and Roads	0.015
Water	0.025
Improved Grass	0.04
Natural Grass	0.045

Land Cover	Manning's n value
Dense Grass or Crops	0.05
Vegetated Sparse	0.06
Vegetated Light	0.07
Vegetated Dense	0.08
Obstructions	0.1

5.2.5 Bridges and culverts

Bridge and culvert crossings were modeled using a combination of survey data, FNI site visit, and aerial imagery. Ineffective flow areas were placed upstream at a 1:1 ratio and downstream at a 3:1 ratio of these hydraulic structures and at any locations where channel flow was obstructed, per the HEC-RAS manual and industry standard.

5.2.6 Flow data

The HEC-RAS model was executed as 1-D steady-state flow simulations. For the steady state simulations, the peak discharges under existing and ultimate conditions were utilized for the hydraulic model. The 2-, 5-, 10-, 25-, 50-, 100- and 500-year return period storm events were modeled. The HEC-RAS input flows for each flow change location were taken from the corresponding peak discharge outputs from the HEC-HMS model. The flow change location data is reported in Exhibit B-7.

5.2.7 Lateral structures

At several locations, streams are hydraulically connected prior to the confluence. To improve model accuracy in these cases, lateral structures were placed between the two streams' cross sections to exchange flows prior to the confluence point. Other, more unique situations that utilize lateral structures are described in the following section.

Lateral structure between the tributary to North Bosque River and North Bosque 4

As the Tributary to North Bosque River connects with the North Bosque River, the small parallel channel to the south of the North Bosque River quickly becomes inundated and part of the main channel's floodplain. The centerline of the tributary ends immediately upstream of where this combination begins and uses a normal depth boundary condition matching the slope of the terrain. A lateral structure along the last three cross sections of the tributary allows flow to cross over to the main branch in larger storm events.

Lateral structure at North Bosque 4

Along the North Bosque River near the North Graham Street bridge, another tributary that is not a part of the detailed study joins the North Bosque River. Since this area is naturally low lying due to the river, the floodplain isn't contained within the cross sections, so a lateral structure has been added here to contain flow and assume an equivalent backwater elevation. Additionally, setting up the model with this lateral structure allows for this tributary to be more easily added in future model versions as needed.

Lateral structure at the railroad on Dry Branch

At the railroad on Dry Branch, there is a secondary opening south of the modeled structure. To model flow passing through the secondary opening, a lateral structure was added between the two cross sections directly upstream of the railroad and connected to the two cross sections that are on either side of the downstream opening. Since the two sets of cross sections lie perpendicular to each other, the stations were defined by the user and the lateral structure is not georeferenced. Weir calculations use the terrain from the railroad between the two downstream cross sections.

5.2.8 Hydraulic results

As part of this study, 100-year floodplains were delineated, and computed water surface elevations (WSEL) were determined for each return event. All elevations have a vertical datum of North American Vertical Datum of 1988 (NAVD 88).

Exhibit C-1 provides the existing 100-year floodplain along with stream flow lines, cross section layout, elevation contour data, FEMA lettered cross sections, and aerial photography. Appendix F contains the digital hydraulic models. Refer to Table 5-8 below for a comparison of the peak 100-year WSEL compared to the Erath County FIS WSELs. Exhibit C-2 shows the location of the FEMA lettered cross sections along with a comparison of the FEMA effective floodplain and the existing conditions 100-year floodplain produced in the FIF study. Hydraulic output for existing conditions is included in Exhibit C-4.

Table 5-8: 100-Year FIS versus FIF Study Existing WSEL Comparison.

Stream	FEMA Section	FIF Section	FEMA WSEL	FIF WSEL (Existing)	Difference (FIF- FEMA)
Dry Branch	A	1928	1254.6	1259.26	4.66
	B	4478	1258.8	1262.41	3.61
	C	5549	1259.1	1265.64	6.54
	D	6795	1263.1	1267.96	4.86
East Fork Dry Branch	A	1461	1268.9	1263.20	-5.7
	B	2052	1271.1	1269.49	-1.61
	C	3492	1280.5	1276.33	-4.17
North Bosque River	A	18556	1238.4	1238.30	-0.1
	B	21150	1241.5	1240.57	-0.93
	C	23420	1244.3	1244.58	0.28
	D	26420	1247.2	1253.00	5.8
	E	28621	1252.5	1255.66	3.16
	F	30234	1256.4	1259.51	3.11
	G	32905	1260.3	1262.69	2.39
	H	34820	1262.8	1267.50	4.7
	I	37265	1267.5	1271.28	3.78
	J	38398	1268.0	1271.86	3.86
	K	39075	1268.5	1272.21	3.71
	L	40221	1270.8	1273.59	2.79
Storm Drain/ College St Branch	A	1400	1244.6	1244.82	0.22
	B	1935	1252.1	1251.86	-0.24
Town Creek	A	22898	1312.9	1313.90	1
	B	23483	1313.0	1314.48	1.48
	C	24405	1319.1	1317.91	-1.19
	D	25455	1324.7	1326.39	1.69
	E	25951	1325.2	1327.64	2.44
	F	26475	1328.1	1330.62	2.52
	G	29588	1358.3	1358.40	0.1
Tributary to North Bosque River	A	3242	1283.6	1286.10	2.5
	B	3363	1284.1	1286.14	2.04
	C	4388	1293.7	1295.02	1.32
	D	5747	1307.9	1306.09	-1.81

Hydraulic results indicate that the FIF peak WSELs range from 5.7 feet below to 6.54 feet higher than the effective FEMA WSELs. The changes in the computed WSELs can be attributed to updated topographic data and more detailed hydraulic modeling and methodology. Updated detailed hydrologic modeling also account for differences, particularly along tributaries.

Roadway overtopping

Within the project area, there are 43 total roadways, 4 of which are pedestrian bridges and crossings. These roadways have a large range of levels or service, shown in Figure 5-1.

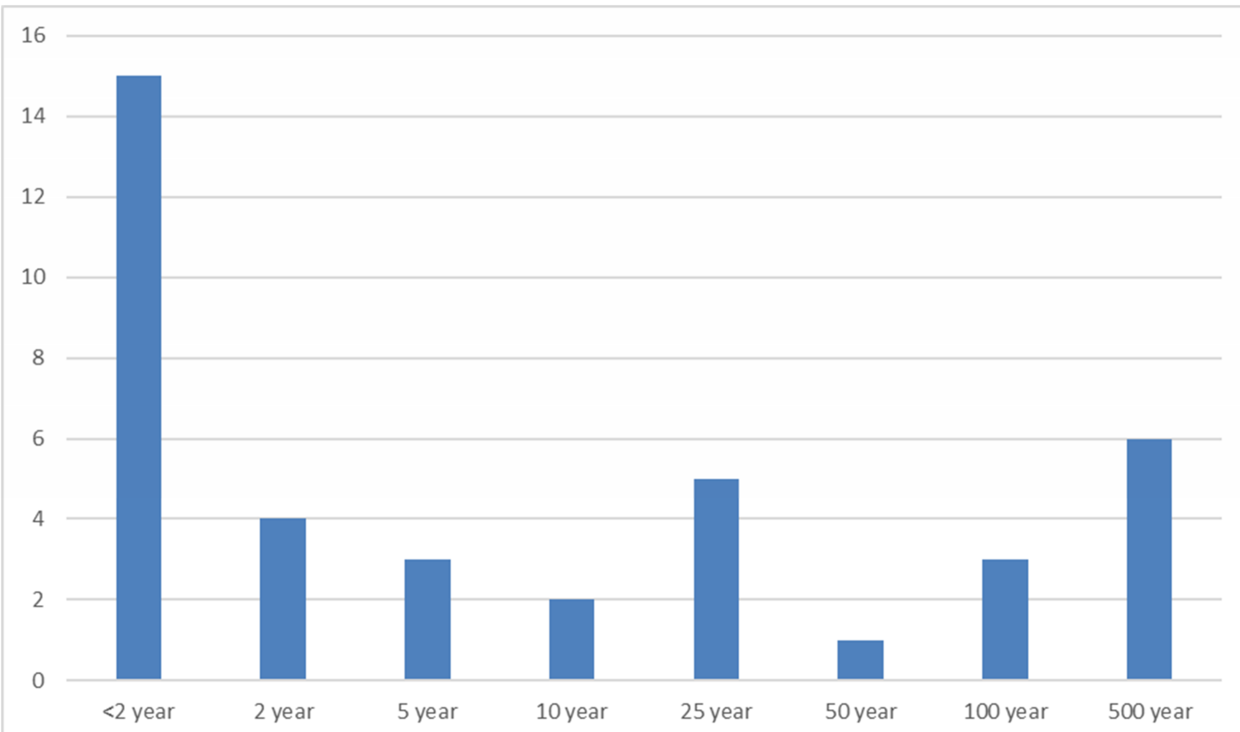

Figure 5-1: Number of Roadways by Level of Service.

Thirty of the 43 structures are overtopped in the 100-year event. Table 5-9 summarizes the level of service and overtopping depths at each roadway crossing during the 100-year storm under existing conditions.

Table 5-9: Road Overtopping.

Road Name	Reach Name	Level of service	Overtopping Depth in Existing 100-year (ft)
College St	College St Branch	50 years	1.21
Long St	College St Branch	25 years	2.08
College Farm Branch Rd	Dry Branch	5 years	0.30
E Lingleville Rd	Dry Branch	500 years	-
Railroad	Dry Branch	100 years	-
Morgan Mill Rd	East Fork Dry Branch	500 years	-
Golf Course 1	East Fork Dry Branch	50 years	0.11
Golf Course 2	East Fork Dry Branch	2 years	0.75
N Graham St	North Bosque River	25 years	3.48
E Lingleville Rd	North Bosque River	25 years	3.14
Railroad	North Bosque River	500 years	-
E Collins Rd	North Bosque River	<2 year	7.00
E Washington St	North Bosque River	25 years	0.70
E Long St	North Bosque River	<2 year	15.23
S Graham Ave	North Bosque River	5 years	0.66
Pedestrian Bridge	North Bosque River	50 years	6.09
W South Loop	North Bosque River	500 years	-
Park Bridge	North Bosque River	<2 year	10.42
CR 454	North Bosque River	<2 year	6.34
US 67	Pole Hollow Branch	500 years	-
US 281	Pole Hollow Branch	25 years	0.66
CR 454	Town Creek	<2 year	2.89
NW Loop	Town Creek	5 years	0.55
W Frey	Town Creek	10 years	1.80
W Brenda St	Town Creek	<2 year	3.88
Pedestrian Bridge	Town Creek	<2 year	6.87
Walgreens	Town Creek	2 years	4.70
W Washington St	Town Creek	2 years	2.59
Railroad	Town Creek	500 years	-
CR 256	Town Creek	<2 year	4.62
Private Rd 1424	Town Creek	<2 year	5.21
FM 914	Town Creek	25 years	4.75
Heritage Way	Town Creek	<2 year	5.14
Private Road	Town Creek	<2 year	5.69
Private Road 1422	Town Creek	<2 year	5.13
Smith Springs Rd	Tributary to Dry Branch	<2 year	2.71
Morgan Mill/US 281	Tributary to Dry Branch	2 years	1.28
W Lingleville Road	Tributary to North Bosque River	2 years	2.12
Prairie Wind Blvd	Tributary to North Bosque River	<2 year	2.82
FM 914	Tributary to Town Creek 1	10 years	1.39
Small road off 454	Tributary to Town Creek 1	100 years	-
CR 256	Tributary to Town Creek 2	<2 year	2.08
Lockhart Rd	Tributary to Town Creek 3	<2 year	2.00

The level of service for each crossing is also shown in Exhibit C-1.

Inundated structures

FNI used the structure footprints provided by the TWDB building dataset, with a 6" foundation assumed for all structures. Therefore, structure inundation is assumed to occur when depths produced from the HEC-RAS models at the structure footprints were greater than 0.5 feet. To determine with certainty if a structure's finished floor elevation (FFE) is below the calculated 100-year WSEL, a survey or elevation certificate detailing the actual FFE would need to be provided. Inundated structures are shown in Exhibit C-1.

6 Critical flood hazard alternatives analysis

Based on the previously discussed results and discussions with City staff, FNI focused on five areas of concern and completed alternative analyses to identify projects that could alleviate the hazards at these sites. These areas of concern and associated alternative analyses are discussed below, as are the methods and assumptions which meet TWDB scope requirements, including requirements for inclusion to the Regional Flood Plan (RFP). All alternatives propose solutions that are permittable, constructable, and implementable.

6.1 Alternatives evaluation

Alternatives were evaluated in a variety of ways. The methodology and assumptions for each metric are described in this section. An Opinion of Probable Construction Cost (OPCC) was developed for each alternative and details are provided in Appendix D.

Requirements for inclusion to the RFP include modeling, a BCR, and a no negative impact evaluation. Data for these Flood Mitigation Projects (FMPs) is summarized in the table in Exhibit D-1 in Appendix D. The TWDB formatted FMP GIS layer is also provided in Appendix D.

As part of the supplemental Task 6 effort, as described in the Grant Agreement Amendment 2, the highest rank alternative was to be evaluated further. The additional evaluation included the following for a single alternative that was agreed upon through discussion with the City of Stephenville:

- Develop conceptual layout and grading of the design elements in CAD.
- Identify utility conflicts the project elements needed to relocate the conflicting utilities.
- Define additional cost components such as erosion control elements.
- Identify property acquisition needs.
- Confirm no negative impacts.
- Confirm Opinion of Probable Construction Cost and Benefit Cost Ratio
- Review permitting requirements and strategy for identified project

This supplemental analysis occurred on the Prairie Wind Boulevard Alternative 2 evaluation and is further discussed and results presented in Appendix E.

6.1.1 Benefit-cost analysis

The benefit-cost analysis (BCA) was generated for each alternative, and the spreadsheets used to develop these values are provided in Appendix F. They were developed using a TWDB benefit-cost analysis input tool in conjugation with the FEMA BCA Toolkit 6.0. The process makes several assumptions, including (AECOM, 2022):

- 7% discount rate
- Annual inflation is ~2%
- Each residence houses 3 people (including 2 workers or employed residents)
- The per diem for displaced residents is $240/day per household (this includes 1 hotel room and meals for 3 people)
- Residential square footage based on house size:
  - Small = 1,000
  - Average = 2,500
  - Large = 5,000
- Each commercial building employs 10 people
- Commercial property value is $100/square foot.

Parameters used to quantify benefits to structures, roadways, and other infrastructure were taken directly from model results and applied to the BCA spreadsheet. To determine roadway overtopping durations, 1D unsteady HEC-RAS models were created directly from the 1D steady state HEC-RAS models. The durations obtained from these unsteady models are planning level estimates, as detailed unsteady models are not in scope for this project effort. The impacts from 2-, 5-, 10-, 25-, 50-, and 100-year 24-hour synthetic storm events as described in section found. Were considered for all alternatives.

6.1.2 No negative impact assessments

Each identified FMP must demonstrate that no negative impacts on a neighboring area would result from its implementation. No negative impact means that a project will not increase flood risk of surrounding properties. Using best available data, the increase in flood risk is measured by the 100-year storm event water surface elevation.
The following requirements, per Exhibit C, should be met to establish no negative impact, as applicable:

1. Stormwater does not increase inundation in areas beyond the public right-of-way, project property, or easement.
2. Stormwater does not increase inundation of storm drainage networks, channels, and roadways beyond design capacity.
3. Maximum increase of 1D Water Surface Elevation must round to 0.0 feet (<0.05 ft) measured along the hydraulic cross-section.
4. Maximum increase of 2D Water Surface Elevations must round to 0.3 feet (<0.35 ft) measured at each computation cell.
5. Maximum increase in hydrologic peak discharge must be <0.5 percent measured at computation nodes (subbasins, junctions, reaches, reservoirs, etc.). This discharge restriction does not apply to a 2D overland analysis.

A comparative assessment of pre- and post-project conditions for the existing conditions 100-year storm event was performed for each alternative (Exhibit D-1 in Appendix D). The floodplain boundary extents and resulting water surface elevations were compared at pertinent locations to determine if the FMP conforms to the no negative impact requirements. All alternatives met the requirement for no negative impact. The No Negative Impact table for recommended FMPs is in Appendix D as Exhibit D-3.

6.1.3 FMP GIS requirements

Each alternative was created in GIS using the FMP layer template provided by TWDB. In order to complete the fields in the feature class, the following assumptions were made:

- GOAL_IDs were referenced from the Lower Brazos Draft Regional Flood Plan.
- AREA_SQMI is the entire area of the feature, which includes contributing drainage areas per Exhibit D, as well as areas slightly downstream of the impacted crossings to include potential construction areas.
- For Long Street, the contributing drainage area extends further than the detailed hydraulic model's extents. To get AREA_100 and AREA_500, the FEMA 100-year floodplain area upstream of the model extents was added to area in the 100- and 500-year flood extents produced by the hydraulic model.
- ROADCLS was estimated based on LOS. For REMROADCLS, the closures associated from the existing LOS was compared with the closures associated with the alternative LOS.
    - <2-year LOS: 10 closures over the past 10 years
    - 2-year LOS: 5 closures over the past 10 years
    - 5-year LOS: 2 closures over the past 10 years
    - 10-year LOS: 1 closure over the past 10 years
    - 100-year LOS: 0 closures over the past 10 years

6.2 Prairie Wind Boulevard

Prairie Wind Boulevard is in the northwestern side of Stephenville in a residential neighborhood. Prairie Wind Boulevard crosses the Tributary to North Bosque River just upstream of the confluence to the North Bosque River. The flooding that occurs at this crossing is a known issue to the City and currently has a less than 2-year level of service (LOS), creating frequent disruptions for residents. This area was identified as a hot spot in the screening assessment, with an identified flood hazard vulnerability of 5 and an overtopping depth of 2.5 feet in the 100-year storm. The existing culverts include (3) 60" CMPs and a 100-year storm event results in twelve buildings being inundated greater than 0.5 foot. This site was previously studied as a part of the 2020 Master Drainage Plan.

Flood patterns in this area are unique, as there is a low point, or ditch, parallel to the existing tributary outside of the left bank that, as flow escapes the banks of the tributary, it will flow through. When this happens, the ditch is then overwhelmed, and flow continues to residential properties and structures along the south side of Blue Jay Drive. Two different methodologies are explored over three alternatives for this issue. Alternatives 1 and 2 address the problem by containing flow within the banks of the existing tributary, not allowing it to escape the main channel to the parallel ditch, in addition to upsizing the existing culverts and extending the channel directly to the North Bosque River. Alternative 3, originally conceptualized in the 2020 Master Drainage Plan, increases the capacity of the parallel ditch, adds in new culverts at the low point of the road, and creates a channel from the low point to the North Bosque River. Each of these alternatives is described in further detail in the following sections.

6.2.1 Alternative 1

The first alternative developed for Prairie Wind Boulevard allows for a 10-year LOS at the crossing with the tributary to the North Bosque River and removes all twelve structures from the 100-year flood extent. This is done by performing channel grading upstream of the crossing to contain the 10-year storm event, replacing the existing culverts with (5) 9’x5’ RCB culverts, and realigns the existing channel to cut from the crossing straight to the river, as shown in Exhibit 1-A in Appendix D. It is recommended that rock riprap is added along the east bank to provide erosion protection for the nearby Dollar General to mitigate potential erosion concerns.

This alternative poses potential Section 404 Clean Water Act permitting issues due to extensive grading of the existing creek. This potential additional cost is accounted with the permitting contingency for in the OPCC and will be evaluated further during design. Additionally, once field survey is obtained for this project location, localized grading could also be implemented behind the homes on Blue Jay Drive to ensure 100-year LOS against property inundation.

OPCC: $5,116,000

BCR: 0.56

6.2.2 Alternative 2 (FMP ID 83001298)

The second alternative developed for Prairie Wind Boulevard allows for a 100-year LOS at the crossing over the tributary to the North Bosque River and removes all twelve structures from the 100-year storm event. This alternative is similar to alternative 1 in that it includes channel grading upstream of the crossing, realigning the existing channel from the crossing to the North Bosque River, and replacing the culverts. The channel grading and excavation is more intensive for this alternative, as it contains the 100-year flood event, and the culverts are larger, at (5) 10’x6’ RCB.

This alternative is shown visually in Exhibit 1-B in Appendix D. Additionally analysis and design constraints were considered for this alternative only. A detailed schematic and additional discussion regarding the Prairie Wind Boulevard Alternative 2 design evaluation is provided in Appendix E. There are no negative impacts resulting from this alternative, this is shown in Exhibit D-3.

OPCC: $11,030,000

BCR: 0.1

6.2.3 Alternative 3

The third alternative developed for Prairie Wind Boulevard allows for a 10-year LOS at the low point of the road crossing the tributary to the North Bosque River, removes all twelve structures from the 100-year storm event, and was originally conceptualized in the 2020 Master Drainage Plan.

This alternative differs from the other alternatives in that it addresses flooding at the low point of the road, rather than where the tributary crosses the road. It does this by constructing a swale behind the residential structures on Blue Jay Drive, installing (5) 6'x5' RCB culverts (and leaving the existing culverts at the tributary as-is), and constructing a channel from the new culverts to the North Bosque River. A small channel will connect the tributary to the new conveyance areas and allow low flows to travel along the existing tributary, eliminating potential permitting issues identified in the other alternatives.

This alternative is shown visually in Exhibit 1-C in Appendix D.

OPCC: $3,603,000

BCR: 1.1

6.3 Lingleville Road

Lingleville Road, or Farm to Market Road 8, is located upstream of Prairie Wind Boulevard. The existing crossing has (2) 5'x5' RCB culverts with no guardrail and provides a 2-year LOS. There is no associated structure flooding, but roadway overtopping is a known concern. This area is within TxDOT right-of-way.

6.3.1 Alternative 1

The first alternative allows for a 5-year LOS for the crossing and includes replacing the existing culverts with (2) 10'x6' RCB. This alternative originally caused a rise to due to added guardrail along the crossing and increased embankment. To mitigate these upstream WSEL rises, 1,400 cubic yards of upstream grading is also included. This alternative is shown in Exhibit 2-A in Appendix D.

OPCC: $1,587,000

BCR: 1.0

6.3.2 Alternative 2 (FMP ID 83001299)

The second alternative allows for a 100-year LOS for the crossing and involves replacing the existing culverts with (4) 10'x6' RCB. This alternative originally caused a rise to due to increased embankment. To mitigate upstream WSEL rises, 3,700 cubic yards of upstream grading is also included. This grading is more extensive than in alternative 1. This alternative is shown in Exhibit 2-B in Appendix D.

OPCC: $2,014,000

BCR: 1.1

6.4 County Road 256

County Road 256, or W Cedar Street, is located southwest of Stephenville, outside of the city center. However, future development is anticipated in this area, which makes it of interest for a proactive mitigation project. Therefore, BCRs are likely to increase over time as development occurs in this area. This area was identified as a hot spot in the screening assessment due to a flood hazard vulnerability of 5 and a 100-year flood depth of 3.3 feet. The current crossing over Town Creek of (3) 42” CMP culverts provides a less than 2-year LOS. There are four inundated structures near this crossing.

This project site offers several challenges for flood hazard mitigation projects. This location is just upstream of an existing stock pond, which contributes to higher tailwater at the crossing. Additionally, the existing crossing has no guardrail. With the addition of larger culverts, increased embankments and a guardrail is necessary, but it induces WSEL rises in the 100-year storm event that cannot be mitigated without extensive grading. While the alternatives below offer solutions involving channel grading, this would likely be a large stream restoration project that could have additional implementation hurdles. Therefore, this project site is not recommended as a site for an isolated culvert improvement project. If a larger road reconstruction is planned for this road, culvert improvements could be included in the larger project, potentially with upstream detention options to mitigate WSEL increases. Property owner waivers to allow slight WSEL increase, which will reduce the amount of required grading and therefore reduce costs and implementation hurdles, could also be obtained.

6.4.1 Alternative 1 (FMP ID 83001300)

The first alternative raises the road 1.5’ from the low point, constructs (7) 10’x9’ RCB, and has grading along the creek, both deepening and widening it, including through the existing stock pond. This allows for a 5-year LOS at the road crossing, removes 2 buildings from the 5-year flood extent, and removes 1 building from the 100-year flood extent. This alternative is shown in Exhibit 3-A in Appendix D.

OPCC: $4,145,000

BCR: 0.54

6.4.2 Alternative 2

The second alternative for CR 256 involves no road raising. Instead, the creek is graded along similar extents as alternative 1 but less extensively, and (7) 10’x7’ RCB are installed. This produces a 2-year LOS at the road crossing and removes 1 building from the 100-year flood extent. This alternative is shown in Exhibit 3-B in Appendix D.

OPCC: $3,688,000

BCR: 0.60

6.5 Morgan Mill Road

Morgan Mill Road, or US Highway 281, is in northeastern Stephenville and crosses over the Tributary to Dry Branch. This area was identified as a hot spot in the screening assessment due to 16 structures inundated in the 100-year storm event. This hot spot was confirmed in the detailed hydraulic model with a 2-year LOS at the existing crossing of (5) 6’x7’ RCB and 18 inundated structures around the crossing. These structures include a variety of residences and businesses. This project lies within TxDOT right-of-way.

6.5.1 Alternative 1 (FMP ID 83001301)

The first alternative for Morgan Mill Road involves grading around the road and replacing the existing culverts with (6) 12'x7' RCB. This allows for a 100-year LOS at the road and removes 13 structures from 100-year flood extents. This alternative is shown in Exhibit 4-A in Appendix D.

OPCC: $2,661,000

BCR: 1.8

6.5.2 Alternative 2

The second alternative for Morgan Mill Road includes channel grading from the crossing down to just before it joins with Dry Branch in addition to replacing the existing culverts with (6) 12'x7' RCB. This allows for a 100-year LOS and removes 14 structures from the flood extents and removes more downstream land from flood extents to make it available for future development. This alternative is shown in Exhibit 4-B in Appendix D.

OPCC: $3,513,000

BCR: 1.4

6.6 Long Street

Long Street is located near central Stephenville and crosses over the North Bosque River. The existing culverts of (4) 60" CMP provide a less than 2-year LOS. In the screening assessment, it was identified as having a high flood hazard vulnerability of 6 and a depth of 14.8 feet during the 100-year storm. This hot spot was confirmed in the detailed hydraulic model with a depth of 15.6 feet in the 100-year storm. Because of these overtopping concerns, alternatives were evaluated on how to best reduce risk.

6.6.1 Alternative 1 (FMP ID 83001302)

The first alternative for Long Street is to remove the existing road and culvert and install a bridge. This bridge has a 425' span, with several hundred feet of road elevation on either side to tie into the existing road system. To mitigate rises and decrease the length of the bridge span, the bridge opening is benched to the west. The proposed bridge has a freeboard of 2' above the 100-year WSEL. The alternative is shown in Exhibit 5-A in Appendix D.

OPCC: $8,993,000

BCR: 0.1

6.6.2 *Alternative 2*

The second alternative for Long Street is to remove the crossing altogether. This would require barricades and signage, as well as some grading in the channel around where the road would be removed. The road would only be removed between the closest driveways on either side of the river. The alternative is shown in Exhibit 5-B in Appendix D.

OPCC: $547,000

BCR: 0.9

6.6.3 *Alternative 3*

The third alternative for Long Street is to add additional or replace existing signage and barricades. These will alert drivers to the possibility of flooding, and in storm events, prevent access to the crossing. The alternative is shown in Exhibit 5-C in Appendix D.

OPCC: $345,000

BCR: 1.4

6.7 Project ranking and scoring

Each alternative was evaluated based on the BCR, placement in the hot spot analysis, interest from the city, and the final LOS to determine a final project ranking. Each metric was evaluated on a scale of 0 to 3 for each project.

The score for the BCR was determined based on a statistical analysis of the BCRs for all developed projects. The average (μ) was 0.92 and the standard deviation (σ) was 0.45. From this, $\mu - \sigma = 0.47$ and $\mu + \sigma = 1.37$. Using these values, the point distribution is shown in Table 6-1.

Table 6-1: Points for BCR.

Points	BCR
0	0 – 0.47
1	0.48 – 0.92
2	0.93 – 1.37
3	1.38+

The score for hot spot placements was determined based on the priority determined for each site at the end of the screening assessment. The point distribution is shown in Table 6-2.

Table 6-2: Points for Hot Spot Prioritization.

Points	Hot Spot Prioritization
0	Not Identified in Hot Spot Analysis
1	Low
2	Medium
3	High

The score for LOS was determined based on the alternative's final LOS. The point distribution is shown in Table 6-3.

Table 6-3: Points for LOS.

Points	LOS
0	N/A or <2-year
1	2-year
2	5 – 10-year
3	100-year

The final metric considered in ranking the projects was interest from the City of Stephenville. Based on discussion with the city, Prairie Wind Boulevard was given the highest number of points at 3, Long Street and Morgan Mill Road were given 2 points each, and all remaining projects were given 1 point.

To turn these scores into rankings, each metric was weighted. The weighing assigned to each scoring category is shown in Table 6-4. LOS and City interest were given slightly higher weights than BCR and hot spot prioritization. This was done to prioritize health and safety through the LOS and to give important to City knowledge of hazardous locations.

Table 6-4: Weighting for Scoring Categories.

Scoring Category	Weight
BCR	20%
Hot Spot Prioritization	20%
LOS	30%
City Interest	30%

The final scores and ranking for the top alternative at each project site are shown in Table 6-5. The recommended alternatives are shown bolded. The highest scoring project of all alternatives is the Prairie Wind Blvd Alternative 2, which provides a 100-year LOS by replacing culverts and creating an additional channel to the North Bosque River. Both Morgan Mill Road projects have an equal score, but FNI recommends Alternative 1 due the higher BCR with the same LOS and higher constructability, as Alternative 2 could face additional implementation issues due to the extensive grading of the creek. For Long Street, the top alternative is Alterative 1, which constructs a new bridge across the river. At Lingleville Road, the highest ranked alternative is Alternative 2, which has a 100-year LOS. For County Road 256, Alternative 1 is the higher ranked project.

Table 6-5: Project Ranking.

Project Name	BCR	BCR Score	Hot Spot Prioritization	Hot Spot Score	City Score	LOS	LOS Score	Total Score
Prairie Wind Blvd Alt 2 (FMP ID 83001298)	**0.1**	**0**	**Medium**	**2**	**3**	**100-year**	**3**	**2.4**
Prairie Wind Blvd Alt 3	1.1	2	Medium	2	3	10-year	2	2.3
Morgan Mill Rd Alt 1 (FMP ID 83001301)	**1.8**	**3**	**Low**	**1**	**2**	**100-year**	**3**	**2.3**
Morgan Mill Rd Alt 2	1.4	3	Low	1	2	100-year	3	2.3
Long St Alt 1 (FMP ID 83001302)	**0.1**	**0**	**High**	**3**	**2**	**100-year**	**3**	**2.1**
Prairie Wind Blvd Alt 1	0.56	1	Medium	2	3	10-year	2	2.1
Long St Alt 3	1.4	3	High	3	2	<2-year	0	1.8
Lingleville Rd Alt 2 (FMP ID 83001299)	**1.1**	**2**	**None**	**0**	**1**	**100-year**	**3**	**1.6**
County Road 256 Alt 1 (FMP ID 83001300)	**0.54**	**1**	**Medium**	**2**	**1**	**5-year**	**2**	**1.5**
Long St Alt 2	0.9	1	High	3	2	N/A	0	1.4
Lingleville Rd Alt 1	1	2	None	0	1	5-year	2	1.3
County Road 256 Alt 2	0.6	1	Medium	2	1	2-year	1	1.2

To obtain funding for further design and construction, all alternatives will be submitted to the Region 8 Flood Planning Group. This will allow them to be included in the 2023 Amended Regional Flood Plan, which opens opportunities for funding by the Texas Water Development Board.

7 Dam safety assessment

The Dam Safety Assessment studies ten high risk dams in the North Bosque River Watershed. All the dams were originally constructed by the Natural Resources Conservation Service (NRCS), then known as the Soil Conservation Service (SCS), between 1965 and 1970 as part of the Watershed Protection and Flood Prevention Act. This study presents a breach analysis, hazard classification, and conditions assessment for all the dams included in the project. Recommendations include developing an implementation plan to address the maintenance, repairs, and rehabilitation needs identified. Additionally, a hydraulic adequacy analysis of the high hazard dams is recommended to be conducted to identify structures that need more attention. The full analysis is available in the separate Dam Safety Assessment Report.

8 Conclusion

As part of the TWDB FIF study, FNI performed a screening assessment and dam safety assessment in Erath County and a detailed hydrologic and hydraulic analysis of the North

Bosque River in and around the City of Stephenville, Texas. From the screening assessment, 28 hot spots were identified as hazardous areas. The detailed H&H models have updated results compared to that of the effective FEMA modeling, allowing the City of Stephenville to have more updated floodplain mapping. It is also recommended the city and other stakeholders use these floodplain maps and models to evaluate and mitigate flood risk in the future. These floodplain maps show floodwater inundation width and depth. Development near or within the floodplains should be managed to minimize damage to infrastructure and public safety risks. Building inundation and roadway overtopping were also evaluated to inform the City about potential hazards.

After the modeling was developed, results were used to identify 12 capital project alternatives over 5 project sites, which were developed with exhibits, OPCCs, and BCRs. After ranking the projects, the top recommended project was Prairie Wind Boulevard Alternative 2 (FMP ID 83001298), followed by Morgan Mill Road Alternative 1 (FMP ID 83001301), Long Street Alternative 1 (FMP ID 83001302), Lingleville Road Alternative 2 (FMP ID 83001299), and then Country Road 256 Alternative 1 (FMP ID 83001300). Prairie Wind Boulevard Alternative 2 (FMP ID 83001298) was evaluated further, and schematic information and an additional technical memorandum is provided in Appendix E.

All projects were then shared for inclusion to the Regional Flood Plan to be eligible for future funding for implementation from the TWDB. From the Dam Safety Assessment, FNI recommends the next step be to create a plan for the dam safety program to develop the hydraulic adequacy analysis to refine the prioritization scheme to implement the necessary maintenance, repairs, and rehabilitation identified through this study. Potential funding sources include NCRS O&M grants, NRCS watershed rehabilitation program funding, TWWSCB Supplemental Funding, TWDB loans, and tax development. All 8 tasks in the TWDB's Category 1 grant agreement between the TWDB and the City of Stephenville were completed successfully.

9 Acknowledgements

We would like to thank the City of Stephenville, Erath County, the City of Dublin, and the Cross Timbers Soil and Water Conservation District for providing data and input throughout the development and completion of this study.

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