# Delwau Lane
# Low Water Crossing Upgrade
# Feasibility Study

**City of Austin**
**Watershed Protection Department**
**Watershed Engineering Division**

***July 2018***

# TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES



## LIST OF APPENDICES

## EXECUTIVE SUMMARY

The Delwau Lane crossing of Boggy Creek was identified as the fourth highest ranked low water crossing improvement priority as part of the FY2018 master planning efforts for the Creek Flood Risk Reduction (CFRR) mission due to the expected depth and frequency of overtopping, as well as being the sole access point to the properties in the vicinity of the crossing. Additionally, in April 2018 the crossing was identified by the City's Public Work's Department (PWD) in a memo to the Mayor and City Council as one of five bridges in the City which requires major rehabilitation or replacement after PWD completed an investigation of the structural state of bridges within the City. The purpose of this report is to document the existing flood risk at this crossing and to identify potential options to both reduce the dangers of flood risk associated with the current crossing and investigate upgrade opportunities to the crossing.

The roadway currently consists of two-lanes, with 30-foot wide asphalt pavement and a 50-ft right-of-way and is functionally classified as a local city street. The Austin Transportation Department (ATD) performed a 24-hour bi-directional traffic count on March 5, 2018 resulting in a total traffic volume of 306 trips. This crossing is located in the Boggy Creek watershed, which is considered an urban watershed. The Delwau Lane Bridge currently conveys low flows through the structure, but does not have capacity to convey even the pre-Atlas 14 2-year event. In addition to the overtopping concerns from Boggy Creek flows, the crossing is also susceptible to overtopping from backwater effects of the Colorado River. According to the City of Austin regulatory floodplain model for Boggy Creek, the crossing experiences roadway overtopping of 1.52 feet during the 2-year flood and 8.49 feet during the 100-year flood (8.60 feet from the Colorado River backwater on the site). See **Figure 1** for a project location map.

The following alternatives were considered for this feasibility study:

1. **Alternative 1: Improved Flood Risk Notification/Emergency Access Improvements**– Minimal improvements to increase awareness of flood risk and provide better access to first responders in emergency operations. These goals will be accomplished by increase signage and improvement of an access path.

2. **Alternative 2: DCM Complaint Bridge with Improvements to Shelton Road** – Replace existing bridge with a new bridge that complies with DCM requirements for overtopping depths and elevates portions of Shelton Road out of the floodplain which connect Delwau Lane to US 183.

3. **Alternative 3: Providing Access from the North to Delwau Lane** – Acquire Right-of-way in order to construct a new road which provides access from the north which does not traverse the floodplain and close crossing upon road completion.

4. **Alternative 4: Maintain Existing Bridge** – Address the crossing's structural issues by repairing or replacing it with an in kind or similar bridge. These alternative will not seek to reduce the flood risk as its primary goal but offer a repair/replacement option for PWD.

5. **Alternative 5: Buyout of Properties and Closing Bridge–** Explores acquiring properties that rely on crossing for access and closing the crossing to the remove flood risk associated with the crossing

This report documents the findings of these five alternatives and makes the following recommendations in order to reduce the current flood risks associated with the Delwau Lane low water crossing: implement Alternative 1 for a near term solution and implement Alternative 5 for the long term risk reduction solution.

Alternative 5 provides complete removal of the flood risk associated with the crossing. Alternative 5 is the most cost effective solution that addresses the current overtopping risks associated with the existing Delwau Lane Bridge to DCM standards. This option meets the goals of the Creek Flood Hazard Mitigation group, as it decreases the hazard at the creek crossing and does not increase flood elevations elsewhere. Alternative 5 is also the most cost effective option, costing approximately $4.9 million.

It is recommended that prior selecting this alternative, Real Estate Services should be engaged to perform a more accurate and in depth market appraisal of the area to confirm buyout cost estimates. If Alternative 5 is pursued, discussions with WPD management about using this approach to remove low water crossing risks with a buyout should be explored as we will need to explore both the idea of purchasing homes which conform to current floodplain regulations as well as purchasing commercial properties. This alternative will also result in likely relocation or closure of the urban farm Urban Roots which provides social and community benefits which are not easily quantified. With all of these considerations, the preliminary estimated cost savings of Alternative 5 are significant.

# 1.0 INTRODUCTION AND STATEMENT OF NEED

This feasibility study is intended to build upon and further explore potential flood risk reduction projects previously investigated by the Creek Flood Risk Reduction (CFRR) as documented in the Delwau Lane Low Water Crossing Upgrade Feasibility Analysis completed in September of 2012 as well as explore other alternatives not investigated during the 2012 report. The conclusion of the 2012 Feasibility Analysis stated that a DCM compliant bridge may be feasible but it would require extensive coordination with other WPD sections and City departments, and potentially cost more than purchasing the properties that the bridge currently serves. The 2012 report however did not investigate other risk reduction alternatives or provide cost estimates for the DCM compliant crossing upgrade. The current feasibility provides a range of options to addressing the flood risk currently posed by the existing crossing and estimate the cost and benefits of the investigated alternatives.

The Delwau Lane crossing of Boggy Creek inundates during a sub 2-year flood event. The Watershed Protection Department (WPD) of the City of Austin (COA or City) has this low water crossing on a list of routine emergency closures, and it currently ranks number 4 on the CFRR low water crossing priorities list. The COA Flood Early Warning System (FEWS) group indicates that the crossing has been closed X times since July 2018 but may have been overtopped and not closed in some rain events due to lack of resources. Of these documented over topping events, the 2015 Memorial Day Flood caused significant structural damage to the bridge as well as significant erosion along Boggy Creek upstream of the crossing as a result of the flooding and required extensive emergency repairs by Public Works Department (PWD) to the crossing. Similar damages and repairs to the bridge also occurred in 1998 and November 2001.

In addition to the flood safety concerns associated with the current overtopping situation of Delwau Lane, the bridge has document safety risks associated with the current structural state of the bridge. In April 2018 Delwau Lane was identified by

the PWD in a memo to the Mayor and City Council as one of five bridges in the City which requires major rehabilitation or replacement after PWD completed an investigation of the state of bridges within the City. The memo highlighted that "Serious repairs were required after four major flooding events over the last 20 years. The bridge was closed for multiple days on several occasions at great inconvenience to the residents. This 50 foot bridges is a bottleneck in the South Boggy Creek which has a 500' flood plain at this point in the channel… These flood events have completely damaged the abutments on several occasions requiring major emergency repairs. The appropriate bridge span should be about 3 times the current clear span to minimize the potential for future flood damage." CFRR staff met with PWD Street and Bridge staff to discuss the memo and PWD's current plans for addressing the Delwau Lane Bridge. To date, PWD has neither started the exploration process to upgrade the existing deficient bridge nor identified a funding mechanism to design and construct future bridge improvements.

Finally, the reach of Boggy Creek that Delwau Lane traverses has experienced significant erosion issues. Upstream of the crossing to the US 183 bridges has seen significant expansion of the channel within the past decade. WPD has been actively addressing and monitoring erosion in the area within this timeframe. After the May 2015 storm, the WPD's Stream Bank Restoration group placed bend-way weirs or flow training measures on the channel's south overbank in order to stabilize the channel and prevent further channel erosion along the creek throughout the reach. While erosion upstream of the crossing is a significant issue, downstream of Delwau Lane Boggy Creek's channel is relatively stable without visible, active erosion. It appears as though the current crossing acts as grade break that controls erosion downstream of the crossing. Alternatives should attempt to maintain the current stabilizing influence of the Delwau Lane crossing.

The overall objectives of this feasibility study is to analyze potential structural and non-structural improvements at Delwau Lane that will reduce flood hazard, increase public safety, and reduce or eliminate the need for City staff to mobilize at the site

during rain events. Increasing the conveyance capacity of the existing bridge structure through crossing improvements, installing and updating automated warning and monitoring systems around the crossing, providing alternative access options and closing the bridge, and investigating the purchase of properties serviced by the bridge will meet the project goals. Alternatives considered in this feasibility report include replacement bridges, alternative access, increase warning signs, buy outs and road closure.

## 2.0 EXISTING CONDITIONS

The low water crossing at Delwau lane is greatly undersized. It currently has bridge structure, with a span that is approximately 40 feet wide and elevated 16 feet above the creek bottom. According to the latest hydraulic models, it experiences roadway overtopping by approximately 1.52 feet during a 2-year flood event and by approximately 8.49 feet from Boggy Creek and 8.60 feet from the Colorado River during a 100-year flood event when evaluating it based on fully developed conditions. The existing bridge system has a capacity of 5750 cubic feet per second (cfs) before overtopping. Current modeling show approximately 23,000 cfs of flow for the fully developed conditions 100-year flood in Boggy Creek at the Delwau Lane crossing.

### 2.1 Location, Jurisdiction, and Roadway

The Delwau Lane crossing of Boggy Creek is located in the very bottom portion of the watershed on the main stem of Boggy Creek. Approximately 13.5 square miles of the total 13.8 square miles of Boggy Creek's contributing drainage area contributes to the flow at the Delwau Lane crossing. The Boggy Creek watershed is considered an urban watershed and consists of a mix of both residential and commercial development. Due to the amount of development currently present in the watershed, City of Austin regulatory models consider the existing development to be the fully developed condition for modeling purposes. **Figure 1** demarcates the location of the crossing in reference to the watershed.

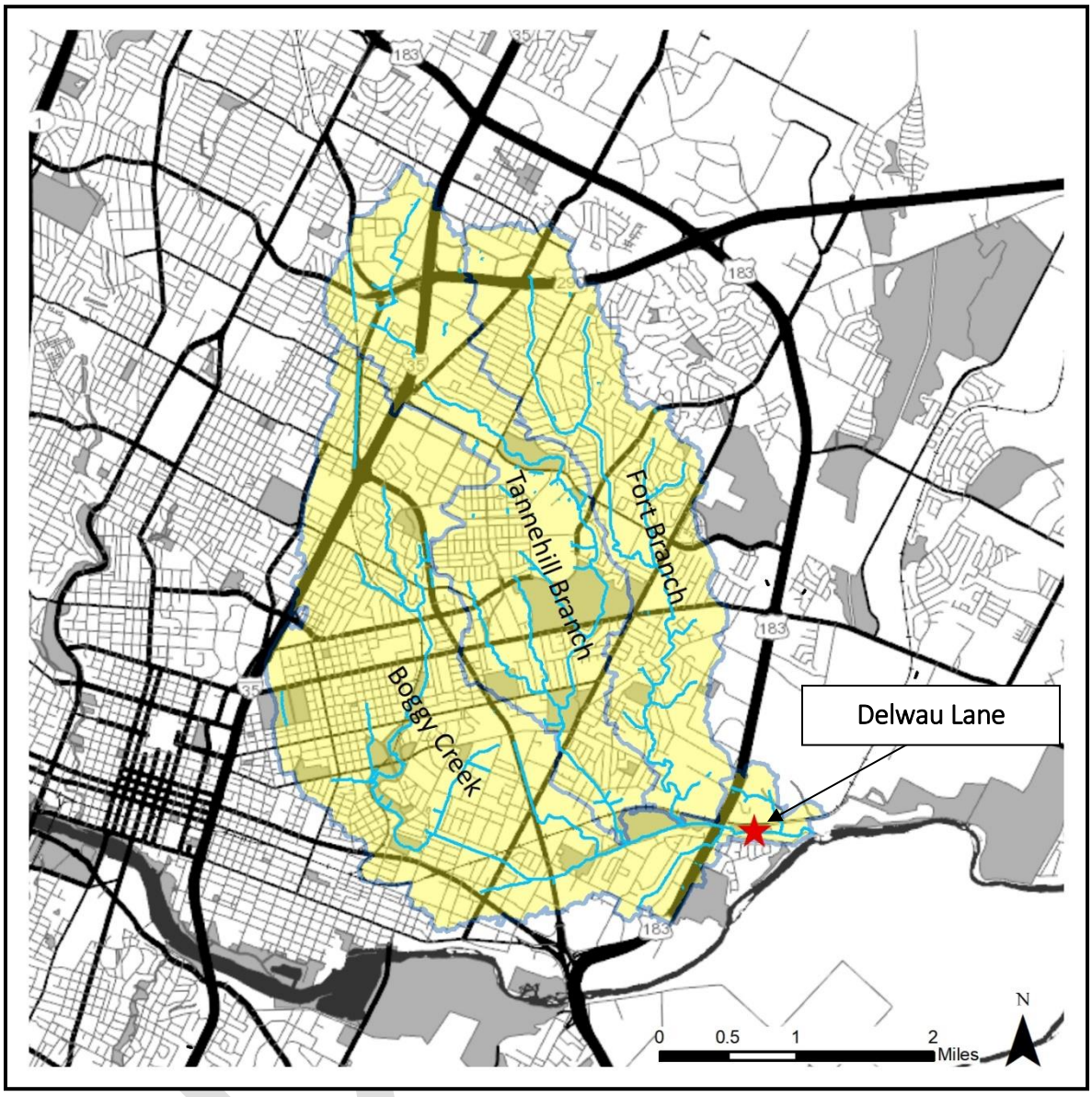


**Figure 1:** Delwau Lane Location Map

Delwau Lane was originally constructed in 1952 and has been in the City of Austin Full Purpose Jurisdiction since it was annexed in 1976. The existing roadway serves as the only access to five residences and three commercial properties. The existing driving surface of Delwau Lane consists of 2 lanes of concrete pavement. There are no existing sidewalks or bike lanes in the right-of-way at or approaching the current crossing. Currently on the north and south bound approaches of the bridge WPD has installed flashing lights which engage during flooding events. FEWS also has plans

to install a camera monitoring system at the crossing to better observe conditions at the crossing during flooding events.

In 2018, the Austin Transportation Department (ATD) performed a traffic count survey of Delwau and determined that the 24 hour bi-directional traffic volume of the bridge was 306 trips.

## 2.2 Hydrology and Hydraulics

As part of the feasibility study, the City of Austin's regulatory floodplain study of Boggy Creek was utilized. At the time of this feasibility report, the City of Austin's regulatory model was the 2012/2013 study completed by Atkins, Crespo and CPE. They performed a hydrologic analysis of Boggy Creek watershed, including Boggy Creek, Fort Branch and Tannehill watersheds, used the Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) version 3.5. The Boggy Creek watershed HEC-HMS model was developed utilizing the Soil Conservation Service (SCS) method 24-hour duration storm with Type III distribution. The precipitation is based on the USGS Depth-Duration-Frequency Tables for Travis County developed by Dr. William Asquith in 1998. Weighted curve numbers were based on hydrologic soil type using a base soil curve number representative of open spaces in fully developed urban areas in fair condition as documented in the Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55). Upland zone impervious cover was used in combination with land use to generate weighted impervious cover values. The impervious cover values in the model are considered to be fully developed impervious cover values. The HEC-HMS modeling is included in this report's electronic attachments.

In conjunction with the HEC-HMS model, the regulatory floodplain study of Boggy Creek was developed as a steady state hydraulic model using the Army Corps of Engineers Hydrologic Engineering Centers River Analysis System (HEC-RAS) version 4.1.0. Cross-sections, slopes, and existing crossing structure geometry was generated using the City's 2003 Lidar topography (and supplementing it with survey information in the vicinity of the Street low water crossing). Manning's "n" values were determined by COA aerial photography and field observations. The HEC-RAS model is also included in this report's electronic attachments.

The Delwau Lane crossing currently has bridge structure, with a span that is approximately 40 feet wide and elevated 16 feet above the creek bottom. **Figure 2** presents a recent photograph of the existing bridge at the upstream face of the crossing. As the bridge's location in the watershed is so close to Boggy Creek's confluence with the Colorado River, the bridge is also susceptible to overtopping from the backwaters from the Colorado River in addition to floodwaters from Boggy Creek. According to the latest hydraulic models, it experiences roadway overtopping during storm events as low as the 2-year recurrence interval based on fully developed conditions. The current elevation of the roadway crossing is 423.69 feet above mean sea level (msl), and the depth of inundation during the fully developed 100-year flood event from Boggy Creek is approximately 8.49 feet and 8.60 feet from the Colorado River. **Table 1** presents the flow and inundation depths of the roadway for floods from Boggy Creek with the 2-year through the 500-year recurrence intervals as well as the backwater inundation depths from the Colorado River, and **Figure 3** presents the HEC-RAS model cross-section showing the water surface elevations

**Figure 2: Existing Bridge at Delwau Lane Crossing (looking downstream)**

**Table 1: Current Conditions Delwau Inundation Depths**

| Flood Recurrence Interval | Boggy Creek Flow | Inundation Depth (Boggy/Colorado River) |
|---|---|---|
| (Years) | (CFS) | (Feet) |
| 500 | 29925 | 10.29/na |
| 100 | 23052 | 8.49/8.60 |
| 25 | 16975 | 6.86/0.63 |
| 10 | 12966 | 5.61/0.00 |
| 2 | 6436 | 1.52/0.00 |

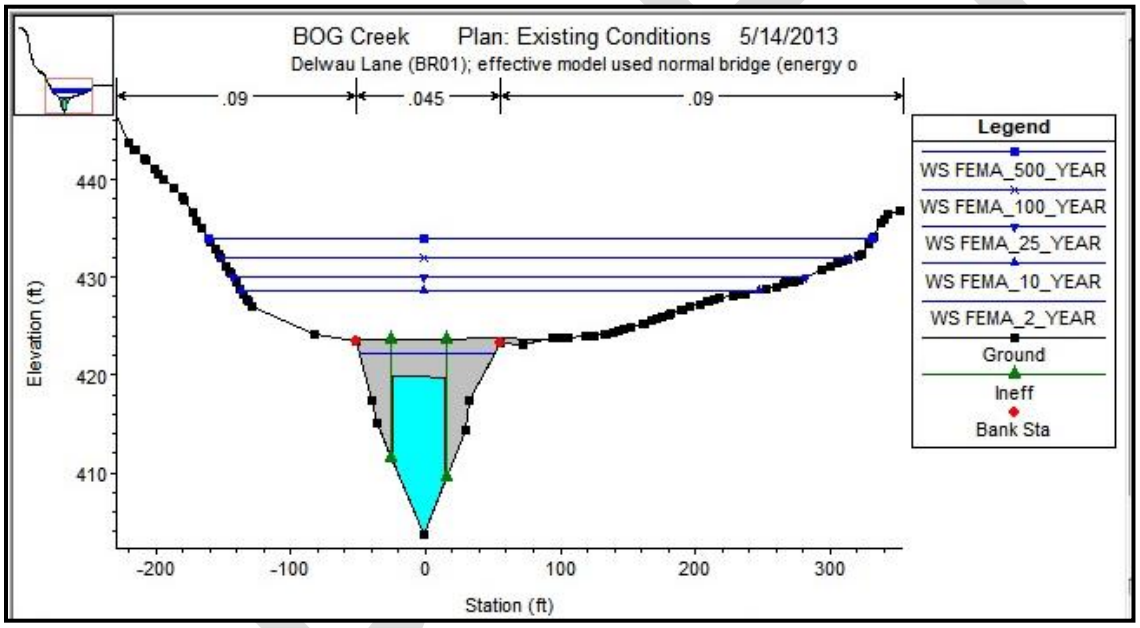


**Figure 3: Upstream RAS Cross-Section View of Delwau**

## 2.2.1 Revised Effective Model

The regulatory model was reviewed and some corrections are proposed to the existing modeling. These changes evolve around two main issues. The first stems from the existing bridge having a rail along the up and down stream faces of the current Delwau Lane bridge

configuration. A field inspection of the crossing revealed the presence of the railing and the railing was estimated to be 2 feet higher than the road deck. As a result a two foot rail was added into the regulatory model on the Delwau Lane crossing. The introduction of the railing increased the two year overtopping of the road deck by 0.5 feet and had slight impacts to the other considered design storm events.

The second issue stems from the erosion that has occurred in the reach of creek between US Highway 183 and Delwau Lane since the completion of the regulatory model. The corrections made to the regulatory model include updates to the cross sections between US Highway 183 and Delwau Lane in order to account for the increased conveyance capacity of the channel through the noted reach. Cross sections in this reach were updated with the latest 2017 LiDAR. Other cross section were compared to the 2017 LiDAR both upstream of US 183 and downstream of Delwau Lane and were found to be similar. As a result no other cross sections were updated with the new terrain.

The revised effective hydraulic modeling can be found in the attached HEC-RAS modeling in the RevisedEx_Delwau plan.

## 2.3 Accessibility

To reach to the Delwau Lane crossing, currently only Shelton Road provides access. However, large portions of Shelton Road are also inundated during by both the 25-year and 100-year floodplain. In order to reach the Delwau Lane crossing during a 25-year flooding event, one would have to traverse over 1790 feet of floodwaters on Shelton Road with depths up to 3 feet. During a 100-year event the distance is over 1800 feet with depths of up to 5 feet. **Figure 4** below shows the travel path along Shelton Road to Delwau Lane with the associated road profile and water surface elevation profiles for the 25-year and 100-year flooding events.

Currently Delwau Lane is the only access that serves five residential properties and three commercial properties. The three commercial properties are an urban farm (Urban Roots), an abandoned gravel mine, and a race track facility. Any alternatives that are considered will be required to maintain access to these properties through the duration of the project. This would

mean that is the current bridge were to be replaced, the new bridge would have to be placed at different location or a temporary construction bridge would have to be built if the current bridge alignment was preserved.

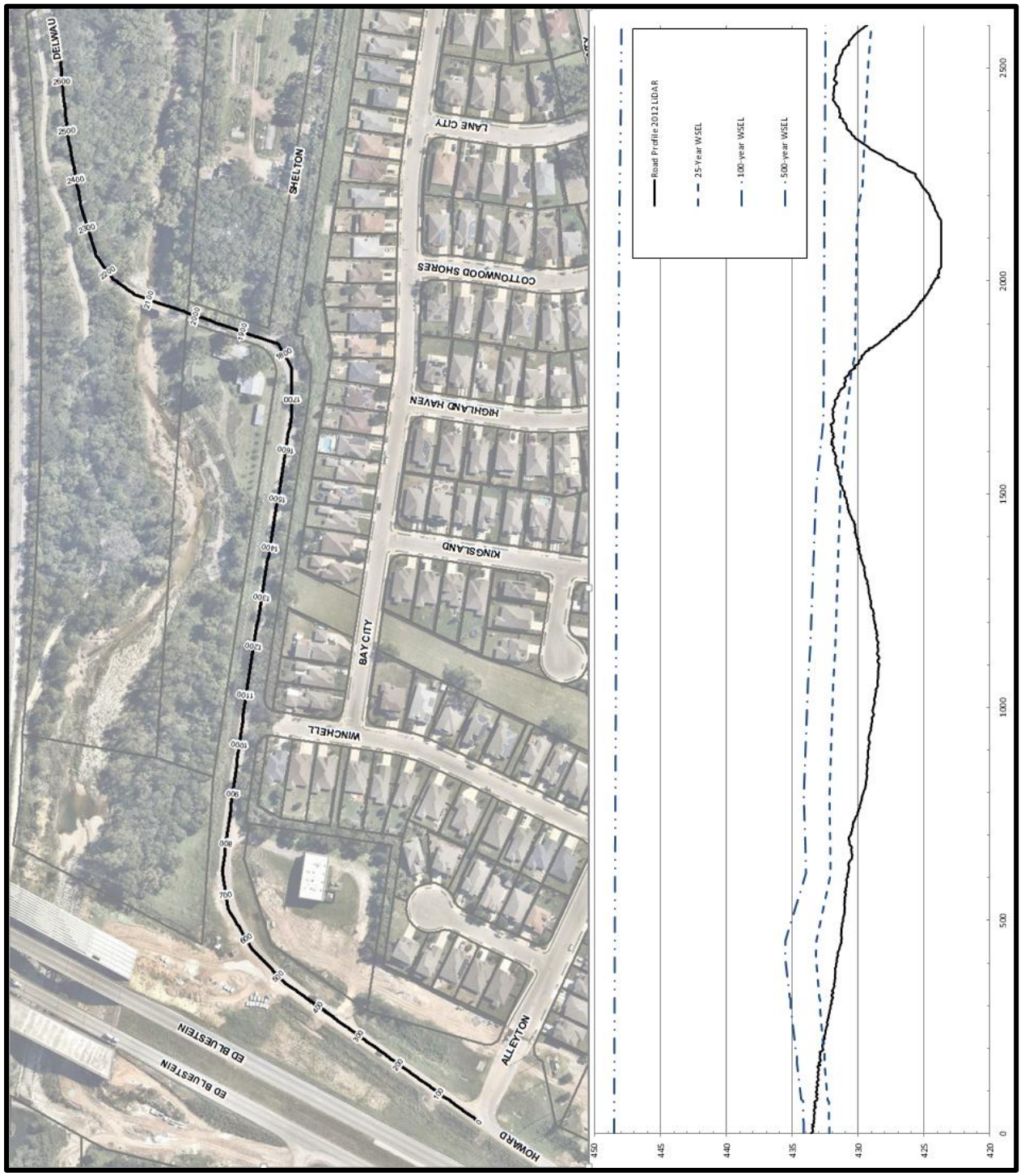


**Figure 4:** Shelton Road & Delwau Lane Profile

## 2.4 Existing Utilities

The existing utility locations were identified using the existing available data on the City Geographic Information System (GIS) and TCEQ's Water District Map Viewer. The design consultant involved in any future phases will be responsible for confirming all existing utilities. The following is a summary of the findings.

Wastewater Main (AWU) – There are no COA wastewater mains located within the project limits.

Water Main (AWU) – There is currently a COA water main attached to the bridge. It would likely be required to be relocated if the current bridge is changed.

Electric (AE)– There are overhead electric lines on utility poles on the north side of Shelton Road and utility poles parallel to the west face of the Delwau Lane bridge.

Telecommunications (varies) – From an inspection of the area it appears that most of the telecommunication utilities are attached to the utility poles, but this should be confirmed during any further PER.

Gas – there is currently a gas line attached to the bridge. It would likely require relocation if the current bridge is changed.

During future phases of the project, it will be necessary to more specifically locate and identify the existing utilities in the area. Currently, the identifiable utility conflicts include the both the waterline and gas line attached to the current bridge structure. Depending on the chosen alternative for this project and the depth and layout of the existing utilities, they may need to be relocated. The poles supporting the overhead electric lines may need to be moved or supported if a structural alternative is implemented. The overhead lines may also pose a clearance issue for larger construction equipment. Close coordination with all utilities in the area will be necessary as the project moves forward.

## 3.0 ANALYSIS AND ALTERNATIVES

The City's Drainage Criteria Manual requires creek crossings to fully convey the 25-year flood with no inundation of the roadway and to convey the 100-year flood with one foot/6 inches or less of roadway inundation. The existing low water crossing at Delwau Lane does not meet the City drainage criteria for creek crossings. If the overtopping goals can't be met, flood safety should be improved either through maximum possible reduction of the overtopping risk or increase awareness of the flood risk to the crossing users. No adverse impacts are allowed.

This section discusses alternatives that will reduce the flood hazards and risks present at the current Delwau Lane low water crossing. Each alternative has a different goal, ranging from meeting the City's DCM criteria for new crossings to providing a more efficient monitoring and warning system at the site. All structural alternatives were analyzed in HEC-RAS 5.0.5 using runoff generated from COA effective hydrologic model for the 2-year through 500-year floods.

Various roadway elevations and hydraulic conveyance systems were explored for each structural goal. The improvements presented for each alternative are the most feasible options explored for each particular goal.

As the Delwau Lane crossing currently serves as the only access point to properties on the north bank of Boggy Creek, the Structural alternatives include consideration for a realignment of the current crossing in order to provide access throughout the entire construction of the project. All alternatives should also attempt to incorporate erosion control measures into the design as the immediate area upstream of the crossing has pervasive and active erosion issues. At a minimum the considered alternatives should not worsen the existing erosion issues. Further exploration of erosion control measures can be designed and considered upon alternative selection.

Cost for addressing the erosion concerns are not considered in the alternative cost estimates.

## 3.1 Alternative 1 – Improved Flood Risk Notification/ Emergency Access Improvements

The goal of this alternative is achieve a higher level of communication of the flood risk associated with the crossing to current road users and provide improved access to the crossing for emergency responders in flood related emergency management activity by leveraging existing easements in the area without making structural improvements to the bridge.

### *3.1.1 Improved Flood Risk Signage*

While there are currently flashing light signs on both the North and South sides of the Delwau Lane crossing as displayed in **Figure 5**, a street user approaching the Delwau Lane crossing from the south would have to travel 1600 feet along portions of Howard and Shelton Roads which are inundated by both the 25-year and 100-year floodplains before reaching the current flashing light on the south side of the crossing. After reaching the flashing light the street user then travels 200 feet to reach the crossing. Additionally, approaching the crossing from the north, a street user would have to travel 1000 feet along portions of Delwau Lane which are inundated by both the 25-year and 100-year floodplains. The recommendation of this alternative is to alert street users that the road is subject to flooding before they access the portions of the right of way subjected to flooding in the 100-year event.

After preliminary discussions with FEWS staff, the following information and guidelines were considered in improving the flood risk notification and signage along Howard Road, Shelton Road and Delwau Lane:

- FEWS has plans to install a camera at the crossing which provides real time snap shots of the bridge conditions on www.atxfloods.com.

- The installation of additional flashing lights should be considered judiciously as the existing network that controls the flashing lights is run on an outdated system that has a limited capacity for new installations.


**Figure 5: Existing Flashing Light Location Map**

With these considerations in mind, the recommended signage improvement is to keep the existing flashing lights in place and add two additional non-flashing light warning signs stating that the road is subject to flooding, near the intersection of the roads and the regulatory 100-year floodplain. In addition to the additional warning signs, also adding a custom sign to find out more information and real time road way closure information at atxfloods.com is recommended. **Figure 6** below has a general location for the proposed signs.

The installation of these additional warning signs would be relatively inexpensive and fast. The signs also could be completed without engaging a PER and would not have extensive permitting requirements. A generous cost estimate would be $10,000 per each additional installed warning sign. After installation, there would be little to no additional maintenance needed for the additional signs. It is recommended that regardless of the alternative selected to investigate further, that the placement of the warning signs should be pursued and completed.

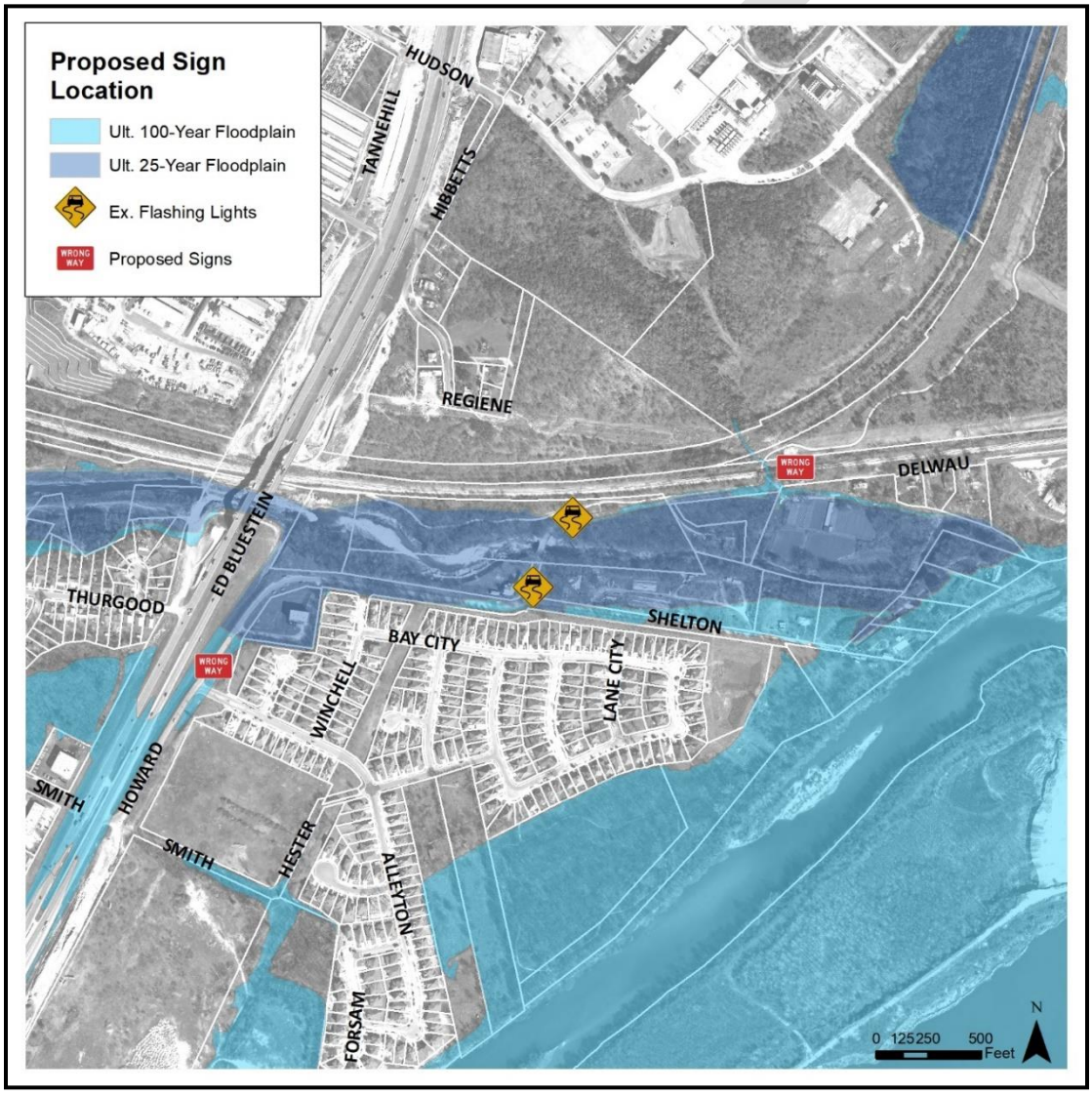


**Figure 6: Proposed Warning Sign Location Map**

*3.1.2 Improved Emergency Access to Shelton Road*

In addition to proposed signage improvements, emergency access to the eastern portions of Shelton Road could be provided by improving a maintenance drive through an existing city maintained pond facility. The subdivision which is adjacent to and the south of Sheldon Road, known as the Knollwood on the Colorado Section 1 (COA case # C8-2007-0135.1B), was constructed and built out within the last 10 years. During the construction of the subdivision, the site was elevated so the homes and streets within the subdivision are located out of the current 100-year floodplain. Per land development code requirements, the subdivision developer designed and constructed a storm water pond to treat and detain runoff from the developed subdivision. The storm water pond is located near a cult de sac at the end of Bay City Bend and connected to ROW by a 12' wide maintenance road located in Drainage Easement Lot. **Figure 7** below shows the location of the pond and the noted access easement.

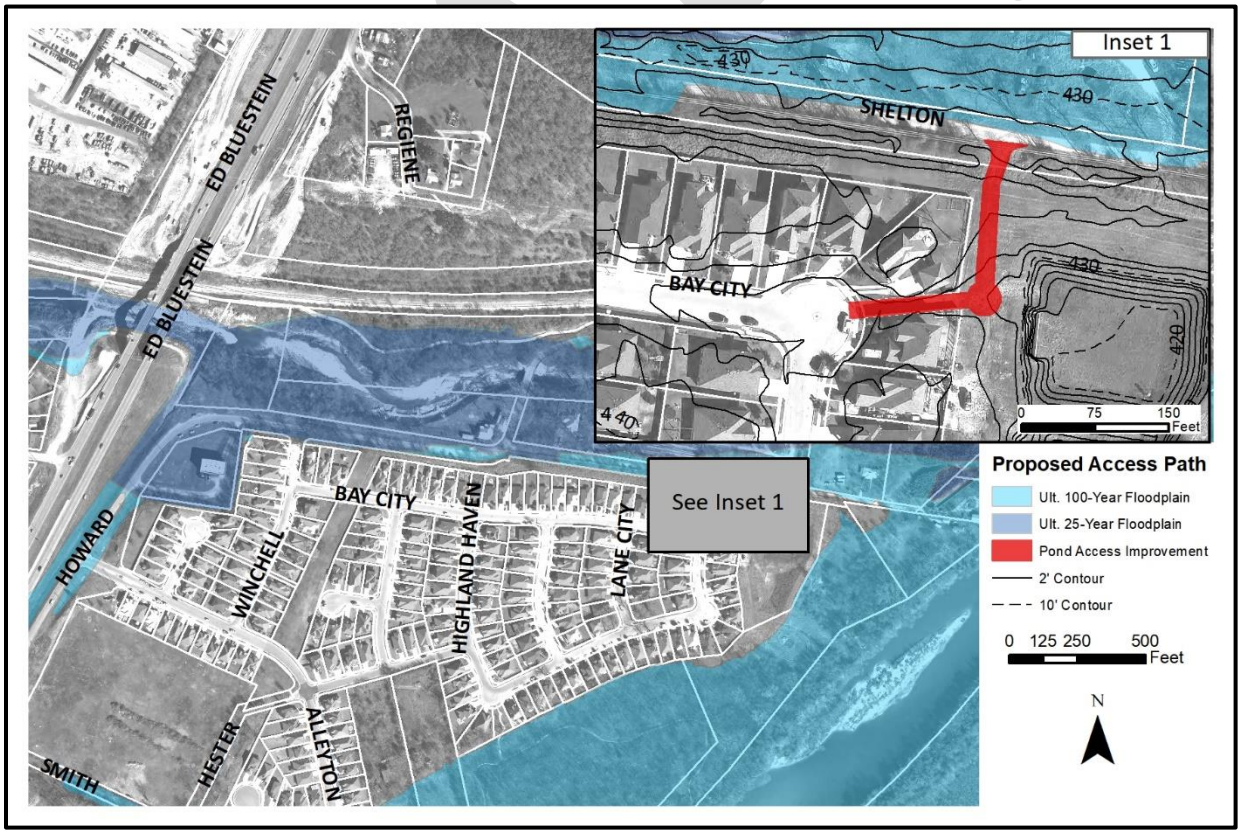


**Figure 7: Proposed Pond Access Path**

The alternative recommendation is to use the existing pond access road to improve it to a concrete paved access road and extent to Shelton Road as seen in **Figure 7**. The

widest possible path does not meet AFD access standards but would provide an additional improved access path to higher ground for residents and emergency responders along Sheldon Road that would be as wide as standard 12' road lane . It would also minimize distance need to travel through deep flood waters to get to the Delwau Lane crossing. Current access to Delwau Lane crossing from Howard Road requires approximately 1,600 feet of travel through the 25-year floodplain to reach Delwau Lane, whereas from the proposed access path it takes 600 feet of travel mostly through the 100-year floodplain to reach Delwau. Also the path would provide better access to the properties east of the proposed access road in the event of a flood emergency.

Assuming the maintenance road is upgraded to an improved concrete drive, it is estimated to cost $250,000 to complete. Cost estimate information can be found the attachments. This improved access road should be considered as an interim solution if no bridge improvement option is selected.

## 3.2 Alternative 2 – DCM Complaint Bridge with Improvements to Shelton Road

The goal of this alternative is to provide a bridge that will replace the existing Delwau Lane crossing of Boggy Creek which conforms to the City of Austin's Drainage Criteria Manual (DCM). Currently the DCM requires passing in the 25-year events and minimizing the overtopping in a 100-year over event to 0.5 feet. Also as PER, design and construction will most likely occur after the adoption of Atlas 14, the current effective 500-year floodplain should also be investigated to see how levels of service provided by the alternative will be effected prior to the adoption of Atlas 14 revised floodplains.

This alternative will also address the access to the crossing along Shelton Lane. As previously discussed, in order to gain access to the Delwau Lane crossing, one must also travel along Shelton Road which is inundated during by both the 25-year and 100-year floodplain. In order to reach the Delwau Lane crossing during a 25-year flooding event, one would have to traverse over 1800 feet of floodwaters on Shelton Road with depths up to 3 feet. During a 100-year event the distance is over 1800 feet with depths

of up to 5 feet. It is only practical to improve the bridge if the road leading to the bridge is also improved to the same level of flood protection as the bridge. Improvements for this alternative include constructing a new bridge and upgrading Shelton Road from Winchell Lane to the proposed new Delwau Lane Bridge.

*3.2.1 Proposed Delwau Lane Bridge Improvements*

A few configurations and bridge span options were investigated for the proposed alternatives. Ultimately a three span bridge which raises the top of the road to the elevation of 436.00' MSL and has a low cord of 430.13' MSL offer the best solution for the meeting DCM requirements, achieving no adverse impacts and helping address potential erosion issues by moving bridge elements out of the low flow areas of the channel. The proposed bridge's spans would be two 135' spans and a 70' span. The bridge would utilize the TxDOT standards for a 40' Roadway using Type TX62 bridge girders. **Figure 8** below has HEC-RAS bridge cross section image for reference.

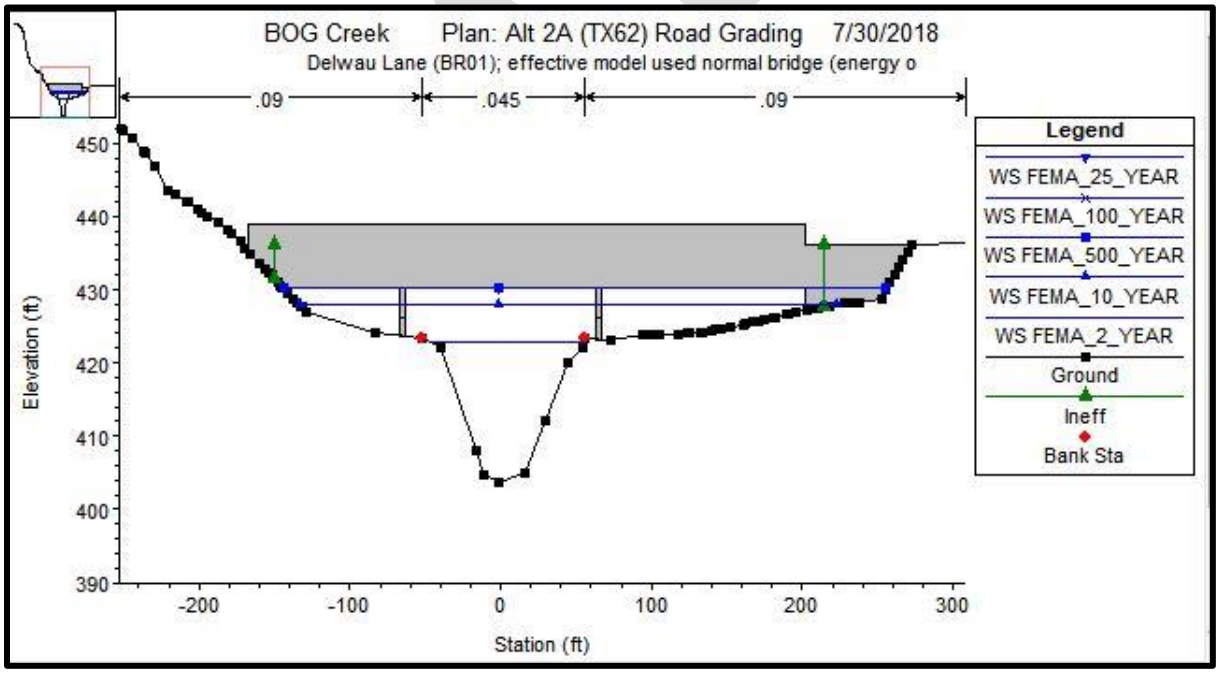


**Figure 8: Alternative 2 HEC-RAS Bridge Cross Section**

*3.2.2 Shelton Road Improvements*

In order to elevate the current ROW leading to the Delwau Lane Bridge above the current floodplain and tie in to the proposed bridge elevation of 436.00 MSL large portions of Shelton and Howard Roads would have to be improved and placed on fill

in order to gain the desired elevation. Some of length of the required improvement could be shorten if the existing ROW of Winchell Lane was connected to Shelton Road. **Figure 9** below shows the proposed ROW improvements as well as the proposed bridge alignment. Initially it was hypothesized that if Shelton Road was improved in this manner, Howard Road could be decommission and all traffic could be routed to Shelton Road via Winchell Lane. After discussions with the Austin Transportation Department (ATD) it is recommended to provide the improved access to Shelton Road from Winchell Lane and continue providing access via Howard Road. ATD suggested that maintaining current access would be a more favorable outcome for the neighborhood instead of increasing traffic in the neighborhood. While access to Howard Road is maintained, it will not be improved or elevated with this alternative.

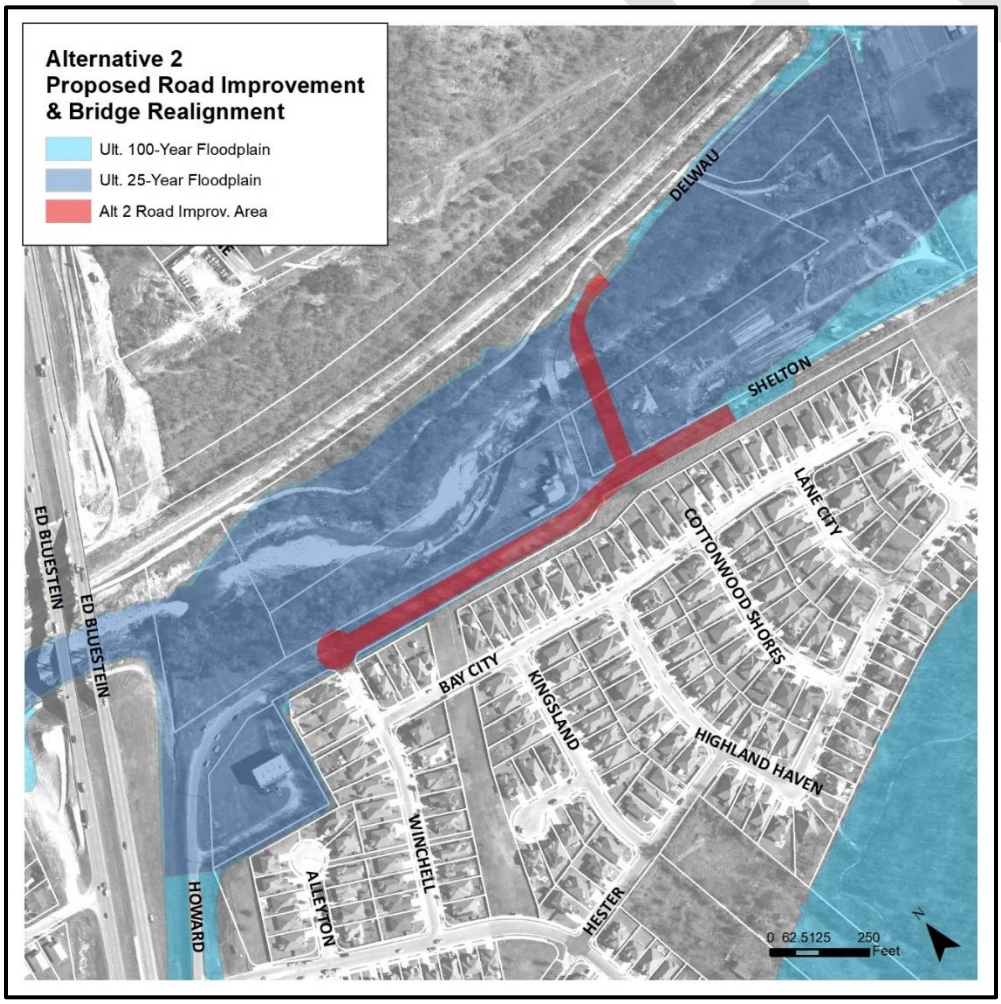


**Figure 9: Alternative 2 Proposed Road Improvements & Bridge Realignment**

*3.2.3 Proposed Bridge Realignment*

As the current Delwau Lane Bridge provides the only point of access to properties and buildings on the north side of Boggy Creek along Delwau Lane, access must be provided throughout the entire construction phase of any selected structural option. This would mean either constructing a temporary bridge if the current road alignment is maintained or selecting a new alignment in order to keep the existing bridge open until the new bridge is complete. As a temporary bridge would likely be very expensive and extend construction timelines, a new alignment is preferable. **Figure 9** above has the proposed realignment considered with this alternative. This realignment will require the purchase of ROW in order to construct the proposed alternative.

*3.2.4 Alternative Overtopping Depth Reductions and Adverse Impacts*

Alternative 2 will require the large amounts of fill in the floodplain in order to elevate Shelton Road out of the floodplain. Using an average grading section multiplied over the length of the improved length of Shelton Road it is estimated that approximately 18 acre-feet of fill will be added to the 100-year floodplain. Currently, the Floodplain Office views the unmitigated loss of floodplain storage volume as an adverse hydrologic impact. However in cases where it can be shown that the fill does not cause adverse impacts it may be allowed. Routing reaches within the regulatory hydrologic models employ Modified Puls Routing which utilizes hydraulic models to determine the flow attenuation provided by the available storage in a reach. When the HMS model routing reaches are modified to account for the new bridge and proposed fill, the results show that the alternative does not result in increases to peak flows calculated by the model. Thus the inference can be made that the fill can be place without mitigation as it does not increase flows or cause an adverse flooding impact.

Water surface elevations were also compared to between the alternative 2 model and the revised effective model to determine if any increases in base flood elevations (BFEs) occur. Increases in the range of 0.01 to 0.07' were noted in the comparisons of the models in the reach between US 183 and the crossing during the 25-year and 100-year events. While the increase in BFEs occur, they are minimal enough to be mitigated for with refined modeling performed in a PER and construction plan phase of the project.

Tentatively, the proposed bridge will both comply with current DCM over reductions in overtopping during the 2, 10, 25, 100 and 500-year water surface profiles. **Table 2** documents the overtopping depth reductions. As shown, the proposed alternative will also convey the current 500-year floodplain without overtopping, making the alternative feasible from a DCM compliance stand point after the adoption of the Atlas 14 rainfall data.

**Table 2: Alternative 2 Delwau Inundation Depths**

| **Flood Recurrence Interval** | **Boggy Creek Flow** | **Current Overtopping Depths (Boggy/Colorado River)** | **Alternative 2 Overtopping Depths (Boggy/Colorado River)** |
|---|---|---|---|
| (Years) | (CFS) | (Feet) | (Feet) |
| 500 | 29925 | 10.29/na* | 0.00/na |
| 100 | 23052 | 8.49/8.60 | 0.00/0.00 |
| 25 | 16975 | 6.86/0.63 | 0.00/0.00 |
| 10 | 12966 | 5.61/0.00 | 0.00/0.00 |
| 2 | 6436 | 1.52/0.00 | 0.00/0.00 |

*3.2.5 Alternative 2 Cost Estimate*

Using both the TxDOT average unit bid tabs for the last 12 months and estimated boundary street fiscal amount accessed by DSD for development application, this alternative's cost was estimated. Quantities for the cost estimate were determined using the projected grading plan to elevate Shelton Road (grading plan included in attachments), linear feet of street to be improved, and TxDOT standard Bridge specifications for a 40' roadway utilizing a Tx62 bridge girder. The estimated cost for this alternative is approximately $9 Million. A large portion of this cost, approximately $5 million, is for elevating and improving Shelton Road. This cost estimate does not include any utility realignments which will likely be need in order to reconstruct Shelton Road and remove the existing Delwau Lane crossing. The line item cost estimate for Alternative 2 can be found in the attachments.

## 3.3 Alternative 3 – Providing Access from the North to Delwau Lane

The goal of this alternative is to reduce the existing risk associated with the substandard crossing by providing alternative access which does not require users to pass through flood waters to reach Delwau Lane. Due to the likely high cost of upgrading the Delwau Lane crossing, and any future bridge's susceptibility to future erosion and structural concerns, this alternative investigates providing access from the north and closing the existing crossing. After discussions with PWD it was determined that it might be a viable option to provide access to Delwau Lane from the north by acquiring right of way and constructing a new road which would be out of the floodplain to connect with Delwau Lane.

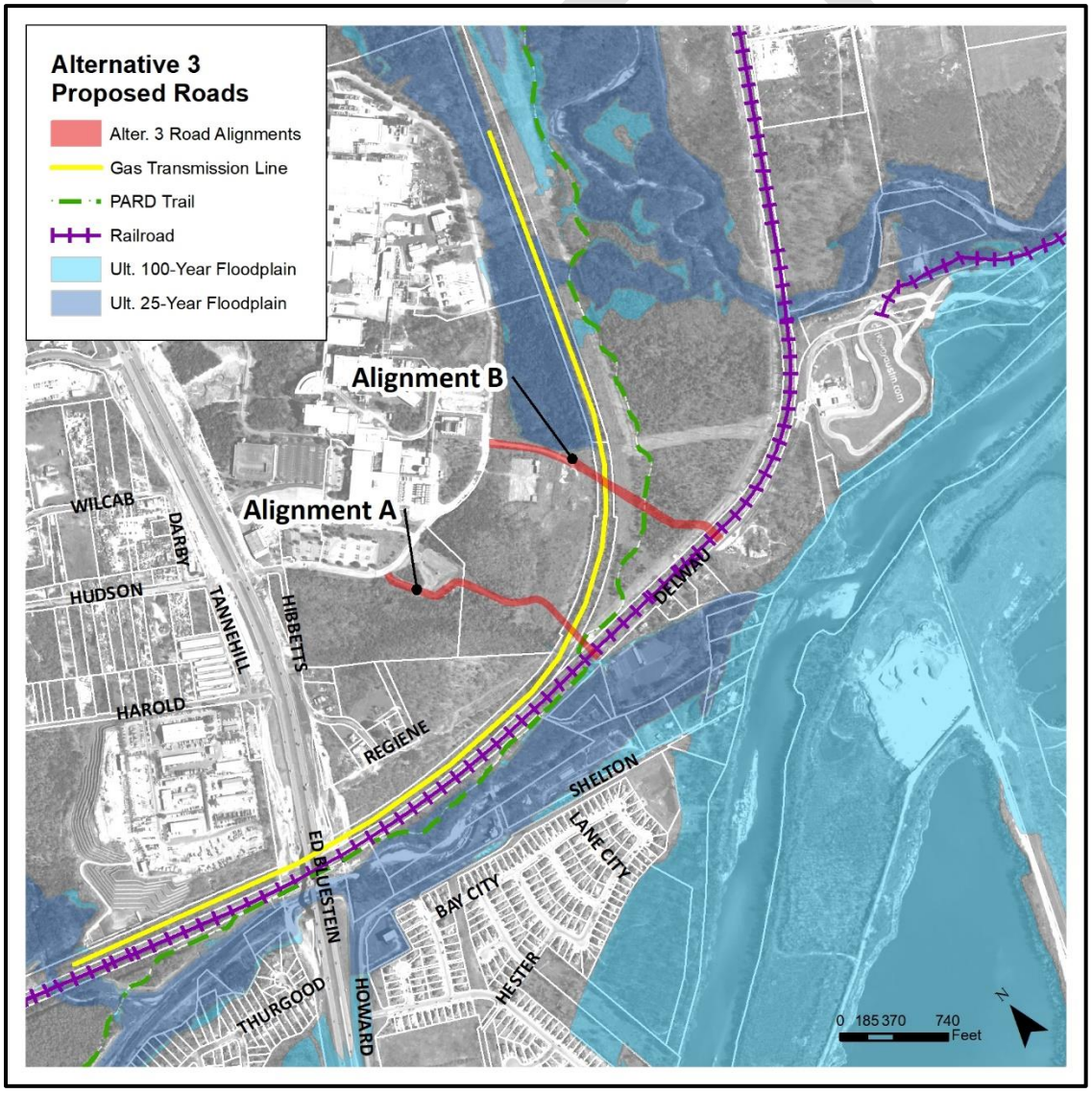


**Figure 10: Alternative 3 Proposed Road Alignments**

**Figure 10** above shows the considered alignments for Alternative 3's alternative access roads. It should be noted that any alignment of a road that would connect Delwau Lane to the north will require the acquisition of right of way, cross a PARD trail and property, cross a gas transmission line and cross a railroad. Also WPD would not be able to use drainage utility funds to cost participate in the road construction as the funds must be used solely for drainage related projects.

*3.3.1 Alignment A*

Alignment A would connect Delwau Lane to the US 183 ROW by acquiring ROW along the alignment path as shown in **Figure 11** below. Ideally this alignment would utilize the existing drive on the HP Data Center property (the purple shaded area on Figure 11) and connect to the drive to Delwau Lane by constructing a new 30' foot local street section on a 50 foot ROW. Also this alignment might be able to use the existing railroad trestle bridge shown in **Figure 12** to cross under the railroad.

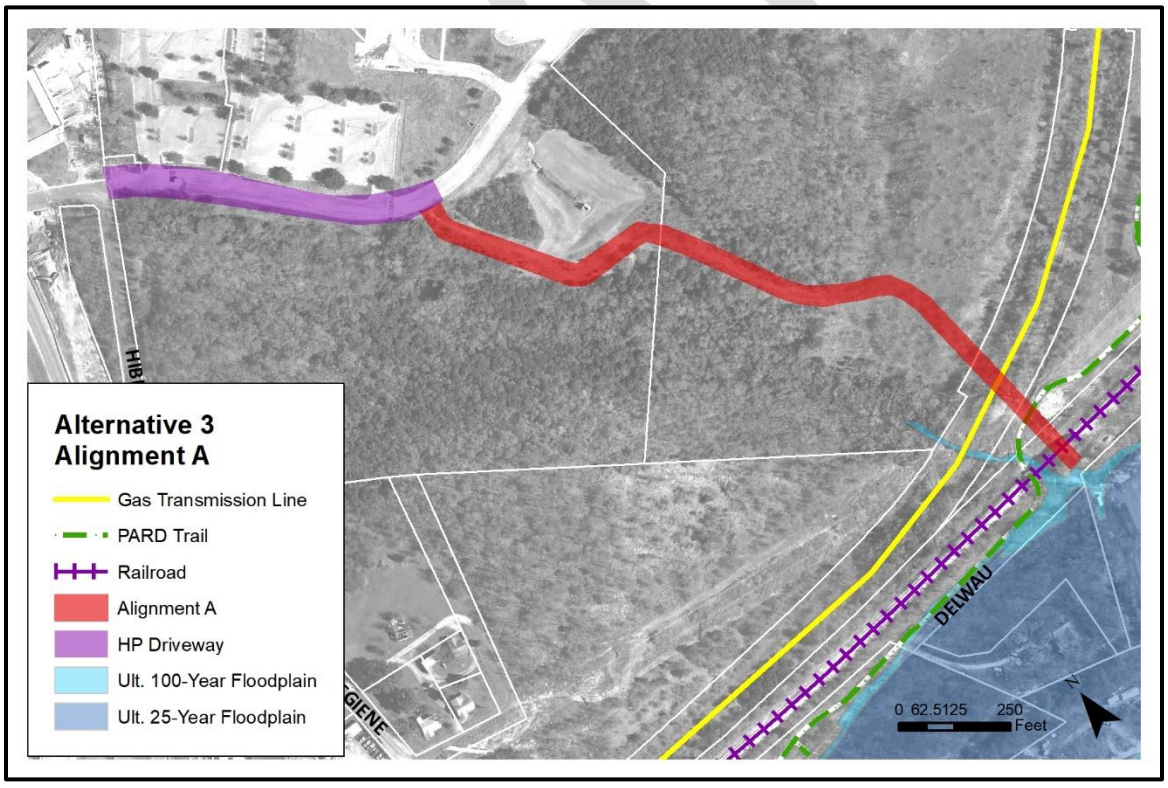


**Figure 11: Alternative 3 Alignment A**

After meeting with ATD about this alignment it was decided that crossing under the existing railroad trestle bridge would not be a feasible option due to safety concerns and the limited spacing provided by the current bridge opening. As such, no further exploration of this alignment was pursued.

**Figure 12: Alternative 3, Alignment A Railroad Bridge crossing location**

*3.3.2 Alignment B*

Alignment B would be similar to Alignment A in that it would utilize the existing drive on the HP Data Center property (the purple shaded area on **Figure 13**) and connect to the drive to Delwau Lane by constructing a new 30' foot local street section on a 50 foot ROW. **Figure 13** shows the proposed Alignment B. Alignment B would require an at grade railroad crossing near its connection with Delwau Lane. This railroad crossing would be preferable to the under bridge crossing needed for Alignment A as it would provide a safer crossing. The at-grade crossing however would be expensive and require a significant amount of time and effort to negotiate the crossing with the owner of the railroad. Conversation with ATD suggested that

the at-grade crossing would have an estimated cost of approximately $5 million just for the crossing.

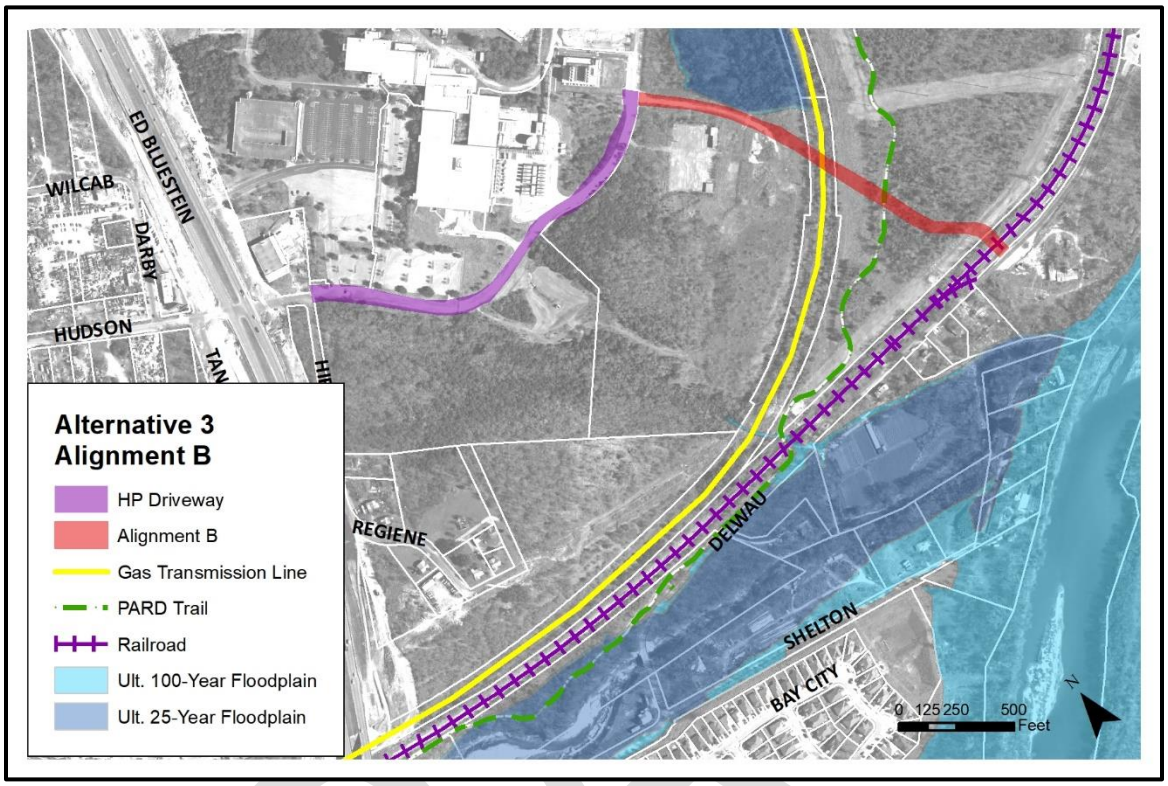


**Figure 13: Alternative 3, Alignment B**

*3.3.3 Alternative 3 Cost Estimate*

Using both the TxDOT average unit bid tabs for the last 12 months, estimated boundary street fiscal amount accessed by DSD for development application and a $3 per square foot of ROW purchase (the $3 per square foot was estimated by the Office of Real Estate Services for ROW acquisition in the general area), the alternative alignment B's cost was estimated. Quantities for the cost estimate were determined by assuming a 50' right of way being acquired along the access path, and linear feet of street to be improved. The estimated cost for this alternative approximately $17 Million. A large portion of this cost, approximately $5 million, is for creating the at-grade railroad crossing. This cost estimate does not include any utility realignments which will likely be need in order remove the existing Delwau Lane crossing. The line item cost estimate for Alternative 3 can be found in the attachments.

*3.3.4 Alternative 3 Other Consideration*

Alternative 3 alignment B will traverse PARD property which will likely require the additional effort and time to acquire the ROW on PARD property. Also crossing the gas transmission line and railroad will require cooperation and coordination from other parties who may not be willing to participate. Finally, the HP data center is currently a secure facility and as such they may not be open to the idea of City acquiring and then using their access drive as a public street without concessions.

*3.3.5 Alternative 3 Overtopping Depth Reductions and Adverse Impacts*

Alternative 3 will not cause adverse impacts to Boggy Creek floodplains does not propose improvement or development activities within the floodplain. Overtopping risks would be mitigated as the bridge would be removed and replaced with a new access road that is not subjected to flood risk. This alternative does not address any structural or access risks due to flooding for properties along Shelton Road

## 3.4 Alternative 4 – Maintain Existing Bridge

The goal of this alternative is to work with PWD to address the structural issues associated with the existing Delwau Lane crossing and not address the current overtopping depths over the crossing. This alternative may be a retrofit to the existing bridge or replacement of the existing bridge with a new bridge structure which maintains the existing conveyance capacity of existing bridge configuration. This alternative minimizes improvements to the crossing by maintaining the existing road profiles leading to the bridge and maintaining the existing bridge elevation. For the purpose of this feasibility study, only a replacement bridge will be considered. Retrofits maybe an option, but it is recommended that PWD explore those options. This is essentially the "do nothing" option for WPD as PWD would pay for this improvement as it relates to the structural stability of the existing bridge. While this option may not impact WPD's operating budget, it will ultimately be money spent by the City used to address the issues at the crossing and should be measured against options were WPD will heavily cost participate.

*3.4.1 Proposed Delwau Lane Bridge Replacement*

A few configurations and bridge span options were investigated for this alternative. Ultimately a single span bridge which maintains the current road elevation of the crossing at the elevation of 423.68' MSL and has a low cord of 419.93' MSL offers the best solution for maintaining the current crossing approaches, achieving no adverse impacts, increasing conveyance, and reducing overtopping depths. The proposed bridge's spans would be a single 95' span utilizing the TxDOT standards for a 40' Roadway using Type 5XB34 X-Beam Span. **Figure 14** below has HEC-RAS bridge cross section image for reference.

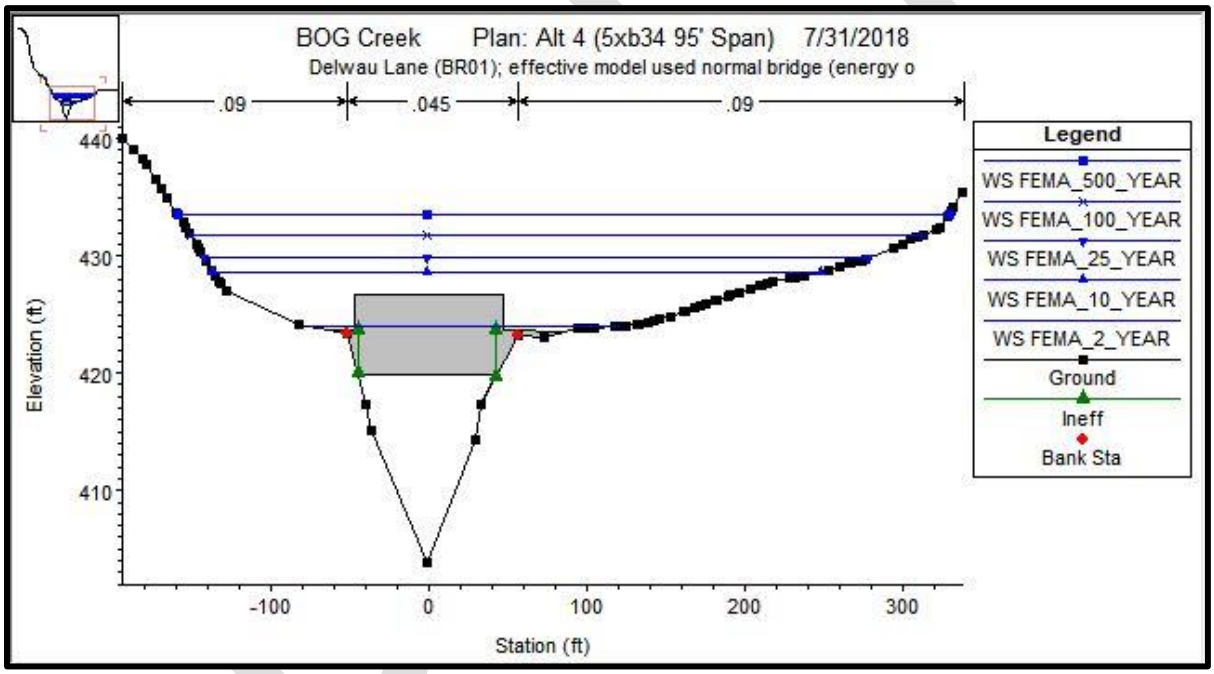


**Figure 14: Alternative 4 HEC-RAS Bridge Cross Section**

*3.4.2 Proposed Bridge Realignment*

As the current Delwau Lane Bridge provides the only point of access to properties and buildings on the north side of Boggy Creek along Delwau Lane, access must be provided throughout the entire construction phase of any selected structural option. As this alternative seeks to maintain the current bridge alignment, constructing a temporary bridge would be needed until the replacement bridge is serviceable or sequencing the construction to allow use

of the new and existing bridges for access prior to completion of the project. A temporary bridge will add additional cost and extend construction timelines, however these costs maybe offset as less construction will be required for the approaching streets.

*3.4.3 Alternative Overtopping Depth Reductions and Adverse Impacts*

Water surface elevations were also compared to between the alternative 4 model and the corrected effective model to determine if any increases in base flood elevations (BFEs) occur. No increases in BFEs were noted as a result of the replacement bridge.

The bridge design proposed in this alternative will not meet current DCM regulations for overtopping depths but minor reduction in overtopping during the 2, 10, 25, 100 and 500-year water surface profiles were noted. **Table 3** documents the overtopping depth reductions. As shown in **Table 3**, the proposed alternative will not convey the current 500-year floodplain without overtopping, so the alternative will not conform to the DCM after the adoption of the Atlas 14 rainfall data. While the replacement bridge does reduce the overtopping depths of all of the investigated events from the Boggy Creek flows, the replacement bridge still has the same overtopping risks form Colorado River floodplains and the crossing still overtops in a 2-year event.

**Table 3: Alternative 4 Delwau Inundation Depths**

| **Flood Recurrence Interval** | **Boggy Creek Flow** | **Current Overtopping Depths (Boggy/Colorado River)** | **Alternative 4 Overtopping Depths (Boggy/Colorado River)** | **Overtopping Reductions (Boggy/Colorado River)** |
|---|---|---|---|---|
| (Years) | (CFS) | (Feet) | (Feet) | (Feet) |
| 500 | 29925 | 10.29/na | 9.82/na | 0.47/na |
| 100 | 23052 | 8.49/8.60 | 8.15/8.60 | 0.34/0.00 |
| 25 | 16975 | 6.86/0.63 | 6.15/0.63 | 0.71/0.00 |
| 10 | 12966 | 5.61/0.00 | 4.87/0.00 | 0.74/0.00 |
| 2 | 6436 | 1.52/0.00 | 0.31/0.00 | 1.21/0.00 |

*3.4.4 Alternative 4 Cost Estimate*

Using the TxDOT average unit bid tabs for the last 12 months and quantities for the cost estimate determined by the replacement bridge were estimated. A general estimate for the temporary bridge was set at $500,000 for estimating purposes. The estimated cost for this alternative approximately $2.3 Million. This cost estimate does not include any utility realignments which will likely be need in order to replace the existing Delwau Lane crossing. The line item cost estimate for Alternative 4 can be found in the attachments.

## 3.5 Alternative 5 –Buyout of Properties and Closing Bridge

The goal of this alternative is the permanent closure of Delwau Lane. As the Delwau Lane crossing is the only access to the properties north of Boggy Creek along Delwau Lane, the noted properties impacted by the road closure would have to be acquired in order to close the road. These properties include both residences and businesses. To date WPD has not actively pursued the buyout of business or commercial properties for the purpose of flood risk reduction, so criteria would need to be establish for such activity. Cost estimates for the buyouts utilize recent available Travis County Appraisal District data from 2018 with the following multipliers: 2X the appraised value for residences and 4X the appraised value for businesses. Pursuing this option would likely consist of a multi-year effort to purchase the properties and may require the use of eminent domain to acquire properties with title issues or from unwilling property owners.

*3.5.1 Alternative 5 Cost Estimates*

**Figure 15** below shows properties that would need to be acquired to close the Delwau Lane crossing. Also **Table 4** below summarizes the list and estimated buyout cost for the identified properties. Of the residential properties, one has expected inundation in 10-year event while the others currently do not encroach into the current pre Atlas 14 100-year floodplain. The business properties consist of Driveway Austin, an auto racing track, and an unoccupied tract which was formally a gravel mining business. The former gravel mining business tract was recently rezoned to allow for alcohol service and owners of the tract have met with the floodplain office to discuss plans to redevelop the tract into an RV campground with a microbrewery. While the overall cost of a comprehensive buyout will be determined by market

conditions at the time of property acquisition, overall it is estimated based on 2018 TCAD values the buyout cost will be $4.9 million.

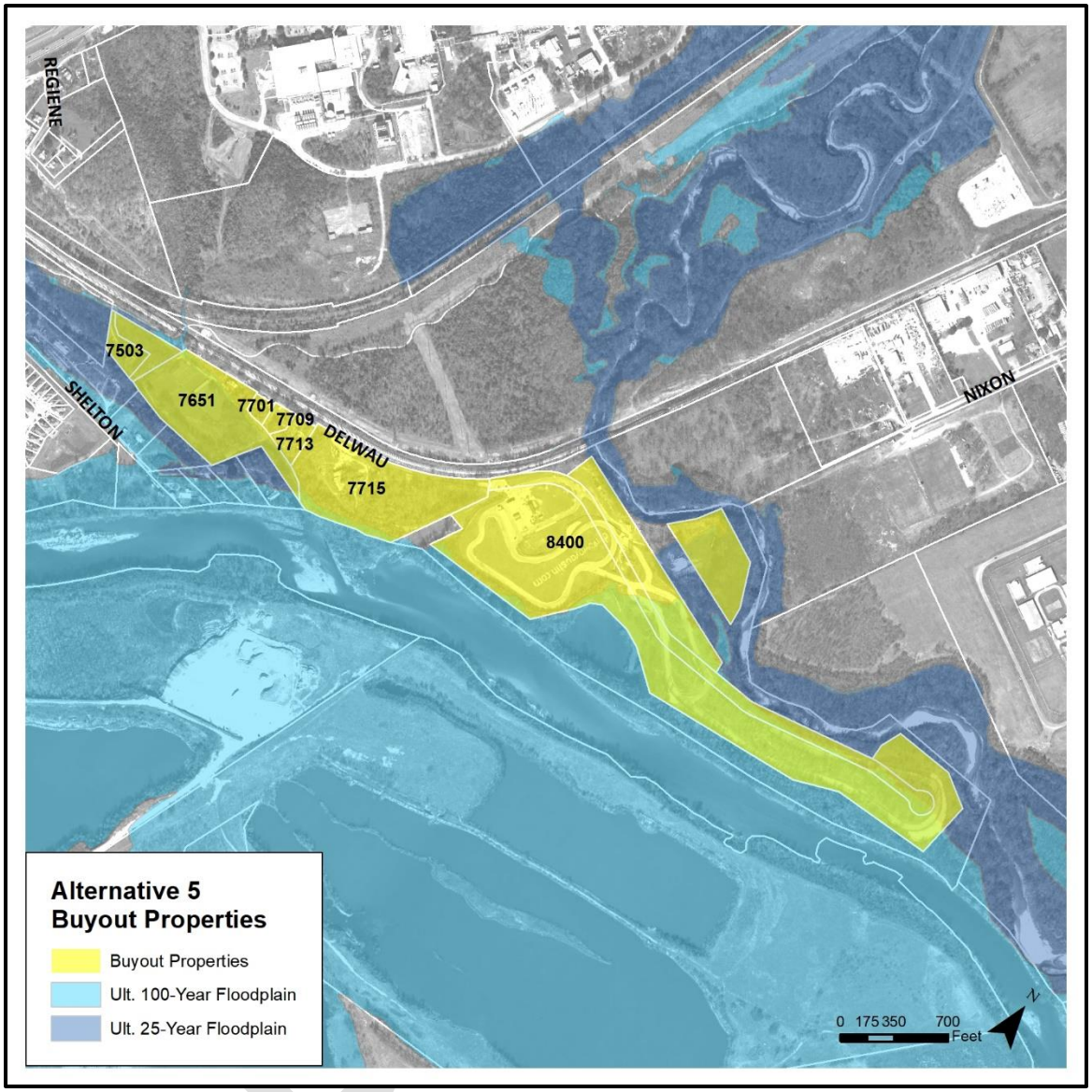


**Figure 15: Alternative 5 Buyout Property Location Map**

*3.5.2 Alternative Overtopping Depth Reductions and Adverse Impacts*

Alternative 5 will not cause adverse impacts to Boggy Creek floodplains as it does not propose improvements or development activities within the floodplain. Overtopping risks would be mitigated as the bridge would be removed.

**Table 4: Estimated Property Buyout Costs**

| Address | TCAD ID | Land Value | Structure Value | Multiplier | Estimated Buyout Cost |
|---|---|---|---|---|---|
| 7503 DELWAU | 0202210205 | $ 21,600 | $ 126,785 | 2 | $ 296,770 |
| - | 0202210206 | $ 7,755 | $ - | 2 | $ 15,510 |
| 7651 DELWAU | 0202210231 | $ 16,000 | $ 122,001 | 4 | $ 552,004 |
| 7701 DELWAU | 0202210223 | $ 20,000 | $ 46,870 | 2 | $ 133,740 |
| 7709 DELWAU | 0202210232 | $ 11,400 | $ 106,394 | 2 | $ 235,588 |
| 7713 DELWAU | 0202210233 | $ 21,400 | $ 72,944 | 2 | $ 188,688 |
| 7715 DELWAU | 0202210221 | $ 254,826 | $ 20,540 | 4 | $ 1,101,464 |
| 8400 DELWAU | 0202310106 | $ 41,319 | $ - | 4 | $ 165,276 |
| 8400 DELWAU | 0202310107 | $ 252,967 | $ 309,084 | 4 | $ 2,248,204 |
| | | | | **TOTAL EST. BUYOUT COST:** | **$ 4,937,244** |

## 4.0 COMPARISION OF ALTERNATIVES

A summary of the five analyzed alternatives overtopping depth reductions and cost is included in **Table 5** below. The main criteria used in comparing the alternatives are the roadway inundation depth reductions and cost. As all alternatives investigated were found to not cause adverse impacts this will not be a consideration of the alternatives

The alternatives illustrate that a structural low water crossing upgrade (structural indicating a replacement of the existing crossing with a new crossing) will likely have a range of costs associated with the reduction of inundation depths produced by the improved crossing. Alternative 4 presented an example of a minimal structural solution whereas Alternative 2 presented a full DCM solution. The reductions to overtopping depths provided by these alternative present a wide spectrum of benefits ranging from small to no overtopping reductions all the way to removal of all design flood overtopping risks. Alternative 2 and 4 also present a cost range that a structural solution will cost, ranging from $2.2 million to $9 million.

**Table 5: Alternatives Comparison Table**

| Alternative | Flood Recurrence Interval | Flow (cfs) | WSEL (ft-msl) | Roadway Inundation (ft) | Inundation Reduction (ft) | Cost Estimate |
|---|---|---|---|---|---|---|
| Existing Site Conditions | 2-Year | 6436 | 425.21 | 1.52 | - | |
| | 10-Year | 12966 | 429.30 | 5.61 | - | |
| | 25-Year | 16975 | 430.55 | 6.86 | - | |
| | 100-Year | 23052 | 432.18 | 8.49 | - | |
| | 500-Year | 29925 | 433.98 | 10.29 | - | |
| Alternative 1 | 2-Year | 6436 | 425.21 | 1.52 | 0 | $270,000 |
| | 10-Year | 12966 | 429.30 | 5.61 | 0 | |
| | 25-Year | 16975 | 430.55 | 6.86 | 0 | |
| | 100-Year | 23052 | 432.18 | 8.49 | 0 | |
| | 500-Year | 29925 | 433.98 | 10.29 | 0 | |
| Alternative 2 | 2-Year | 6436 | 422.8 | 0.00 | 1.52 | $9,033,804 |
| | 10-Year | 12966 | 429.3 | 0.00 | 5.61 | |
| | 25-Year | 16975 | 430.39 | 0.00 | 6.86 | |
| | 100-Year | 23052 | 431.91 | 0.00 | 8.49 | |
| | 500-Year | 29925 | 433.57 | 0.00 | 10.29 | |
| Alternative 3 | 2-Year | 6436 | - | 0.00 | 1.52 | $17,041,877 |
| | 10-Year | 12966 | - | 0.00 | 5.61 | |
| | 25-Year | 16975 | - | 0.00 | 6.86 | |
| | 100-Year | 23052 | - | 0.00 | 8.49 | |
| | 500-Year | 29925 | - | 0.00 | 10.29 | |
| Alternative 4 | 2-Year | 6436 | 424 | 0.31 | 1.21 | $2,227,111 |
| | 10-Year | 12966 | 428.56 | 4.87 | 0.74 | |
| | 25-Year | 16975 | 429.84 | 6.15 | 0.71 | |
| | 100-Year | 23052 | 431.84 | 8.15 | 0.34 | |
| | 500-Year | 29925 | 433.51 | 9.82 | 0.47 | |
| Alternative 5 | Buy out alternative, assumed to remove inundations over road | | | | | $4,937,244 |

Alternatives 3 and 5 also achieve a removal of overtopping risk by providing an avenue to close the crossing through means of providing alternative access or a buyout. These options should be weighed against the Alternative 2 as they all remove the overtopping risk. With this in mind, alternative 5 provides the most cost effective solution to mitigate the current overtopping risks.

## 5.0 MISSION INTEGRATION

The mission of the WPD is to reduce the impacts of flooding, erosion and water pollution on our community in order to protect lives, property and the environment. As part of the WPD goals to integrate the three missions, every project must look at ways to incorporate goals and objectives of each mission. The WPD has a specific process that must be followed for all capital improvement projects administered by the department. The Mission Integration Prioritization (MIP) team serves to identify, prioritize, and integrate responsible funding plans for capital solutions to implement improvements in water quality, channel stability and stormwater conveyance.

All of the alternatives have the opportunity to help address the active erosion in the reach immediately upstream of the crossing. Collaboration to address the erosion issues should be fostered during any PER phase in order to offer stabilization for the channel and to protect any proposed crossing structure. The water quality mission can also be included in any restoration activities provided by the scope of a selected alternative solution.

## 6.0 PERMITTING AND REGULATORY REQUIREMENTS

Due to the size of this project, it is expected that structural improvements at this low water crossing would need to be implemented under a City's site development permit. In addition, the structural alternatives presented in this feasibility study are expected to include channel modifications in and around the creek crossing at Delwau Lane. As Boggy Creek is identified as a water of the United States as defined by the Clean Water Act; therefore it is subject to all related permitting requirements. If this low

water crossing is selected for structural upgrades, the design engineer will be responsible for identifying and verifying all permit requirements.

## 7.0 TOTAL PROJECT COST ESTIMATES

A feasibility level cost estimate for each alternative has been prepared and the totals are as follows:

- Alternative 1: $270,000
    - Goal – Increase flood risk awareness, provide improved emergency access
    - Does not include potential ongoing maintenance costs
- Alternative 2: $9 Million
    - Goal – Upgrade to a DCM compliant crossing
    - Does not include utility realignments or costs to address regional erosion issues
- Alternative 3: $17 Million
    - Goal – Provide alternative access to close the crossing
    - Does not include utility realignments or costs to address regional erosion issues
- Alternative 4: $2.2 Million
    - Goal – Address the structural concerns of the crossing
    - Does not include utility realignments or costs to address regional erosion issues
- Alternative 5: $4.9 Million
    - Goal – Remove crossing and buyout impact properties
    - Does not include bridge removal costs or real estate service fees

The cost is based on the infrastructure that was recently bid TxDOT. More detailed cost estimate information is included in attachments.

## 8.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

Based upon the findings described in the analyses and alternatives section of this feasibility study, the following are recommendations to consider during future phases of this project.

It is recommended that improved signage proposed in Alternative 1 be pursued and completed immediately. The signage improvements offered by the alternative provide increased awareness to the current flood risks in the area until a mitigation alternative can be completed. Installation of the signage can be completed by PWD Street and Bridge crews. The improved access path proposed by the alternative should be pursed unless Alternative 2, the DCM compliant bridge with improvements to Shelton Road, is pursued. The access road will improve emergency access to properties along Shelton Road east of the Delwau intersection and would provide the same benefits to those properties if Alternative 3, 4 and 5 are completed. The access road may be able to be constructed by WPD crews or by an IDIQ contract.

Of the alternatives that reduce the overtopping risks at the crossing to levels prescribed by the DCM (no overtopping in the 25-year event and 6" in the 100-year event) Alternative 5 provides the most cost effective option and is the recommended alternative. Before selecting this alternative, Real Estate Services should be engaged to perform a more accurate and in depth market appraisal of the area to confirm buyout cost estimates. If this alternative is pursued, discussions with WPD management about using this approach to remove low water crossing risks with a buyout should be explored as we would need to explore both the idea of purchasing homes which conform to current floodplain regulations as well as purchasing commercial properties. This alternative will also result in likely relocation or closure of the urban farm Urban Roots which provides social and community benefits which are not easily quantified. With all of these considerations, the preliminary estimate cost savings of the buyout approach are significant and need to be considered and weighted as a viable alternative.

As a second option, Alternative 2 is recommended. If the Alternative 5 in unable to garner management support, Alternative 2 improvements remove the flood risk associated with the current Delwau Lane crossing. Alternative 2 provides a less expensive flood risk reduction option when compared to Alternative 3, and while alternative 4 provides a more cost effective option it does not significantly address the current flood risks at the bridge. In addition to the reduced flood risk, the alternative will provide better flood safe access to properties along Shelton Road and provide better connectivity and trail access to residents of the Knollwood on the Colorado neighborhood. This alternative will also be compatible with changes to the regulatory floodplains after the adoption of the Atlas14 rainfall data.

It is recommended that upon engaging real estate services, CFRR should approach WPD management to consider a buyout option. If a buyout option is found to be unfavorable, then a more refined analysis of the above alternatives be performed with more field visual and topographic survey taken as necessary to complete a full design of the project. Impacts to the water surface elevation and existing structures, as well as roadway inundation and cost should be kept as the leading design criteria.

## 9.0 SUMMARY OF RESULTS

This report documents the findings of five alternatives found upon completing the analysis of the Delwau Lane low water crossing. Alternative 1 is recommended for near term implementation with Alternative 5 recommended for the long term risk reduction solution. Alternative 5 provides complete removal of the flood risk associated with the crossing. It, Alternative 5, is also the cheapest alternative that does reduces the overtopping risks associated with the existing Delwau Lane Bridge to acceptable standards. This option meets the goals of the Creek Flood Hazard Mitigation group, as it decreases the hazard at the creek crossing and does not increase flood elevations elsewhere. Alternative 5 is also the most cost effective option, costing approximately $4.9 million.