Chancellor's Honors Program Honors Thesis Project
In conjunction with,
CE 400 Senior Design Project.
Faculty Advisor: Dr. Jennifer Retherford

Sidewalk Infrastructure Improvements Design for Calhoun, TN

May 9, 2016

Liam Weaver

Department of Civil and Environmental Engineering
325 John D. Tickle Engineering Building
851 Neyland Dr.
Knoxville, TN 37996

This submission is part of a group submission for a civil engineering senior design project including team members Bailee Young (also Honors), Mark Nichols, Trenton Smith, Brian Walker, and Marquise Webb. This project was part of the Smart Communities Initiative (SCI). The Smart Communities Initiative is designed to connect faculty and students to counties, cities, districts, or other governmental organizations to benefit an area through service learning. Many of the projects help to enhance the economy, society, or environment of the location. This year, the Smart Communities Initiative partnered with the Southeast Tennessee Development District (SETDD). The University of Tennessee, Knoxville partnered with twenty-two projects this year which included projects in the following areas: architecture, engineering, agricultural economics, educational psychology and counseling, economics, graphic design, law, history, and geography. This is the second year that the Smart Communities Initiative has taken place. The first year UT partnered with the City of Cleveland, Tennessee, and next year, SCI will be partnering with Lenoir City, Tennessee.

As part of the Smart Communities Initiative, the Civil and Environmental Engineering senior design team partnered with Calhoun, TN. The purpose of the senior design project was to develop sidewalk infrastructure to increase pedestrian connectivity throughout the City of Calhoun. The City of Charleston is adjacent to the City of Calhoun, south on Highway 11, and has existing sidewalk infrastructure that stops north of the bridge on Highway 11. The team worked with Greg Thomas, Cleveland MPO Coordinator, to determine the needs and goals of the project. As a city planner, Greg really wanted the team to focus on connecting Calhoun to the existing sidewalk infrastructure in Charleston, see **Figure 1**. Resolute Forest Products Paper Mill is located on Highway 11, and the owners advocated for sidewalk infrastructure on Highway 11 in order to benefit the plant's employees. Another important stakeholder in determining the goals for the project was the City of Calhoun's government. Calhoun's government wanted the sidewalk to connect S.R. 163 to Highway 11, and for the sidewalk on S.R. 163 to establish pedestrian infrastructure to the city's town hall which houses the library, post office, and police department. Calhoun officials also wanted to connect S.R. 163 to Calhoun Elementary School, possibly creating a Safe Routes to School network. The team considered all of these goals and worked to incorporate each goal into the final design.

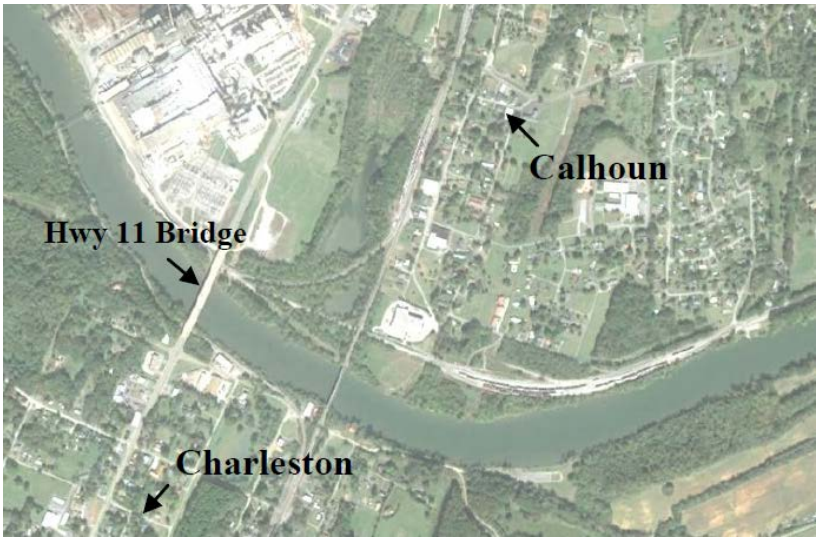

Figure 1: Overview of Charleston and Calhoun connected by the Highway 11 Bridge

Several challenges existed in achieving each of the desired goals. One challenge was determining a way to transport pedestrians through an underpass that is located on S.R. 163. The underpass is 27 feet wide with 12 ft lanes and 1.5 ft shoulders, making it difficult to accommodate pedestrians. Another issue the team dealt with was designing the sidewalk along S.R. 163 west of the underpass as the road has narrow shoulders which are bordered by guardrails since the topography immediately slopes down to the flood plain. The road was not wide enough to add pedestrian sidewalks; therefore, another method had to be introduced to get pedestrians over the segment of road. As sidewalks were designed, crosswalks became necessary, and the sight distances of drivers approaching the crosswalks became a concern.

In order to address the goals of the project, the team decided to construct new sidewalk along the following route: north on Highway 11 from the bridge to S.R. 163 and east on S.R. 163 stopping 500 feet east of Lyncrest Ave., see **Figure 2**. A loop was formed by designing new sidewalk south down Main St., east down Sherwood Ave., and north on Highland Ave. and Lyncrest Ave. By choosing the specified route, each goal for the project was met. Charleston was connected to Calhoun by the sidewalk on Highway 11. The town hall was connected to other parts of Calhoun, including Resolute Forest Products Paper Mill and Calhoun Elementary School. Neighborhoods were connected to the sidewalk providing accessibility to the school. The network increases pedestrian connectivity, allowing pedestrians to have more access to important town features.

Figure 2: Sidewalk Network

Several methods were investigated to address the project's underpass challenge, and five options were discussed. Two options were identified as the most feasible based on pedestrian safety and cost. One option was to reduce the traffic to one lane through the underpass by incorporating traffic signals and creating an elevated sidewalk on the north side of the underpass. Reducing traffic to one lane would increase vehicular safety as vehicular conflicts would be reduced since vehicles would be time separated by the traffic signal. The other method investigated was to mark a 5 feet wide bike and pedestrian lane to the left of the pavement's edge on the north side of the underpass. This method would incorporate two traffic signals which would stop all traffic whenever a pedestrian is present. The signals would be pedestrian actuated so that the flow of traffic would only be inhibited when a pedestrian is present. Three other options were presented and analyzed in the report.

One of the other challenges, the narrow portion of S.R. 163 west of the underpass, was addressed by designing a segmental retaining wall. The wall is 350 feet long, 16.5 feet high, and is offset 15 feet from the edge of the road. The edge of the retaining wall furthest from the road has a 3 feet high parapet with a fence located on top to provide a protective barrier for the pedestrians. This was an unexpected challenge that was discovered and overcome as the project progressed.
The transportation portions of the projection included geometric design and traffic operations. For geometric design, the sidewalk, curb, and shoulder were designed according to the Americans with Disabilities Act Accessibility Guidelines. Sight distance was evaluated for crosswalks and locations where new traffic signals were introduced. Traffic operations for the project included markings, signs, pedestrian signalization, and warning beacons. The project required other engineering disciplines, besides transportation. For the retaining wall, a geotechnical analysis was performed. In addition, stormwater infrastructure was designed to handle the changes made by the new sidewalk. Calculations were performed to modify the swales and design stormwater inlets.

My role in this project was the role of project manager. This included all administrative tasks, including: organization and scheduling of all site visits, meetings, workdays, and subteam projects, presentations, work supervision and revision, poster design, video production, and communications with the client. Additionally, I worked in writing the general descriptions sections and editing the entirety of the thesis report attached, with work on ensuring clarity, accuracy, and consistent revisions within the project construction drawings. The remainder of this report contains the full project report which covers transportation, water, geotechnical, and construction engineering portions of the project. The appendix is available upon request. A set of AutoCad drawings were designed to supplement the report, and they are also available upon request.

To: Greg Thomas
Cleveland Metropolitan Planning Organization
185 2nd Street NE, Cleveland, TN 37311

Chuck Hammonds
Southeast Tennessee Development District
1000 Riverfront Parkway Chattanooga, TN 37402

From: Trlimamababr Consultants Group
CE400: Senior Design Student Team (Spring 2016)
Department of Civil & Environmental Engineering
University of Tennessee, Knoxville

Subject: Calhoun Sidewalk Plan: Infrastructure Improvements

Mr. Thomas and Mr. Hammonds,

This report outlines a design for pedestrian sidewalk and supporting stormwater management infrastructure improvements for Calhoun, Tennessee. This project was developed as a single contract as part of a larger Smart Communities Initiative contract between the University of Tennessee and the Southeast Tennessee Development District. Design considerations include pedestrian safety, accessibility and connectivity, excavation and construction, and stormwater drainage. The following team of engineering students was assembled to provide the necessary engineering services:

Bailee Young:	Transportation Designer, Engineering Intern
Marquise Webb:	Transportation Designer
Brian Walker:	Geotechnical/Construction Designer
Mark Nichols:	Water Resources Designer
Trenton Smith:	Water Resources Designer
Liam Weaver:	Project Manager, Engineering Intern

Because each member has supplementary skills including surveying, AutoCAD, and construction estimation, all of the necessary work was able to be completed efficiently and effectively in-house. Included in this report is the project design work, including: an evaluation of the transportation network system considerate of pedestrian crossings at major roads and state highways, consideration of ADA access and adherence to applicable codes, new infrastructure for stormwater drainage, roadway markings to accommodate pedestrian traffic along the route, and evaluation of the larger sidewalk network to develop safe multi-modal connectivity.

Trlimamababr Consultants Group appreciates the opportunity to address the needs of this community and looks forward to communicating further after a review of the services performed. While this work has been well-prepared, the team does not currently contain any licensed engineer professional nor liability insurance. Implementation of any work recommended in this report requires review and re-evaluation by a licensed engineer.

Best regards,

Bailee Young	_____	Mark Nichols	_____
Marquise Webb	_____	Trenton Smith	_____
Brian Walker	_____	Liam Weaver	_____

Sidewalk Infrastructure Improvements Design for Calhoun, TN

Full Report

CEE 400 Senior Design (Spring 2016)

in collaboration with

Southeast Tennessee Development District, Cleveland Metropolitan Planning Organization, and University of Tennessee, Knoxville Smart Communities Initiative

April 29th, 2016

Table of Contents

1.0 Project Description……....pg. 4
2.0 Initial Site Survey……..…pg. 7
3.0 Hydrologic Engineering…….…...pg. 10
3.1 Sherwood Avenue Swale Improvements…….….....pg. 11
3.2 Stormwater Drain Design Infrastructure...…….…….…….....pg. 13
3.2.1 Etowah Road……...…….……..pg. 13
3.2.2 U.S. Route 11…….pg. 14
3.3 Flood Plain Considerations…….…….....pg. 15
4.0 Transportation Analysis…….……...pg. 16
4.1 Sidewalk Design.……...……...pg. 16
4.2 Shoulder and Curb Design……..…….....……pg. 17
4.3 Sight Distance……...pg. 21
4.4 Crosswalk Design ……pg. 23
4.3.1 Markings……pg. 23
4.3.2 Signs……..……pg. 23
4.3.3 Pedestrian Signalization……pg. 24
4.3.4 Warning Beacons……..pg. 25
5.0 Railway Underpass Design and Option Evaluation…….pg. 26
5.1 Traffic Lane Reduction Design (Option 1)…….…pg. 26
5.1.1 Pedestrian Infrastructure Design through Underpass ……...pg. 28
5.1.2 Traffic Signals……..……..……...pg. 28
5.1.3 Traffic Signal Timing……pg. 28
5.2 Widening of Railway Underpass (Option 2)…….……...pg. 29
5.3 Signalized Pedestrian Walkway (Option 3)…….……pg. 30
5.3.1 Traffic Control……..pg. 31
5.3.2 Traffic Signals…….……..pg. 31
5.4 Pedestrian Tunnel (Option 4)……...pg. 32
5.5 At-grade Crossing South of Underpass and Extended Sidewalk (Option 5)…...pg. 32
5.6 Design Recommendations……pg. 33
6.0 Retaining Wall Design…….…….……...pg. 34
7.0 Construction……...……....……pg. 35
References……..…..……..pg. 41
Appendix A……...……pg. 42
Appendix B……...…pg. 74
Appendix C……...pg. 109
Appendix D……...pg. 121
Appendix E……...pg. 145
Appendix F……...pg. 150
Appendix G……...pg. 153

List of Tables

Table 3.1: Swale Flow Depth Calculations…….…….pg. 12
Table 3.2: Rational Method Design Parameters……..pg. 13
Table 3.3: Rational Method Parameters Results…….…….pg. 14
Table 3.4: Storm Drain Calculation Summary for Etowah Road……...…….……pg. 14
Table 3.5: Storm Drain Calculation Summary for U.S. Route 11……...pg. 15
Table 4.1: Intersection Sight Distances…….....……pg. 22
Table 4.2: Crosswalk Locations and Features..…….....……...…….……pg. 25
Table 5.1: Signal Timing Interval……pg. 29
Table 7.1: Phase 1 Construction Cost Breakdown……..……pg. 38
Table 7.1: Phase 2 Construction Cost Breakdown……...…pg.39
Table 7.1: Phase 3 Construction Cost Breakdown ……..……pg. 40

List of Figures

Figure 1.1: Identification of Key Components…….…….……...pg. 4
Figure 1.2: Railway Underpass……...…….…...pg. 5
Figure 2.1: Figure 2.1: Map of Roadway Survey, Component I….…….…….……..pg. 8
Figure 2.2: Figure 2.2: Map of Roadway Survey, Component II & III……...……pg. 9
Figure 3.1: Existing Stormwater Management……pg. 10
Figure 3.2: Existing Stormwater Management, Highway 11…..……pg. 11
Figure 3.2: FEMA 100-year Flood Plain Map……..……..pg. 15
Figure 4.1: Site Conditions with 11% Grade……..pg. 17
Figure 4.2: Barrier Type Curb……pg. 18
Figure 4.3: Existing Curb Radii……..……pg. 19
Figure 4.4: Curb Radius Schematic…….……pg. 19
Figure 4.5: Parallel Curb Ramp Setup…..……...pg. 20
Figure 4.6: Detectable Truncated-Dome……pg. 20
Figure 4.7: ISD Measurement Method……pg. 21
Figure 4.8: Non-Vehicular Warning Sign and Warning Plaques from USDOT…….pg. 24
Figure 4.9: One-section Pedestrian Signal Indications, USDOT ……...……pg. 25
Figure 5.1: 2016 Southern Constructors, Inc. Elevated Sidewalk……...pg. 27
Figure 5.2: 2016 Southern Constructors, Inc. Signalized Approach……...pg. 27
Figure 5.3: Bicycle and Pedestrian Permitted Signs…….…….…….pg. 31
Figure 5.4 Pedestrian Route at At-Grade Crossing……pg. 33
Figure 6.1 Retaining Wall Block Elements……pg. 34
Figure 7.1 Phase Separation Diagram……pg. 35
Figure 7.2 Phase 1 Scheduling……pg. 36

1.0 PROJECT DESCRIPTION

Trlimamababr Consultants Group was consulted regarding the design of appropriate sidewalk infrastructure improvements in Calhoun, TN. A stakeholder meeting helped to specify the primary goals and various needs of the surrounding community. **Figure 1.1** illustrates the town of Calhoun with the location of the infrastructure improvements identified, separated into three components to address three primary needs: a connectivity loop within Calhoun, a feasibility analysis for a railway underpass, and a link to Charleston. An introduction to the goals and broad design considerations of these components is within this section, with further details and design work included in the remainder of the report. The report is structured by civil engineering discipline, not by component, for ease of reference by a peer engineer. Priority was given to safety, cost, and accessibility as indicated by the client.

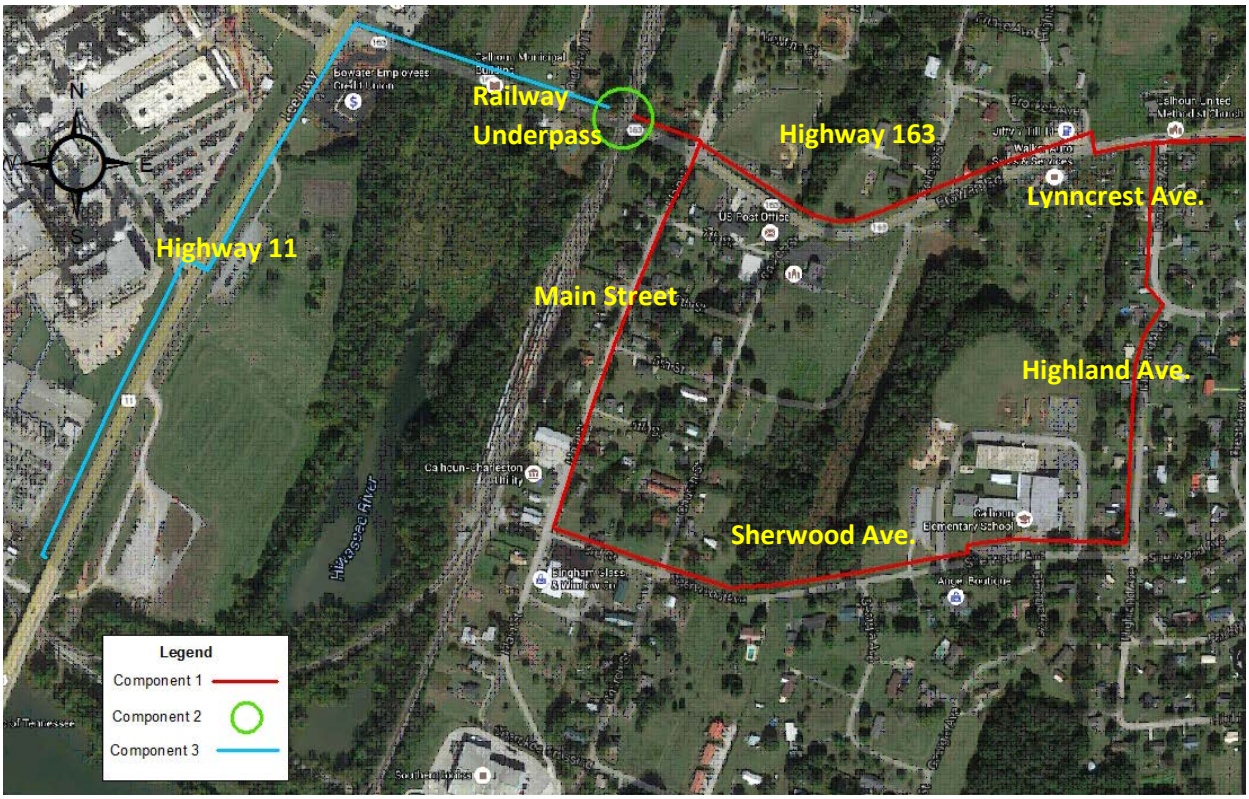

Figure 1.1: Identification of Key Project Components

Component I: ***Connectivity Loop within Calhoun*****.** Calhoun's city center consists of the following community entities: a Methodist Church, an Elementary School, an existing historic sidewalk (formerly the original path of the Trail of Tears), a baseball field, and the City Hall and Public Library, all throughout a quaint neighborhood atmosphere. The objective of this component is to link the community and provide a safe and Americans with Disabilities Act (ADA) accessible pedestrian route between these local points of interest. Design considerations for this component of the overall project include safety concerns for crosswalks across a heavy-traffic highway, the need for expansion of currently narrow shoulders with existing swales immediately along Highway 163, and several high-grade slopes alongside the road that lead up to private properties, which limit constructible area and require re-grading.

Component II: ***Feasibility Analysis for Railway Underpass.*** Highway 163 continues out of the heart of Calhoun and west towards the Bowater Paper Mill. West of the baseball field, the road descends into a railway underpass. The narrow shoulders provide limited vertical and horizontal clearance for truck traffic, leaving no current safe route for a pedestrian to traverse the railroad, shown in **Figure 1.2.**

Figure 1.2: Railway Underpass

Five alternatives for developing a safe route are investigated for feasibility within this report:

Option 1: Reduce the total number of lanes from two to one under the underpass, providing horizontal clearance for an elevated sidewalk on the north side (right side as oriented in **Figure 1.2**). Design considerations include disruption of traffic flow, safety clearance for pedestrians, and stopping sight distance (SSD) for vehicles.

Option 2: Widen the Highway 163 railway underpass to simultaneously accommodate safe passage of truck traffic and pedestrian traffic. Design considerations include limitations of right of way to railway-owned parcels, geotechnical stability analysis, cost, and proper safety clearance for both vehicles and pedestrians.

Option 3: Maintain two active lanes of traffic, but design a signalized pedestrian walkway parallel to the flow of traffic. The designed system would allow pedestrians to press a button to turn traffic signals in both directions to red. The pedestrian could then enter the road in a modified bike lane, traverse the underpass, and connect back to the sidewalk on the opposite side. Design considerations include safety, user familiarity with unique signalized system, warranting and permitting guidelines, and SSD.

Option 4: Design a pedestrian tunnel that cuts through the embankment below the railroad, adjacent to the road. Design considerations include soil stability, infiltration rates, disruption of railway foundation, and cost of similar projects.

Option 5: Use an at-grade crossing south of railroad, and construct a trail through the surrounding woods and floodplain that reconnects to Highway 163 west of the railway underpass. Design considerations include flood zone risk, accessibility to crossing, added distance to route, and requirements to purchase right of way from private landowners.

Component III: *Link to Charleston*. West of the railroad, Highway 163 connects to Route 11, which continues alongside the Bowater Paper Mill and connects to a bridge for pedestrians to access shopping centers in Charleston, TN. Design considerations for this component include modifications to existing slopes from the road surface along Highway 163 down to a wetland zone below, the need for a crosswalk between the Paper Mill and the parking lot on the opposite side of the road on Route 11, connection to the existing sidewalk on the west side of the bridge, and a potential buffer between pedestrians and the rapidly moving traffic along Route 11.

2.0 INITIAL SITE SURVEY

Since there was no existing survey data available for the proposed 2.0 mile sidewalk development as shown previously in **Figure 1.1**, a topographic survey was required before any detailed design work could be done. The purpose of this survey was to locate existing features in Calhoun including but not limited to: pavement, sidewalks, slopes, culverts, storm drains and surveying monuments. Locating the existing infrastructure in the town is necessary for determining the placement of the sidewalk route, slopes that require re-grading and stormwater facilities that need to be relocated. Because of the length of the proposed route, the roadway survey was divided into 4 major components: Sherwood Avenue & Main Street, Etowah Road, Lynncrest Avenue & Highland Avenue, and Route 11. Five total survey trips were required culminating in over 112 dedicated person hours.

The portions of Sherwood Avenue, west of Highland Avenue, and Main Street between Sherwood Avenue and Route 163, were surveyed on February 5, 2016. The topographic survey was performed with a Topcon Hiper V GPS unit to facilitate the use of an arbitrary coordinate system. The survey was initially established on an arbitrary coordinate system due to the inability to use the GPS system to locate the USGS control point in an area with abundant tree coverage. The edge-of-pavement, existing sidewalks and swales were located during this survey to allow the team to begin the preliminary design work for the sidewalk network. In order to establish surveying benchmarks to reference in a subsequent survey, a fire hydrant and a water valve at the northeast end of Main Street were also located.

On February 12, 2016, State Route 163, commonly known as Etowah Road, between Main Street and the Calhoun United Methodist Church, was surveyed using a Topcon Total Station. Due to the large amount of tree coverage, use of the GPS receiver was not feasible. While referencing the fire hydrant and water valve from the previous survey, three control points were established along this route to facilitate future survey work of the existing culverts, slopes, and Lynncrest Avenue. A topographic survey was performed on the edge of pavement, sloped easement, and concrete channel located on the north side of Etowah Road, adjacent to the baseball field. The USGS control point was located using the total station, which allowed the survey data for the proposed route to

be placed on Tennessee State Plane Coordinates. A week later, on February 19, 2016, the sections of Lynncrest Avenue and Highland Avenue connecting Etowah Road and Sherwood Avenue were also surveyed to complete the existing edge-of-pavement and sidewalk data for Component I in downtown Calhoun. The survey network for Sherwood Avenue & Main Street, Etowah Road, and Lynncrest Avenue & Highland Avenue is shown in **Figure 2.1**.

Figure 2.1: Map of Roadway Survey for Sherwood Avenue & Main Street, Etowah Road, and Lynncrest Avenue & Highland Avenue

Lastly, U.S. Route 11 between Etowah Road and the bridge crossing the Hiwassee River was surveyed on April 8, 2016, highlighted in **Figure 2.2**. The portion of Etowah between Route 11 and the railway underpass, as well as the slope adjacent to the floodplain culvert were located. The two intersections connecting Route 11 to the Paper Mill were surveyed extensively to allow the transportation designers to begin evaluating the crosswalks at these locations. Furthermore, the road profile was captured to provide the water resources designers with the roadway elevation data necessary to design the proposed storm drain.

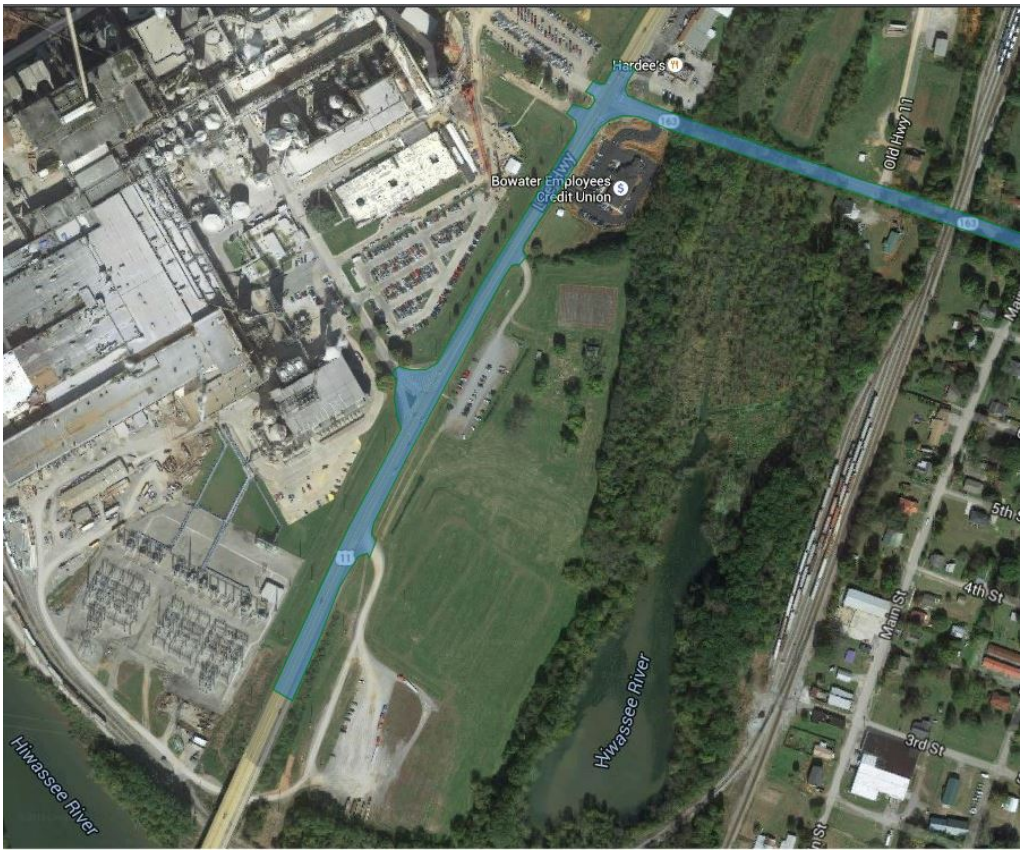

Figure 2.2: Map of the Completed Roadway Survey for Route 11 and remaining stretch of Etowah Road

3.0 HYDROLOGIC ENGINEERING

A hydrologic analysis was performed to identify existing stormwater measures and determine the necessary modifications to accommodate a pedestrian sidewalk. **Figure 3.1 and Figure 3.2** show the existing stormwater infrastructure for the entire network and include four swales, two ditches and a gravel-lined channel. Since the grassy swales are the primary drainage system for the town and provide the area with a notable amount of green space, the sidewalk layout is designed to minimize the disruption of existing stormwater management facilities. The proposed curb and gutter system along Etowah Road and Route 11 will have a noticeable impact on Calhoun's hydrology and will required upgrades to the existing stormwater management. It is also recommend to extend the swale near Calhoun Elementary to replace the existing eroded natural channel while regrading is being performed in the area. Since the existing swale meets TDOT requirements, using this profile to replace the existing natural channel will prevent future erosion issues. The existing swales and ditches adjacent to Etowah Road will need to be removed and replaced with a storm drain to accommodate the proposed curb and sidewalk system and the increased impervious coverage. A storm drain beneath the proposed sidewalk adjacent to Route 11 will also be required to convey the runoff from the added curb and inlets. These stormwater infrastructure improvements are analyzed in the following sections.

Figure 3.1: Existing Stormwater Management

Figure 3.2: Existing Stormwater Management, Highway 11

3.1 Sherwood Avenue Swale Improvements

A gassy swale is recommended to extend southwest along Sherwood Avenue to replace the existing natural channel that is heavily eroded, due to the shallow concentrated stormwater flow. Replacing this shallow channel with a larger, grassy swale will prevent erosion by increasing the cross-sectional flow area, and decreasing the flow velocity and shear stress imparted on the channel. Extending the existing swale near the elementary school will also enhance the aesthetics of the neighborhood while catching localized particulates from runoff and promoting infiltration and groundwater recharge.

Section 438 of the Energy Independence and Security Act of 2007 (EISA) mandates that the pre-development hydrology be upheld during and after the development of a site to prevent stream erosion from the increased stormwater runoff. Consequently, the hydrologic implications of the new sidewalk infrastructure and the stormwater improvements, such as increased impervious coverage and alteration of flow characteristics, need to be assessed prior to construction to prevent erosion and ecological impacts. It is imperative to preserve the health of the existing streams, including the swale that runs southwest along Sherwood Avenue as well as Etowah Road.

The Tennessee Department of Transportation (TDOT) Drainage Manual outlines several standards and suggestions for designing roadside ditches and vegetated swales. These standards highlight the appropriate equations and design storm to determine the discharge, capacity, location and geometry of newly constructed or retrofitted roadside channels. The Rational Method and a 10-year design storm, and maximum erosion resistance were selected based upon the criteria outlined in Section 4 of the TDOT Drainage Manual. The maximum shear stress that a sod-lined swale without turf reinforcement matting (TRM) can accommodate is 2 lb/ft^2. The following paragraph summarizes the calculations performed to ensure the proposed swale extension meets TDOT's capacity and erosion requirements.

The Rational method yielded the post-construction percent increase in the peak storm flow during a 10-year storm to be 1.84%. Additionally, Manning's Equation was used to determine the shear stress imposed on the swale by performing iterations to match the design flow to the corresponding flow depth, as shown in **Table 3.1**. The calculated shear stress applied to the swale during a 10-year storm is 1.42 lb/ft^2.

Table 3.1: Swale Flow Depth Calculations

Trial Depth (ft)	Flow Area (ft2)	Wetted Perm (ft)	R (feet)	n	Q (CFS)	V (FPS)
1.50	11.25	15.30	0.74	0.05	39.82	3.54
1.30	8.45	13.26	0.64	0.06	25.15	2.98
0.95	4.49	9.67	0.46	0.07	8.72	1.94
1.28	8.19	13.05	0.63	0.06	23.91	2.92

τ_{max}=	1.42	lb/ft^2

According to the Drainage Manual, the capacity of the swale still well exceeds the peak discharge from a 10-year storm event and can accommodate the applied shear stress from the stormflow. While the added impervious surfaces do not significantly affect the peak stormflow through the swale, it is recommended to replace the eroded channel during the construction and grading for the sidewalk to control further ecological impacts. Furthermore, it would be most cost effective to

upgrade the eroded channel while the surrounding topography is being regraded. The calculations for determining the peak discharge of the grassy swale in front of Calhoun Elementary School before and after construction of a sidewalk are included on Page 1 in **Appendix A**. The parameters used in these calculations as well as the results are summarized in **Table 3.2 and Table 3.3**.

Table 3.2: Rational Method Design Parameters

Drainage Area (Acres)	6.711
Curve Number (Unitless)	0.55
Storm Intensity (in/hr)	2.36

Table 3.3: Rational Method Design Results

Pre-Development Peak Discharge (ft^3/s)	8.71
Post-Development Peak Discharge (ft^3/s)	8.87
Percent Increase (%)	1.84
Capacity (ft^3/s)	48

3.2 Stormwater Drain Design Infrastructure

To manage the additional stormwater runoff created by the construction of a curb and sidewalk system, storm drains are necessary for sections along both Etowah Road and U.S. Route 11. The placement of the storm drain inlets and the sizing of the reinforced concrete pipe that will transport the runoff follows Section 7 of the TDOT Drainage Manual and is outlined in the following sections.

3.2.1 Etowah Road

A storm drain will be placed beneath the proposed sidewalk between Lynncrest Avenue and Main Street. The primary design considerations for inlet placement according to the Drainage Manual are roadway geometry and gutter flow spread. Inlets should be placed before intersections and at the bottom of sag curves, with a maximum spacing of 400 feet. Furthermore, the inlets must be placed to ensure that the spread of the gutter flow does not exceed 8 feet. Considerate of these constraints, a total of 8 inlets are necessary along Etowah Road. Locations of these inlets are identified in the project construction drawings.

The Drainage Manual also recommends using the rational method and Manning's Equation for calculating the size of the reinforced concrete pipe that will convey the stormwater. The runoff from each drainage area, the section of roadway between the inlets, was calculated and summed to produce the design flow rate for the storm drain. Based on the design flow rate, a 13" diameter pipe is sufficient. Due to the Drainage Manual's minimum storm drain sizes however, an 18" diameter pipe was selected. A summary of relevant calculation results for the storm drain calculations is featured in **Table 3.4**.

Table 3.4: Storm Drain Calculation Summary for Etowah Road

Drainage Area (Acres)	1.82
Design Flow (ft^3/s)	8.502
Storm Intensity (in/hr)	5.484
Pipe Diameter (in)	18

3.2.2 U.S Route 11

Seven inlets are required for Route 11, with the calculated placement of each highlighted in the project construction drawings. The max spacing for the first inlet was calculated using an allowable gutter spread of 8 feet and determined to be 682.44 feet. However, an inlet will be placed at a shorter distance since the entrance to the Bowater Credit Union intersects Route 11 before the maximum spacing for the first inlet. Furthermore, inlets are required at least every 400 feet due to the specifications outlined by the drainage manual. An extra inlet was placed before the crosswalk connecting the Paper Mill to the auxiliary parking lot to limit the gutter flow in an area with high pedestrian traffic. An extra inlet was also placed at the bottom of the sag curve as recommended by the drainage manual. The design flow rate and required pipe diameter were also determined using the Rational method and Manning's equation, and are reported in **Table 3.5.** Due to a shallower longitudinal roadway slope, the time of concentration for the drainage area of Route 11 is about 10 minutes longer than for Etowah Road. As a result, the storm intensity value for Route 11 is noticeably smaller and produces a smaller design flow rate. A 13" diameter pipe would be acceptable for this storm drain, but an 18" diameter pipe was selected to comply with the TDOT Standards.

Table 3.5: Storm Drain Calculation Summary for U.S. Route 11

Drainage Area (Acres)	1.81
Design Flow (ft^3/s)	5.16
Storm Intensity (in/hr)	3.36
Pipe Diameter (in)	18

3.3 Flood Plain Considerations

According to the Federal Emergency Management Agency (FEMA), a portion of the proposed sidewalk just west of the railway underpass intersects with the Zone AE 100-year flood plain, illustrated in **Figure 3.3**. Federal law requires that any new infrastructure improvements in a Zone AE flood plain must be properly elevated and documented as such. Before all the proposed sidewalk infrastructure improvements can be constructed, a Professional Engineer or Professional Land Surveyor must prepare a FEMA elevation certificate. Additionally, a city permit is required by Section 14-2 of the Calhoun City Municipal Code to document that the hydrologic impacts of new construction on flooding are properly addressed.

Figure 3.3: FEMA 100-year Flood Plain Map

4.0 TRANSPORTATION ANALYSIS

The transportation scope of the project includes designing new sidewalks, crosswalks, warning signs, pedestrian signalization, and traffic signals to support the new sidewalk infrastructure. The existing sidewalks, shoulders, and intersections are evaluated to ensure pedestrian safety and identify any required modifications. Design adheres to guidelines from the following associations: the Federal Highway Association (FHWA), United States Department of Transportation (USDOT), Tennessee Department of Transportation (TDOT), American Association of State Highway and Transportation Officials (AASHTO), Manual on Uniform Traffic Control Devices (MUTCD), the American with Disabilities Act (ADA), the United States Access Board (USAB), and the Transportation Research Board (TRB). The key components of transportation analysis for pedestrian infrastructure are described further in the following sections: sidewalk design, shoulder and curb design, sight distance determination, and crosswalk design.

4.1 Sidewalk Design

AASHTO pedestrian facility guidelines dictate that an access route intended for pedestrians must meet ADA requirements. Sidewalks should be accessible, have an adequate width, and allow pedestrians to have a sense of safety, continuity, clarity of routes and convenience to the users. The Calhoun sidewalk dimensions are designed according to ADA requirements and remain consistent throughout the entirety of the route with a 6 inch concrete thickness, 5 foot width, and 2% cross slope. However, since the sidewalk is an extension of the road, the grade of the sidewalk must maintain the same elevation as the existing grade of the road. All grading along the proposed sidewalk route meets ADA requirements of 8.33% grade except for a segment of sidewalk located on Lyncrest Ave. around 500 feet south of the Methodist Church (between Station 7+00 and Station 10+00 in the project construction drawings) where the grade was measured at 11%, pictured in **Figure 4.1**. The United States Access Board (USAB) acknowledges that existing physical constraints make the requirements for new construction infeasible at certain locations. Since the sidewalk is added to existing infrastructure with driveway entrances located throughout the 200 ft portion of the roadway, modifications to accommodate the appropriate grade are infeasible without hindering drivers' access to driveways. The USAB mandates that, "compliance

is required to the extent practicable within the scope of the project". This portion of the walkway makes up only 1.85% of the total walkway and can be avoided through an alternate route by continuing south and then west onto Sherwood Ave.

Figure 4.1: Site Conditions with 11% Grade

4.2 Shoulder and Curb Design

An analysis of current shoulder and curb radii is required to determine appropriate safety measures and modifications when incorporating new pedestrian infrastructure into the system. Current shoulder widths of 2 ft of asphalt on the entirety of the sidewalk route, with the exception of 6 ft concrete on Highway 11 due to its higher classification of traffic volume, were all determined to provide a safe and acceptable distance of separation and required no need for modification. However, installation of a 6 inch concrete barrier curb, shown in **Figure 4.2,** is recommended to provide drainage control, delineation of the pedestrian walkway, and assistance in roadside development. This barrier curb in addition to the existing shoulders increases the separation from the traveled roadway and the pedestrian walkway and thus increases pedestrian safety.

Figure 4.2: Barrier Type Curb

To analyze the safety for pedestrians traveling alongside intersections, the existing curb radii for each intersection were measured and calculated using Google Maps images, demonstrated in **Figure 4.3** with supporting figures and calculations in **Appendix B.** Measured curb radii ranged from 20 to 140 feet and were in most cases inconsistent, unclear, or didn't exist. To slow traffic speeds, a small effective curb radius of 16 feet is recommended from AASHTO's range for all intersections except for where Highway 11 intersects the Paper Mill. The larger radii here can be maintained to allow for the necessary vehicle deceleration and acceleration lanes. The modifications to curb radius require constructing the curb into the road, with a schematic of general effective radius shown in **Figure 4.4**. In addition to slowing traffic speeds, these modifications allow perpendicular curb ramps to be positioned parallel to the crosswalk path of travel, decrease crossing distances for pedestrians, and enhance the distinction between perpendicular and parallel traffic for people with vision impairments.

Figure 4.3 Existing Curb Radii

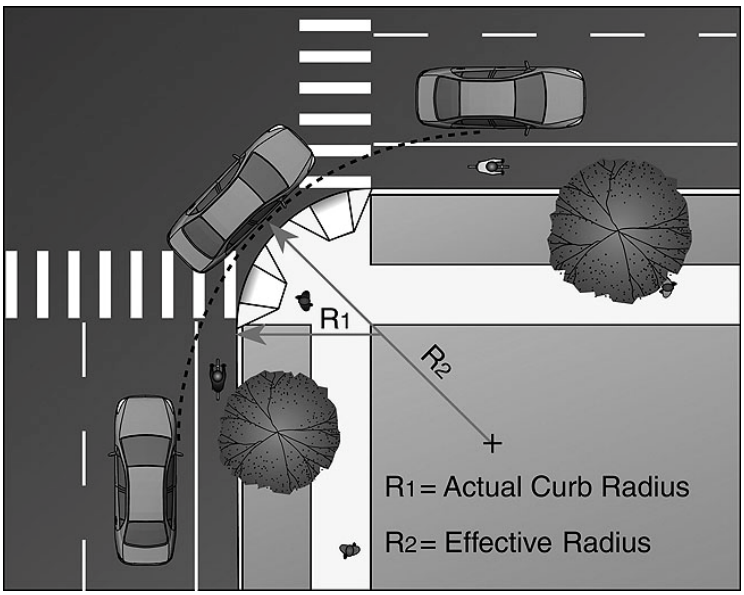

Figure 4.4: Curb Radius Schematic

To accommodate ADA accessibility, curb ramps must be included where crosswalks intersect the curb. Common curb ramp types of perpendicular and parallel were considered, but parallel was ultimately chosen because the perpendicular curb ramp is intended for 8 ft sidewalks and would not allow for sufficient landing area. **Figure 4.5** illustrates how the parallel curb ramp runs in line with the thinner sidewalk and maximizes use of space to meet grading requirements.

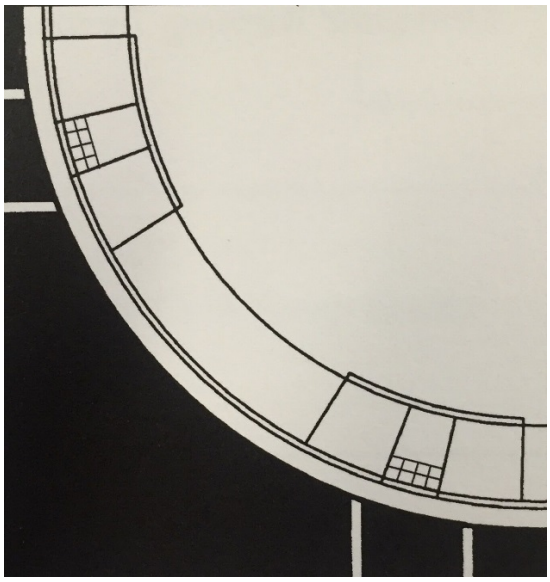

Figure 4.5: Parallel Curb Ramp Setup

The width of the parallel curb ramp is designed as 5 feet to match the width of the sidewalk, exceeding the minimum AASHTO requirements of 4 feet. To mark the street edge for the vision impaired, detectable truncated-dome warnings 2 feet in width are provided at each curb ramp, pictured in **Figure 4.6.**

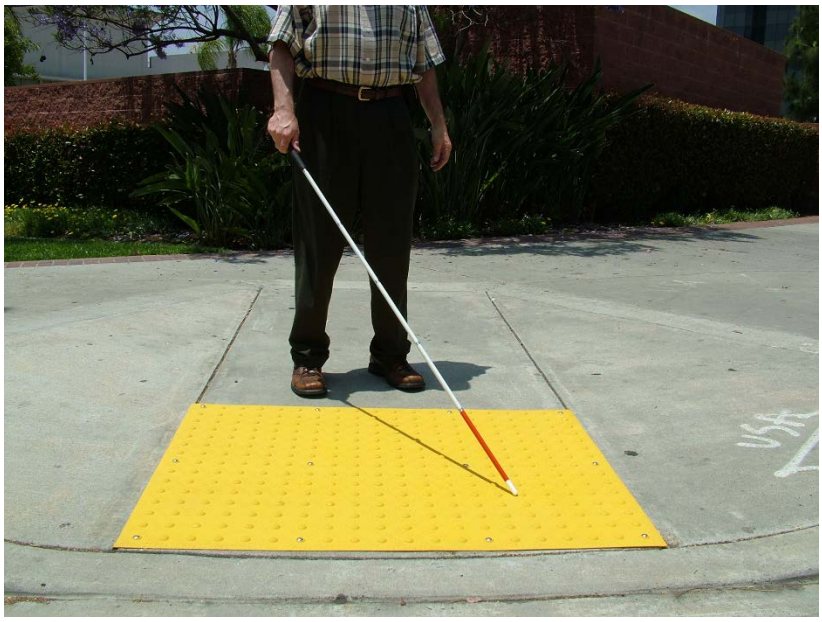

Figure 4.6: Detectable Truncated-Dome

4.3 Sight Distance

Intersection Sight Distance (ISD) was determined to ensure minimum requirements for the distance immediately after a driver is able to spot an object or individual to make a decision before the vehicle arrives at the specific intersection or crossing point. There are 8 critical intersections in the Calhoun sidewalk network where pedestrians will cross routes that vehicles enter and exit: Main Street & State Route 163, Sherwood Avenue & Church Street, State Route 163 & Lynncrest Avenue, State Route 163 & College Street, State Route 163 & Crockett Avenue, U.S. Highway 11 & Bowater Paper Mill entrance, and U.S. Highway 11 & State Route 163. All of these roadways have a speed limit of 35 miles per hour. According to AASHTO Guidelines, this 35mph speed limit corresponds to a minimum ISD of 390 feet. The ISD for each critical intersection was measured and calculated manually on site with a rolling tape measurer, demonstrated in **Figure 4.7** with further calculations in **Appendix B.** The ISD's for each critical point are show in **Table 4.1,** with distances that didn't meet the minimum requirement highlighted in yellow.

Figure 4.7 ISD Measurement Method

Table 4.1: Intersection Sight Distances

Intersection	Direction of Travel	ISD (FT)
Main Street & State Route 163	vehicle traveling west on State Route 163 towards the crosswalk intersecting State Route 163	918.6
Main Street & State Route 163	vehicle traveling east on SR 163 towards the crosswalk intersecting SR 163	597.1
Main Street & State Route 163	vehicle traveling south on Main St towards the crosswalk intersecting Main St	708.7
Main Street & State Route 163	vehicle traveling north on Main St towards the crosswalk intersecting Main St.	524.9
Sherwood Avenue & Church Street	vehicle traveling west on Church St towards the Crosswalk intersecting Church St	498.7
State Route 163 & Lynncrest Avenue	vehicle traveling west on SR 163 towards the crosswalk intersecting SR 163	502
State Route 163 & Lynncrest Avenue	vehicle traveling east on SR 163 towards the crosswalk intersecting SR 163	341.2
State Route 163 & Lynncrest Avenue	vehicle traveling north on Lynncrest Ave towards the crosswalk intersecting Lynncrest Ave	357.6
State Route 163 & College Street	vehicle traveling south on College St towards the crosswalk intersecting College St	361
State Route 163 & College Street	vehicle traveling east on SR 163 making a left turn onto College St	315
State Route 163 & Crockett Avenue	vehicle traveling east on SR 163 making a left turn onto Crockett Ave towards the crosswalk intersecting Crocket Ave	754.6
State Route 163 & Crockett Avenue	vehicle traveling west on SR 163 making a right turn onto Crockett Ave towards the crosswalk intersecting Crockett Ave	656.2
US Highway 11 & Papermill Entrance	vehicle traveling west on Highway 11 towards the crosswalk intersecting Highway 11	912
US Highway 11 & Papermill Entrance	vehicle traveling east on HWY 11 towards the crosswalk intersecting HWY 11	1804.5
US Highway 11 & Papermill Entrance	vehicle traveling west on HWY 11 making a right turn into the Papermill towards the intersecting crosswalk	656.2
US Highway 11 & State Route 163	Traveling north on SR 163 making a right turn onto HWY 11	426.5
US Highway 11 & State Route 163	Traveling west on HWY 11 making a left turn onto SR 163	524.3
US Highway 11 & State Route 163	Traveling east on HWY 11 making a right turn onto SR 163	426.5
US Highway 11 & State Route 163	Traveling west on HWY 11	787.4
US Highway 11 & State Route 163	Traveling east on HWY 11	1148.3
US Highway 11 & State Route 163	Traveling north on SR 163 making a right turn onto HWY 11	426.5

Two critical points did not meet minimum distance required for ISD: State Route 163 & College Street and State Route 163 & Lynncrest Avenue. Additional warning signs are therefore required for vehicles traveling south on College St, traveling east on SR 163 making a left turn on College St, traveling east on SR 163 towards the crosswalk intersecting SR 163, and traveling north on Lynncrest Ave towards the crosswalk intersecting Lynncrest Ave. With these additions, the designed sidewalk network will be clear of sight distance conflicts.

4.3 Crosswalk Design

The Calhoun pedestrian infrastructure improvements lead pedestrians to cross roads at 13 locations across the route, calling for the design of 13 total crosswalks. The following comprehensive crosswalk design incorporates all necessary components of markings, signs, pedestrian signalization, and warning beacons.

4.3.1 Markings

Crosswalk markings are designed to delineate safe paths for pedestrians, alert road users, and legally establish the sidewalk. According to the MUTCD, stop lines must be between 12 and 24 inches wide, and crosswalk lines must be between 6 and 24 inches wide. To enhance driver perception, the width of the lines is differentiated throughout the project: the stop lines are 24 inches wide and the crosswalk lines are 18 inches wide. A team-constructed traffic survey yielded a 10% heavy vehicle percentage, relatively high for a small road. Since the crosswalks may be unexpected and heavy vehicles obstruct sight distance, the crosswalks are marked with white lines at 45-degree angles to increase visibility rather than marking the crosswalk with transverse lines. The dimensions and placement of each crosswalk are located in the project construction drawings.

4.3.2 Signs

USDOT specifies that non-vehicular warning signs are to be used to warn vehicles in cases where conflicts with pedestrians may occur. Warning signs are to be located 500 feet in advance of the crosswalks on Highway 11 and S.R. 163 and at each crosswalk location. The pedestrian warning sign is used along with supplemental warning plaque, 500 ft, to indicate the distance the approaching vehicle is from the crosswalk. At the crosswalk line, the pedestrian warning sign is

used along with a diagonally pointed arrow plaque with the arrow oriented in the direction of the crossing. Each of the warning signs to be used are illustrated in **Figure 4.8.**

Figure 4.8: Non-Vehicular Warning Sign and Warning Plaques from USDOT.

4.3.3 Pedestrian Signalization

In cases where there is not sufficient vehicle signal guidance to indicate when pedestrians should start crossing the roadway, crossings should be pedestrian signalized to reduce vehicle-pedestrian conflicts in compliance with USDOT standards. Pedestrian signal heads are required for four crosswalks throughout the project: at the intersection of Highway 11 and the Paper Mill entrance, the crossing from the overflow parking lot to the northwestern island, the crossing from the southwestern island to the northwestern island, and the two crossings at the intersection of Highway 11 and S.R. 163. Pedestrian pedestals are located between the edge of the crosswalk line and the curb ramp, and the pushbutton detector is located between 1.5 and 6 feet from the edge of the curb for safety and efficiency. Pedestrian actuation signs are located above each pushbutton detector unit with the arrow pointing in the direction of the crosswalk. See the project construction drawings for the pedestrian signal head, the pedestrian pedestal, and the pedestrian pedestal locations.

The following signal and countdown timings are required for the pedestrian signalization operations. As seen in **Figure 4.9**, a one-section pedestrian head is used to illustrate the walking person, upraised hand, and change interval countdown indications. The start of the walk interval coincides with the conflicting vehicular green interval and is followed by the pedestrian change interval. The buffer interval starts at the beginning of the conflicting vehicular yellow interval, and the pedestrian change interval countdown counts down the remaining 10 seconds in the change interval to add safety and transparency to this system. Two modifications were required of vehicular green intervals to accommodate pedestrian crossing time and phase intervals and are located in **Appendix B**. A summary of the crosswalk locations and features can be found in **Table 4.2**.

Figure 4.9: One-section Pedestrian Signal Indications, USDOT.

Table 4.2: Crosswalk Locations and Features

Intersection	Number of Crosswalks	Description	Pedestrian Signals
Highway 11 and Paper Mill Entrance	4	Overflow Parking Lot to NW Island NW Island to Existing Sidewalk SW Corner to SW Island, SW Island to NW Island	Yes Yes
Highway 11 and S.R. 163	2	Crossing Highway 11 (north) & S.R. 163 (east)	Yes
S.R. 163 and Main St.	2	Crossing S. Main St. (north) & S.R. 163 (east)	
Sherwood Ave. and Church St.	1	Crossing Church St. (north)	
S.R. 163 and College St.	1	Crossing College St. (north)	
S.R. 163 and Crockett Ave.	1	Crossing Crockett Ave. (north)	
S.R. 163 and Lyncrest Ave.	2	Crossing S.R. 163 (W) & Lyncrest Ave. (S)	

4.3.4 Warning Beacons

In addition to pedestrian crossing warning signs, warning beacons will be mounted at both unsignalized crossings on S.R. 163. The flashing beacons will be pedestrian actuated so that pedestrians pushing the button will cause a single section of signal face to flash yellow at a rate of 50 times per minute and therefore warning drivers of a pedestrian crossing. Because over thirty percent of first harmful events in highway fatalities each year are caused by roadside obstacles and 20 percent of most harmful events are caused by roadside obstacles, the luminaire supports for flashing warning sign supports are breakaway supported. The breakaway part of the support is designed to release when the support is loaded in shear instead of bending stress when the force is applied at a bumper height of 20 inches.

5.0 RAILWAY UNDERPASS DESGIN AND OPTION EVALUATION

An accessible pathway is required for pedestrians to traverse the railway underpass along S.R. 163 and gain access to western Calhoun and shopping centers in Charleston. The dimensions of the existing railway underpass were evaluated to ensure all standards are currently met for underpass design based on AASHTO Guidelines. With a height of 14.5ft, total width of 27 ft, which is separated into 12 ft wide lanes and 1.5 ft shoulders, the current underpass meets all safety guidelines and does not pose a threat to vehicle traffic safety. Several options for a pedestrian traverse have been identified and are evaluated with respect to safety, cost, and accessibility.

5.1 Traffic Lane Reduction Design (Option 1)

Although the existing underpass dimensions pose no threat to vehicle traffic safety, the limited dimensions provide no available space for a sidewalk to maintain the current lane configuration. One method of transporting pedestrians through the underpass is to reduce the total number of lanes from two down to one. The 27 foot wide underpass provides room for a travel lane, extended shoulders, and an elevated pedestrian sidewalk. Elevating the pedestrian walkway increases pedestrian safety by reducing vehicle–pedestrian conflicts since the pedestrians and vehicles are space separated. In the event a vehicle crossed into the pedestrian walkway portion of the underpass, the vehicle would be prevented from hitting a pedestrian by the concrete walkway which enhances pedestrians' perception of safety. Traffic through the underpass would be regulated by a traffic signal on each approach. Vehicle safety would be maintained as vehicles would be time separated by the traffic signal.

The signalized approach, while ensuring safety for pedestrians, could potentially cause a disruption in traffic flow. Typical average annual daily traffic (AADT) averages around 50,000 for urban routes. A TDOT traffic study reported an AADT of 6,269 for Route 163, significantly lower than this average count. An underpass and signalized approach similar to the one in Calhoun exists on Blount Avenue along the South Knoxville Waterfront, with a lower but comparable AADT of 3,196. In order to accommodate pedestrian traffic, the underpass was reduced to one vehicle lane with an elevated sidewalk, pictured in **Figure 5.1** with a signalized approach illustrated in **Figure**

5.2 (KRTPO, 2014). Traffic flows for volumes as recorded on both Blount Avenue and Route 163 can be reasonably maintained and thus warrant the implementation of a lane reduction. Walkway, signal, and timing design were required to complete the design and are detailed in the following sections.

Figure 5.1: Blount Ave. Elevated Sidewalk (Southern Constructors, Inc. 2016)

Figure 5.2: Blount Ave Signalized Approach (Southern Constructors, Inc. 2016)

5.1.1 Pedestrian Infrastructure Design through Underpass

AASHTO Guidelines mandate grading and elevations for leveled walkways. The raised pedestrian walkway is recommended to be constructed of concrete and will align to the interior face of the underpass abutment wall. The ramps leading up to the leveled walkway under the underpass must not exceed 8% and the height of the walkway must not exceed 30 inches. This maximum height of 30 inches is recommended throughout the central portion of the walkway to maximize separation between vehicles and pedestrians, and the maximum 8% grade on the incline and decline on either side was maintained to limit the total distance of walkway needed. The cross measurements of the walkway follow specifications of the rest of the proposed sidewalk network with a width of 5ft and the cross slope of 2%. Hand railing will be attached to the walkway as specified in AASHTO Guidelines for any grade exceeding 5%. The traveled lane width for this design option will result in 13ft and a shoulder on both sides of 4 feet can be provided. A traffic signal is to be placed 50ft away from the underpass on both sides to alternate between green for westbound vehicular traffic and green for eastbound vehicular traffic.

5.1.2 Traffic Signals

In order to accommodate the modification to one-way traffic beneath the railroad underpass for this design option, cantilever supported traffic signals are to be installed at each approach according to USDOT standards. The vertical positions of the sections follow common MUTCD specifications of circular red, circular yellow, and circular green, from top to bottom. Two signal faces are installed at each approach, with backplates on signal faces to eliminate confusing backgrounds from the underpass. Dimensions and placement for each traffic signal are located in the project construction drawings, supported by calculations in **Appendix B**. Breakaway supports will not be used for the traffic signal supports since a fallen signal post support may be a vehicle obstruction. Instead, the signal supports are located outside of the clear zone for S.R. 163 at 14 feet from the edge of the traveled way.

5.1.3 Traffic Signal Timing

The distance between the outside edges of the stop lines at the traffic signals under the underpass is 135 feet to provide adequate clearance of the wingwalls. Slightly over 5 seconds are required for vehicles to clear the underpass based on vehicles' average rate of acceleration. The average

time to clear the underpass was calculated in **Appendix B** and combined with the headway to ensure the queue would clear without decreasing the level of service. To ensure the intersection operates at a minimum Level of Service of C, vehicle arrival rate during peak hour was used to design the signal timing. The total cycle length is designed to ensure conflicting delay is lower than 35 seconds. Interval length calculations are found in **Appendix B** and signal timing intervals are summarized in **Table 5.1**.

Table 5.1: Signal Timing Interval

Green Interval (s)	13.1
Yellow Interval (s)	5.0
Red Clearance Interval (s)	2.0
Total Cycle Length (s)	20.1 < 35.0

5.2 Widening of Railway Underpass (Option 2)

Another design alternative identified to safely allow pedestrians through the underpass is to lengthen the railway span over State Route 163. The purpose of lengthening the span would be to create a wider passage below the bridge which would maintain two vehicle lanes and allow for a safe pedestrian traffic route to connect the east and west portions of 163. The criteria for the feasibility study contained herein evaluates feasibility of this option with respect to demolition and construction costs and impact to traffic flow during the construction process.

Before any detailed design was considered, a representative from Amec Foster Wheeler Environment & Infrastructure, Inc. with experience in bidding similar projects was contacted to determine practicability in relation to similar projects. The representative referenced two projects in which they participated in the bidding process. The most similar of these projects was a equal span bridge with two 45 foot span lengths. This project required the stabilization of existing abutments and replacement of the bridge spans with an upgraded design. This project was bid on a six month time schedule with bids ranging from $1 million to $1.75 million, inclusive of the cost

of construction only. While this bridge design is of a larger scale than the bridge being considered for this feasibility study, it did not require demolition or reconstruction of the bridge abutments, activities that would significantly increase the financial investment necessary for this option. With a maximum target budget for the pedestrian connection project in Calhoun of $750K, the cost incurred by lengthening the bridge span over 163 would be prohibitive.

A possibility exists to attempt to warrant widening of the railway underpass due to a risk of vehicle safety. However, according to the U.S. Department of Transportation's National Highway Traffic Safety Administration, no fatalities have occurred in 2012, 2013, or 2014 through the underpass on S.R. 163. There have only been two crashes located on public property between 2014 and 2016. One collision occurred in February 2016 between a left turning vehicle traveling southbound on Highway 11 and a northbound vehicle on Highway 11. Another crash occurred November 2015 between a left turning vehicle on Lyncrest Ave. and a westbound commercial vehicle on S.R. 163. The damage was minimal and the crash was reported as property damage, $400-$1500. Since there have been no reported crashes in the underpass in the last two years, the underpass cannot be identified as a safety concern for vehicles and widening the underpass is not warranted due to vehicular safety.

5.3 Signalized Pedestrian Walkway (Option 3)

To avoid reducing the underpass to one lane as in Option 1, two lanes could be maintained with a 5 foot wide bike and pedestrian lane marked from the right edge of the northbound travel lane. The marked bike and pedestrian lane could be accessed through a pedestrian actuated signal. Pedestrian detector pushbuttons could be placed at each pedestrian approach to the underpass. When the pushbuttons are pressed, the vehicular traffic signals at each approach will transition from a green to a red signal indication, temporarily stopping traffic to allow pedestrians and bikes to travel through the underpass without vehicles. The vehicular signal indication will change from red to green after 23 seconds which accommodates pedestrian walking speed and a red clearance interval to ensure pedestrian safety, with supporting calculations shown in **Appendix B**. This option effectively reduces traffic delay by stopping traffic only when pedestrians are present. However, a negative aspect of this option is that separate designated pavement area does not exist

for each mode of travel; instead, vehicles, bikes, and pedestrians travel in the same lane. Bikes and pedestrians are instead time separated from vehicles by the signals. Familiarity with road conditions is a key factor for driver perception time. This option opposes standard driver behavior since drivers must drive through the bike lane, which could reduce vehicle safety as drivers are confused on what action to take.

5.3.1 Traffic Control

In order to accommodate the proposed pedestrian walkway, a defined pavement marking and guidance signs are necessary to indicate the bike and pedestrian travel lane. The bike lane pavement marking is a six inch wide, white line offset five feet from the edge of the travelled way. The bike lane shall be 70 feet long, starting at the base of each wingwall on each side of the underpass approach. Pedestrian pedestals will be located at the start of the bike lane from both directions. Bicycle and Pedestrian Permitted signs will be used at each approach to the bike lane to guide users to walk on the road following MUTCD Section B guidelines, picture in **Figure 5.3**. The location of the pedestrian pedestals and signs are indicated in project construction drawings.

Figure 5.3: Bicycle and Pedestrian Permitted Signs (USDOT, 2009)

5.3.2 Traffic Signals

The traffic signals and traffic signal timing for Option 3 are the same as designed in Option 1, except for the Signal Timing Interval. The green interval is indefinite since the light is pedestrian actuated. The yellow interval lasts 5.0 seconds, and the red interval lasts 23.0 seconds.

5.4 Pedestrian Access Tunnel (Option 4)

A concrete pedestrian tunnel was identified as a fourth alternative as it would eliminate conflicts between vehicles and pedestrians by completely isolating pedestrians from the roadway. This would require boring through the adjacent slope perpendicular to the railroad tracks and excavating the soil from beneath the north side of the underpass. During construction, temporary shoring is recommended as the site conditions do not contain soil material with sufficient capacity to maintain the open cut. Options for construction include either precast or cast-in-place concrete as a structural liner for the tunnel. Several factors are considered for the construction of this specific pedestrian tunnel, including: maintaining adequate drainage, avoiding excessive bearing stresses on the soils, accommodating the weight of the railcars traveling over the underpass, and providing sufficient lighting for the pedestrians traveling through the tunnel. Shallow tunnels such as this one would require the implementation of a 'top-down' modified method of a cut-and-cover technique whereby contiguous bored piling help to construct support walls and capping beams to carry the load of the railway. Although this would allow for a reasonably quick reinstatement of the railway, the disruption in rail traffic would still be significant. This method would be much less costly if it were to be considered at the initial construction of the railway underpass and not as a modification. Similar projects to this pedestrian tunnel range from $700,000 to well over $1,000,000. This would require significant funds for only a small portion of this overall infrastructure project and is thus considered cost prohibitive.

5.5 At-grade Crossing and Extended Sidewalk (Option 5)

Option 5 recommends the design of a pedestrian crossing 0.27 miles south of the underpass at an at-grade crossing, as shown in **Figure 5.5**. A private road crosses the railroad tracks 0.04 miles west of 3rd Street. Sidewalk infrastructure would be required from S. Main St., crossing the at-grade crossing and extending northwest 0.27 miles to connect to the sidewalk on S.R. 163. Pedestrian safety is concerning as pedestrians would be required to cross two lanes of railroad tracks. In addition, the topography is steeply sloped towards the floodplain to the west. ADA's Accessible Routes Guidelines requires cross slope to be 2.1% or less, which would be difficult to maintain across the site. Since the elevation as the route becomes closer to S.R. 163 is much lower than the elevation of the road, the ascent to the road would be greater than 5.0% which would not meet ADA's standards. The route would increase pedestrians' travel length by 0.61 miles to travel

around the underpass which according to AASHTO would inhibit pedestrians' decision to travel as most pedestrians limit their routes to 0.25 miles.

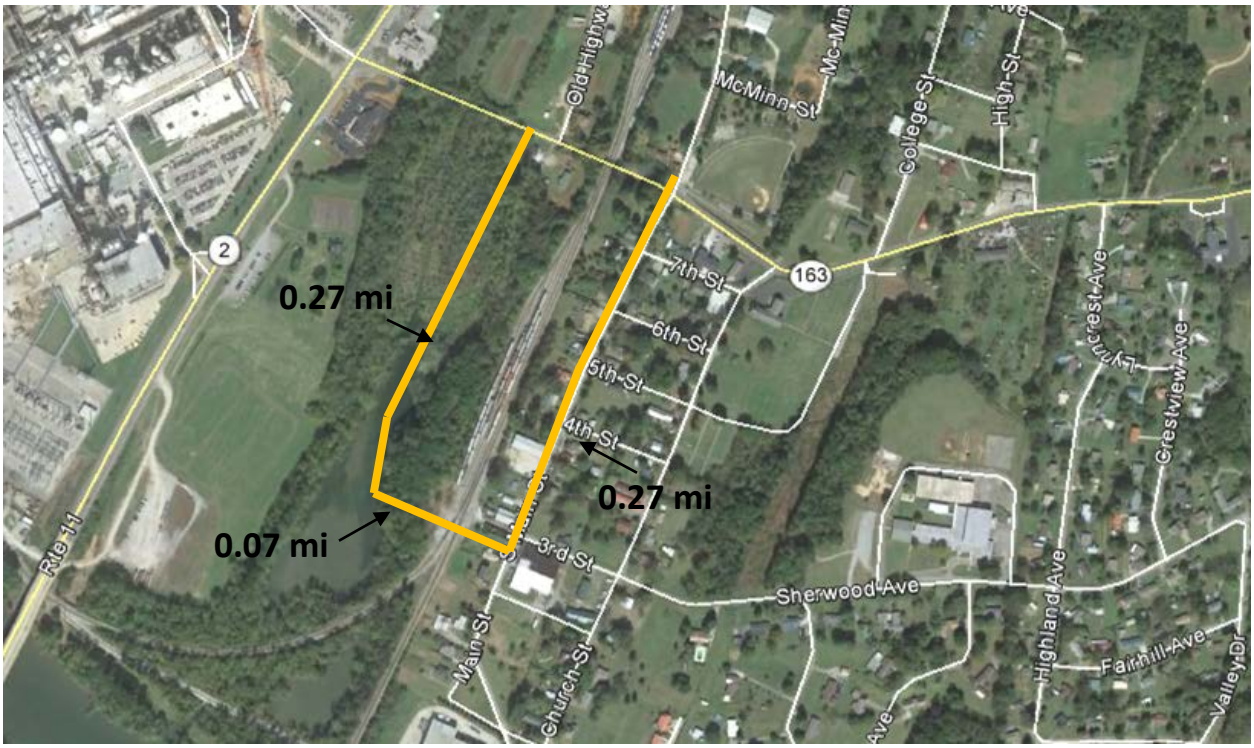

Figure 5.5: Pedestrian Route at At-Grade Crossing

5.6 Design Recommendations

After analysis of the 5 available options for traversing the railway underpass, recommendations for option selection follow primary objectives of safety, accessibility, and economic feasibility. Options 2 and 4 have projected costs beyond the scope of the scope of the project and cannot be justified by pedestrian or vehicular safety requirements. Option 5 extends the route in length and through high grade into a flood plain, all significantly limiting accessibility of the route to pedestrians. Options 1 and 3 were determined feasible through the engineering analysis and design described above. Although Option 1 demands a slightly higher cost and partially disrupts traffic flow, the team determined this as the safest design for both pedestrians and vehicular traffic. Option 3 is a unique design, which decreases the familiarity level of drivers and thus increases the safety risk of the system. Option 3 is still included as an alternative and could serve as a trial run if appropriate permitting was obtained from TDOT. However, the solution that optimizes all three primary objectives is Option 1.

6.0 RETAINING WALL DESIGN

A portion of S.R. 163 is currently restricted because of a steep slop adjacent to the road, making sidewalk construction unviable. In order to accommodate the necessary shoulder and sidewalks without disturbing the floodplain below, a segmental retaining wall is recommended. The front face of the wall is to be offset 15 feet from the existing roadway. The wall will be required to span 350 feet parallel to the road and will have a maximum height of 13.5 feet. A 3 foot segmental parapet is required at the top of the wall and a fence is recommended to improve pedestrian safety. The wall will require backfill comprised of free-draining #57 stone. The base of the wall shall be embedded into the existing soil at an average depth of 2 feet with a 6 inch crusher run leveling pad for structural support.

The brand *Stone Strong* was chosen as commercially available product suitable for such installation. This product was also chosen because its local availability makes it an economical choice. The design of the wall was completed using a proprietary design software offered through *Stone Strong* which conforms to the International Building Code. A sample of the block element configuration is shown in **Figure 6.1**, with full calculations and modeling provided in **Appendix C**. A detailed profile view can be found in the project construction drawings.

Figure 6.1: Retaining Wall Block Elements

7.0 CONSTRUCTION

To aid in developing a construction plan and cost estimation, the project was broken up into phases of similar cost that allowed for logical sequencing of funding and construction. The resulting three phases are illustrated in **Figure 7.1**. The first phase of the project is the west side of Etowah Road from the railroad bridge to the intersection of Etowah Road and Highway 11 and from Highway 11 to the bridge connecting Calhoun and Charleston. The second phase of the project encompasses the railway underpass on Etowah Road to the Calhoun United Methodist Church. The last phase of the project involves connecting downtown Calhoun to the local shops around the town. This component involves construction on Main Street, 3rd Street, Sherwood Avenue, Highland Avenue, and Lynncrest Avenue. Outlined in the follow construction plan is a summary of the scope of work, the scheduling of work, and the cost estimation.

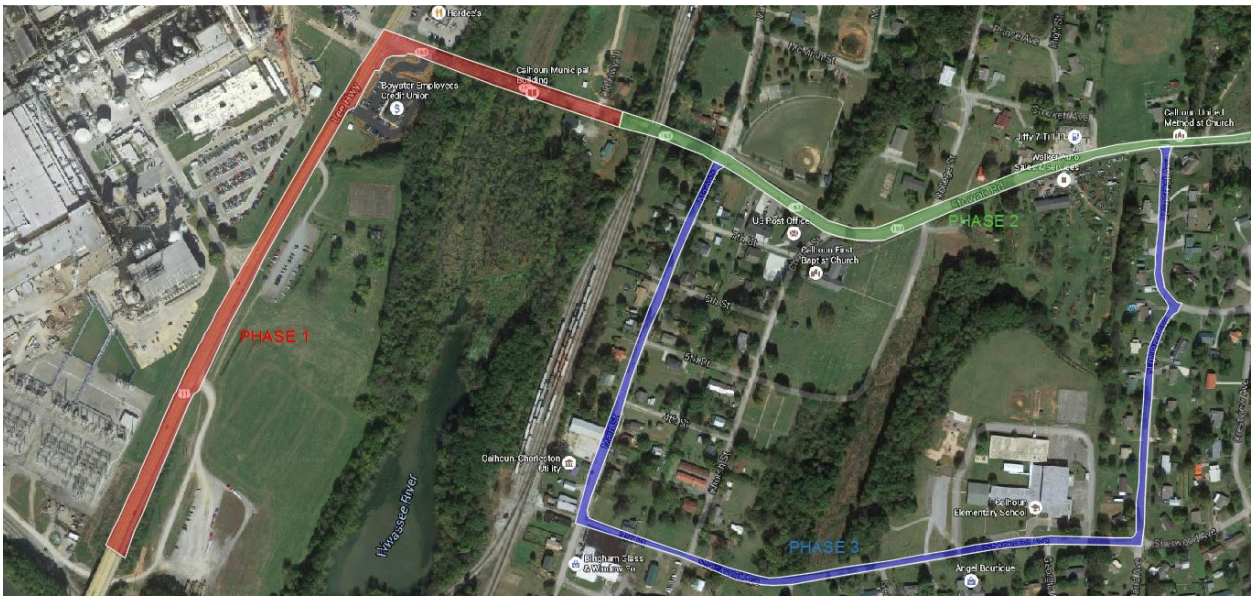

Figure 7.1 Phase Separation Diagram

7.1 Scope of Work

Each phase of the project, while similar, contains unique components to be considered during construction and cost estimation. Phase 1 of the project consists of installing a Redi-Rock retaining wall, sidewalks, curb and gutters, concrete pipe culverts, traffic control, and light clearing and grubbing. Phase 2 consists of installing signalization of the one lane underpass, sidewalk, curb and gutters, concrete pipe culverts, hand railing, and traffic control. Phase 3 of the project consists of

sidewalks, curb and gutters, concrete pipe culverts, and traffic control. The overall traffic control plan that is suggested is to have two flaggers with signalized signs along with barriers to prevent any civilians from entering the construction zone. Professionals from Brian Sitton Construction and PCL were consulted regarding their experience in estimating similar pedestrian infrastructure projects to help validate the estimation process.

7.2 Scheduling of Work

Due to potential corporate funding from the nearby Paper Mill, Phase 1 was expected to commence first. The scheduling of work is to start on Etowah road due to the retaining wall being the time critical aspect of this phase. The retaining wall was estimated to take 14 days to complete, while remaining times for excavation, culvert installation, grading, curbs, gutters, inlets, and sidewalks are summarized in **Figure 7.2** with supporting information in **Appendix D.** Highway 11 was scheduled in conjunction with Etowah road to reduce the overall duration of the phase. Highway 11 is scheduled to start 9 days after Etowah road has commenced with excavation and culverts scheduled to take 40 days due to the length of Highway 11. The overall duration for phase 1 is 43 days for Etowah road and 38 days for Highway 11. Simultaneous construction lead to an overall time of 44 working days to complete phase 1.

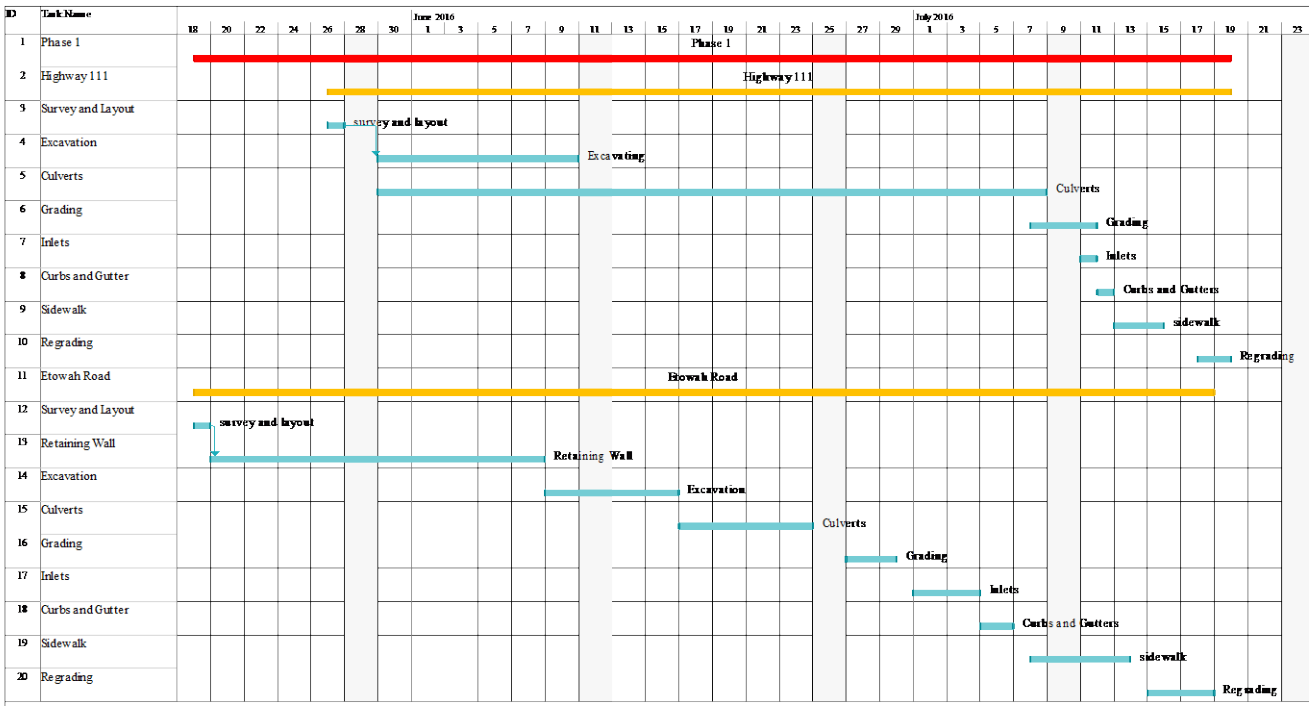

Figure 7.2 Phase 1 Scheduling

The scheduling of work for Phase 2 begins with installation the signalization of traffic lights. The large duration due to this work includes pouring a foundation for the signal poles and allowing the concrete to cure for 7 days to come up to strength as well as installing the electrical components. The durations of this phase have been estimated to be much longer than a typical section due to the large swells and traffic control needed on this phase. The work of this phase was scheduled so that work on the signalization of the underpass and work near the Calhoun Church begin at the same time so that the two crews will not interfere with each other's work. Construction on Etowah road from the church to the underpass is 35 days, with an overall duration of phase 2 of 39 days.

Phase 3 scheduling is planned to start on Main street and continue down to 3rd street, Sherwood Ave, Highland Ave, and then Lynncrest Ave. The durations of Phase 3 are fairly similar with respect to Sherwood Ave and Highland/Lynncrest Ave due to the lengths of the segments. Main Street is scheduled to take 22 days while Sherwood Ave. and Highland/Lynncrest Ave. are scheduled to take 33 and 28 days, respectively. Complete scheduling for three phases can be found in **Appendix D**.

7.3 Cost Estimation

The three phases of construction estimates for the Calhoun sidewalk project were developed based on a cost range of $750,000 to $1,000,000 contracts. This range was selected because it increases the chance of the City of Calhoun to be granted the contracts based on information given by the Tennessee Department of Transportation (TDOT) rather than combining the entire project into one lump sum. Initially, the costs were estimated manually with supporting calculations in **Appendix D.** However, to ensure accuracy and relevance to the project's construction, TDOT's estimation tool was used in determining final costs.

The first phase of the project was estimated at $953,000, idealized at $1,000,000, with a summary in **Table 7.1** and complete project breakdown costs located in **Appendix D**. This phase had a lump sum price of erosion and silt control of $2,500. Since the project site is relatively small a 0.2 quantity was added to the construction stakes, lines, and grades for a total value of $9,687.71. The retaining wall unit price that was selected was $57.27 per sf. This was selected due to Mike Bevin's from Rembco quoting us a price of $50.00 per sf for a Redi-Rock retaining wall. The traffic control

quantity for this phase was also modified to 0.5 for a total price of $10,858.52. This was also due to the relatively small size of this phase. A 0.2 quantity was also added for clearing and grubbing because of the small shrubs near the retaining wall area. Since this phase had a lot of risk factors with the unknowns of the retaining wall, a 10% other items cost and a 25% construction contingency is included in the overall price.

Table 7.1 Phase 1 Construction Cost Breakdown

Route:	**Highway 111 / Etowah Rd.**
Description:	**Component 1**
County:	**McMinn**
Length:	**3,159 ft**
Date:	**April 27, 2016**

DESCRIPTION		TOTAL
Construction Items		
Drainage		$130,400
Appurtenances		$108,800
Structures		$270,300
Earthwork		$48,000
Clearing and Grubbing		$12,200
Pavement Markings		$200
Maintenance of Traffic		$26,800
Mobilization (5%)		$29,800
Other Items	15%	$94,000
Const. Contingency =	25%	$112,600
	Construction Estimate	$833,100
Preliminary & Construction Engineering and Inspection		
Prelim. Eng. (10%)		$83,300
Const. Eng. & Inspec. (10%)		$83,300
Total Project Cost		$1,000,000

The second phase of the project was estimated at $795,000 as shown in **Table 7.2**. This phase used a quantity of 0.5 for the erosion control because the length of the phase was sufficient for a $1,250 erosion control cost. The construction stakes, lines, and grades quantity was determined to be 0.1 because of the length of the phase was around half the length of phase 1. This phase included the installation of traffic signals and after talking to Mike from Progression Electric who installed a similar one lane railroad underpass on West Blunt Ave. in Knoxville a quantity of 1 for the traffic signal at a cost of $120,000 was used. This phase also requires a significant amount of traffic control so a quantity of 0.5 was estimated. Due to the complexity of traffic control system, an 'other items' amount of 25% was used and a construction contingency of 15%.

Table 7.2 Phase 2 Construction Cost Breakdown

DESCRIPTION		TOTAL
Construction Items		
Drainage		$106,700
Appurtenances		$89,400
Signalization		$187,100
Earthwork		$5,500
Signing		$33,700
Pavement Markings		$300
Maintenance of Traffic		$16,300
Mobilization (5%)		$22,000
Other Items	25%	$115,300
Const. Contingency =	15%	$86,400
	Construction Estimate	$662,700
Preliminary & Construction Engineering and Inspection		
Prelim. Eng. (10%)		$66,300
Const. Eng. & Inspec. (10%)		$66,300
Total Project Cost		$ 795,000

The final phase of the project was estimated at $783,000 and is pictured in **Table 7.3**. Phase 3 used a quantity of 1 for the erosion control due to the route of the phase and the length. The construction stakes, lines, and grades quantity that was estimated was 0.6 also due to the amount of swells, route, and length. The traffic control quantity that was used was 0.2 due to the phase being in a neighborhood with low traffic volumes. The other items cost that was estimated was 15% due to these swells and the length. The construction contingency was estimated at 20% for these reasons as well.

Table 7.3 Phase 3 Construction Cost Breakdown

DESCRIPTION		TOTAL
Construction Items		
Drainage		$230,600
Appurtenances		$167,000
Earthwork		$22,600
Pavement Markings		$200
Maintenance of Traffic		$11,800
Mobilization (5%)		$21,600
Other Items	15%	$68,100
Const. Contingency =	25%	$130,500
Construction Estimate		$652,400
Preliminary & Construction Engineering and Inspection		
Prelim. Eng. (10%)		$65,200
Const. Eng. & Inspec. (10%)		$65,200
Total Project Cost		**$783,000**

The total amount of #57 stone under the sidewalk was calculated by determining the cubic feet of the sidewalk and dividing it by 27 to convert to cubic yards. The resulting value was then multiplied by 1.5 to convert to tons. A waste factor of 5% was then added to that number for the final tonnage of #57 stone. The curb and gutter cubic yards were calculated by a provided TDOT formula of 0.598 per linear foot.

The assumptions that were made using the TDOT estimation tool were that the sidewalk unit price included vapor barrier, wire mesh reinforcing, saw cuts, formwork, and sealing and curing. The unit price of the concrete culvert was also assumed that the cost of excavation was included. These three cost estimates are a realistic representation of construction costs if the proposed sidewalk infrastructure is to be constructed, and can be implemented as separate phases to aid in grant application success.

References

American Association of State Highway and Transportation Officials. (2011). *Roadside Design Guide*, 4th Ed. Including Changes through Feb. 2012.

American Association of State Highway and Transportation Officials 2. (2004). *Guide for the Planning, Design, and Operation of Pedestrian Facilities*.

Institute of Transportation Engineers. (2010). *Traffic Engineering Handbook*, 6th Ed.

Knoxville Regional Transportation Planning Organization. (2014). "Traffic Counts." <http://www.knoxtrans.org/traffic-counts>. (Mar. 8, 2016).

National Highway Traffic Safety Administration. (2014)." Location of Fatal Crashes – Tennessee." < http://www-nrd.nhtsa.dot.gov/ departments/nrd-30/ncsa/STSI/47_ TN/2014/Tennessee_Map_1_GIS_DATA_2014 .HTM > (Feb. 24, 2016).

Officer Joseph P. Maus. Calhoun Police Department. (phone call, February 24, 2016).

Southern Constructors, Inc. (2016). "Blount Avenue Reconstruction." <http://www.southern constructorsinc.com/blount-avenue-reconstruction.html> (Mar. 8, 2016).

Tennessee Department of Transportation Design Division. (2012). Traffic Design Manual. < https://www.tn.gov/assets/entities/tdot/attachments/Traffic_Design_Manual.pdf> (April 1, 2016).

Transportation Research Board. (2010). *Highway Capacity Manual 2010*, 5th Ed.

United States Access Board. (2002). ADA Accessibility Guidelines. <https://www.access-board.gov/ guidelines-and-standards/buildings-and-sites/about-the-ada-standards /background/adaag#4.3> (Mar. 10, 2016).

United States Access Board 2. (2002). ADA Accessibility Guidelines. < https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines/chapter-r2-scoping-requirements> (Apr. 7, 2016).

U.S. Department of Transportation. (2009). Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Ed. Including Revisions 1 and 2, dated May 2012.