RECREATIONAL TRAIL SYSTEM

KAKI Engineering, Inc.

Ian Crawford, Kelsey Berens, Ang Liu, Kelsey Andersen

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THE UNIVERSITY OF IOWA
Department of Environmental and Civil Engineering

1. Executive Summary

KAKI Engineering, Inc., an integrated design organization that is based out of Iowa City, Iowa and comprised of four talented civil engineers, has designed a new trail system for the nearby town of Muscatine. Ian Crawford, Ang Liu, Kelsey Berens, and Kelsey Andersen each attend the University of Iowa and have classroom experience and knowledge in designing infrastructure using AutoCAD, optimizing transportation systems, and analyzing different civil engineering materials and properties. Additionally, each team member possesses a specialized set of skills that stems from their individual internships and project experiences.

For the design of the trail system, KAKI mapped out an optimal route using AutoCAD that is best suited for connectivity and accessibility, contrived cross-sectional details with the selected material of Warm-Mixed Asphalt (WMA), determined the correct location for two pedestrian footbridges and designed the appropriate bridge foundations, measured the vertical slop of the trail's landscape to determine which area's require excavation, and implemented the appropriate signage and trail-crossing infrastructure. All design parameters were in accordance with the criteria listed in Chapter 12-B: Bicycle Facilities of the Iowa Department of Transportation (Iowa DOT) Design Manual and the Americans with Disabilities Act (ADA) for Sustainable Design. The trail bridges were designed and will be constructed by Contech Engineered Solutions LLC and in accordance with the Continental Pedestrian Truss Bridge standards for prefabricated bridges. Trail signage, including trail maps, way-finding signs, and mile-marker posts, are in accordance with the Manual on Uniform Traffic Control Devices (MUTCD).

At KAKI, we believe that the Recreational Trail System is an innovative solution to forge connections between the many parks and public spaces that make Muscatine a prosperous town. Additionally, the trail system is a sustainable solution for non-motorized traffic and encourages all-year use to promote community activity. While there are some challenges that KAKI must face in the completion of this project, including steep-sloping landscapes, cold construction weather, possible interferences with traffic, and simultaneous construction with the Welcome Center, all challenges will be met with inventive design at an estimated cost of $2,056,687 for all trail materials, supporting infrastructure, and labor.

2. Introduction

The City of Muscatine aims to increase its recreational opportunities by expanding the existing trail system. Muscatine currently possesses 10 miles of paved and unimproved trails and walkways as well as more than 20 parks with a combined 550 acres of land. Many of the trails are not interconnected and are absent from some regions within the city making it difficult to access parks and portions of the existing trails without a motorized vehicle. KAKI Engineering Inc., has designed a trail route that will not only connect Muscatine's existing trail system, but also improve accessibility to the city's many parks and public spaces.

KAKI Engineering, Inc. was founded by a team of four civil engineers who are currently enrolled in the Project Design and Management course at the University of Iowa. Ian Crawford, Ang Liu, Kelsey Berens, and Kelsey Andersen have each completed three years in the university's civil engineering curriculum and possess a substantial background in engineering principles, materials, and design. Among the four team members, each specialize in a different concentration within civil engineering including business management, architectural design, structures, and sustainable urban planning, respectively. Ian Crawford and Kelsey Berens have experience in surveying and analyzing transportation systems which made them the experts in determining a route best suited for safety, connectivity, and accessibility within Muscatine's already existing trail system. Ang Liu and Kelsey Andersen have experience in drafting designs for proposed infrastructure using AutoCAD and ArchiCAD software, thus authorizing them in the major trail design decisions.

3. Problem Statement

To expand and improve Muscatine's existing trail system, KAKI Engineering, Inc. has been charged to design a trail that connects the existing parks and public spaces by non-motorized traffic. Additionally, as there are many gaps in the existing trail network, the designed trail route shall connect to an existing trail. The trail route shall be designed as a shared-use path for day-time use during all seasons and shall implement the necessary infrastructure and signage along the trail as well as at trail crossings.

3.1. Design Objectives

The City of Muscatine boasts more than 10 miles of paved and unimproved trails and walkways as well as more than 20 parks with a combined 550 acres of land. The current trail system is disconnected and absent from some regions within the city making it difficult to access the many existing parks by non-motorized traffic. A new shared-use trail route is to be designed in the independent right-of-way to primarily benefit recreation and fitness and connect the Soccer Complex, Welcome Center, Agricultural Learning Center, and Discovery Park.

3.2. Approaches

After the initial site visit with City Engineer John Lutz, asphalt was determined to be the best option for the trail material. The trail route runs through heavily-sloped areas and therefore requires a flexible material that will not crack and is simple to repair. The smooth surface not only suits cyclists, runners, and pedestrians, but also adheres to ADA accessibility requirements. A more detailed discussion of the trail material can be found in Section 6, Final Design Details.

All parameters of the Recreational Trail System were designed in accordance with the Iowa DOT and ADA accessibility requirements including the bicycle design speed, minimum radius of curvature, stopping sight distance, trail width, trail material thickness, and minimum clearance to overhead obstructions. A full description of the design process and the equations used to determine the aforementioned parameters can be found in Section 6, Final Design Details.

Two bridges designed and constructed by Contech Engineered Solutions LLC will be required for the trail design. One bridge will be needed to cross the ravine that connects the designed trail to Discovery Park and the other will be installed to replace an existing bridge. The bridges are in accordance with the Continental Pedestrian Truss Bridge specifications for prefabricated bridges. The bridge foundation calculations are further discussed in Section 6, Final Design Details.

Way-finding signs were designed and implemented at intersections to indicate the directions to Muscatine's downtown area, the Welcome Center, and any nearby parks. The beginning of the trail includes a map that encompasses Muscatine's entire trail system as well as connecting regional and national trails. Additional mile-marker signs are stationed at the appropriate intervals along the trail and the appropriate infrastructure is equipped at the areas where the trail crosses a street. All signs follow the design requirements specified in the MUTCD and full explanation of the location and drawings of the signs can be found in Section 6, Final Design Details.

A permit with the Building Department of the City of Muscatine is necessary to begin excavation and grading for the trail system. The permit requires that if more than 500 cubic yards are to be graded, an engineered grading plan must be completed by a civil engineer. At the completion of grading, the civil engineering who prepared the plan must inspect and certify that the project is in accordance with the grading plan. The permit application can be found in Appendix A.

3.3. Constraints

One of the largest constraints that KAKI faced with the design of the Recreational Trail System was the sloping landscape. A large amount of excavation will be needed to make the steep slopes suitable for trail construction and since the trail routes fun though the forest near the Welcome Center, trees will have to be removed. At KAKI, we value sustainability and aim to minimize the impact that this project will have on the surrounding environment, therefore, the trail route was strategically mapped out to have as little impact on the existing landscape as possible while still maintaining the integrity and recreational purpose of the project.

Another high-priority constraint for this project was to coordinate the trail route design with the Welcome Center design as both projects utilize the same plot of land. One of the main roads designed for the Welcome center intersects a portion of the trial system and to accommodate for this interference, the appropriate signage for the trail crossing was designed and implemented by the Welcome Center group.

Soft constraints included the project time limit (February 26 to May 9) and ensuring that the trail system design met the aesthetic and social expectations of Muscatine's residents. By implementing pedestrian footbridges and utilizing asphalt as the trail material, a simple design for a natural and visually appealing trail system was both warranted and feasible in the given time frame.

3.4. Challenges

The Recreational Trail System project is concurrent with the Welcome Center project, therefore the construction periods will occur simultaneously. Additional challenges include making sure that the excavation does not interfere with the natural water drainage and accounting for unpredictable weather changes and temperatures. To account for the possible time lost caused by weather and conflicting construction with the Welcome Center, extra work will have to be done to ensure that the trail system is completed in the given time frame. Added costs due to extra work and the construction of the bridge pose as another challenge in keeping the cost as low as possible while maintaining the design integrity that KAKI guarantees. The Lucas Street crossing will also subject to a level of scrutiny if traffic is negatively impacted by the HAWK beacon.

3.5. Societal Impacts

As stated in the City of Muscatine's Comprehensive Plan, "The ultimate vision is for a fully connected trail network providing access to all areas within Muscatine and with connections to larger regional and national systems." KAKI believes that the completion of the Recreational Trail System will act as a catalyst for further trail development to promote connections between the many parks and public spaces that make Muscatine a thriving town. Additionally, the connection between the Soccer Complex, Welcome Center, Agricultural Learning Center, and Discovery Park will make each of these public spaces more accessible by multi-modal use. Not only with the Recreational Trail System act as a catalyst for new local connections, but it will also recognize the need to forge connections to the federally recognized trail systems that intersect in Muscatine including the American Discovery Trail and the Mississippi River Trail.

In January 2013, Muscatine became a Blue Zones Project demonstration site. As part of this project, Muscatine began incorporating permanent environmental and social policy changes that transition its residents to healthier behaviors that inherently lead to longer and happier lives. These policy changes included designing infrastructure to support non-motorized travel. The Recreational Trail System provides new routes for non-motorized traffic, therefore lending itself to environmental and social sustainability. With the encouragement of non-motorized traffic, KAKI also aims to utilize the trail system all-year long, especially during the winter months. Activities such as cross-country ski trails and different hiking routes will be implemented during the colder months and as a result, promote community within the City of Muscatine.

3.6 Ethical Analysis

Throughout the course of the design and construction of the Recreational Trail System, KAKI Engineering, Inc. recognizes that there are a series of ethical issues such as project impact on the surrounding environment and the safety and security of the trail system, which our organization handles with the utmost integrity and professionalism. The major stakeholders involved in the project include the Muscatine city officials, the Iowa DOT, and the citizens of Muscatine and surrounding town who will be utilizing the trail system.

3.6.1. Environmental Impact

Our organization has carefully mapped out two connecting trails that do not interfere with any private properties and have the least environmental impact as possible. The trail's starting point is located on the northwest corner of the intersection at Hershey Avenue and Houser Street and continues along Houser Street until it divides into two separate paths. The first path heads northwest through a series of winding curves and ultimately snakes around the back entrance of the Welcome Center. Each path meets at the northernmost point of the Welcome Center property and continues past the Agricultural Learning Center along the property boundaries located near Highway 61 until connecting to the existing trails at Discovery Park.

Upon extensive research of the surrounding properties, it was determined that the trail will only intersect properties that are used for public facilities with the exception of the trail crossing at Lucas Street. Directly north of the Welcome Center property, on Lucas Street, resides the outer boundaries of a subdivision. To ensure that the private properties in the subdivision will not be impacted by the trail system, the Lucas Street crossing was proposed to be located further west, near Highway 61. While the location of the crossing ensure that the subdivision properties will not be affected, the only alternative for the trail is to continue through the right-of-way that runs parallel to Highway 61. With the permission from the Iowa DOT, KAKI Engineering, Inc. will utilize the right-of-way so as to not affect the surrounding private properties.

With the concern of the surrounding properties comes the consideration of the impact that the trail system will have on the natural environment. It is inevitable that the threes will need to be removed on the Welcome Center property to accommodate the trail system; however our organization intends to utilize the tree removal as a means of increased visibility. Additionally, asphalt was selected as the trail material to have the least environmental impact because it requires little maintenance due to its durability and flexibility. Warm-Mix Asphalt (WMA) was chosen over Hot-Mix Asphalt (HMA) since it requires less heat and energy, thus further reducing the project's environmental impact. A further comparison between the different trail materials can be found in Section 4, Preliminary Development of Alternative Solutions.

3.6.2. Safety and Security

At KAKI Engineering, Inc. safety is our topmost priority. Our organization ensure that all designs are contrived to optimize the safety of all stakeholders as well as safely implement engineering practices during the construction process. The path curves are designed with a wide radius and few trees for ideal visibility that will inherently prevent collisions between trail users. Additionally, since visibility is decreased during evening hours, trail use is discouraged and promoted through the lack of pathway lighting.

Trail safety is also promoted through clear trail signage and safe crossings. The portion of the trail that runs through the Welcome Center property only requires a trail crossing sign where the trail intersects one of the main roads of the Welcome Center. The rest of the trail is supplemented with informational trails signs that indicate the direction and distance to downtown Muscatine and to surrounding parks and public facilities. A high-intensity activated crosswalk (HAWK) beacon will be installed at the Lucas Street crossing to ensure safety for both trail user and motorists. The beacon acts as an efficient solution to protect trail users while they cross as it only stops the traffic as needed.

4. Preliminary Development of Alternative Solutions

During the development of alternative solutions, our organization was primarily focused on feasibility. For instance, given the time constraints of the project, we felt that it was the most feasible to design a trail with three paving material alternatives rather than three separate trails. We are confident that our trail route utilizes the surrounding landscape in a challenging yet enjoyable way for the trail users.

As asphalt was requested to be the paving material, three asphalt alternatives were considered including warm-mix asphalt (WMA), hot-mix asphalt (HMA), and porous asphalt. HMA is the most durable of the three materials as it has a low moisture content and despite its low viscosity, HMA is quite flexible. Since our organization aims to encourage all year use, especially during the winter months when paved roads suffer from weathering, HMA would be the best option because of its durability; however mixing HMA requires a large amount of energy due to its high mixing temperatures. High consumption of diesel fuel then attributes to higher costs and greenhouse gas emissions.

Porous asphalt was another design option as it has both high flexibility and durability, though it is not as durable as HMA. It reduces the need for storm sewer systems, thus reducing storm water impact fees. Additionally, porous asphalt provides a storm water management system within its paving that promotes infiltration, improves water quality, and eliminates the need for a detention basin. Unfortunately, due to the air voids in the asphalt, a higher volume of material is needed, thus creating higher initial and constructions costs than HMA and WMA. Also, since the landscape is already sloped, water run-off already occurs naturally.

WMA was selected as the trail material as it is both durable and flexible, but also because it is a more sustainable material than HMA. While the initial cost of WMA is more per ton than HMA, it requires less heat to mix therefore requires less fuel and subsequently reduces fuel cost and gas emissions. Additionally, since it can be mixed at lower temperatures, the paving season is extended into the colder months. Per our project's timeline, asphalt paving will occur during the months of November and December. The only challenge that arises from using WMA is adjusting HMA equipment to a steady state flow which could potentially increase construction costs and take up valuable time.

5. Selection Process

To determine the trail route for the Recreational Trail System, the surrounding environment and residents were the main considerations. Our organization has carefully mapped out two connecting trails that do not interfere with any private properties, have the least environmental impact as possible, and still boasts a challenging yet enjoyable trail experience. We chose to split the path on the Welcome Center property to offer trail users different options. The first trail splits off heading west into a series of challenging curves that climb the natural elevation. The second trail is designed to be more leisurely as it follows the slopes of the natural landscape up to the north end of the property. Upon extensive research of the surrounding properties, we found a residential subdivision directly north of Lucas Street. The trail was initially supposed to cross Lucas Street near the subdivision, but in order to cause the least disturbance on private properties as possible, the crossing was moved further west, next to Highway 61.

With the consideration of the surrounding properties comes the concern that this project will have on the natural environment. A large amount of excavation and grading will be needed to ensure safe cross-sectional and vertical trail slopes and it is therefore inevitable that a many trees will need to be removed. Our organization intends to utilize tree removal as a means of increased visibility on the trail curves which inherently will improve safety. The environment was also a large concern when determining which kind of material to use for the trail pavement. WMA was chosen over HMA and porous asphalt because it requires less energy and subsequently reduces gas emissions due to construction.

John Lutz, City Engineer for Muscatine, had suggested that we work with a bridge contractor to design the project's two bridges due to time constraints. Contech Engineered Solutions LLC provided the necessary designs for the bridges while our organization contrived drawings of the bridge foundations and calculated the allowable loads for each foundation.

6. Final Design Details

The trail's starting point is located on the northwest corner of the intersection at Hershey Avenue and Houser Street and continues along Houser Street until it divides into two separate paths. The first path heads northwest through a series of winding curves and ultimately snakes around the back entrance of the Welcome Center. The second path continues north along Houser Street while following the slopes and curves of the natural landscape. Both paths meet at the northernmost point of the Welcome Center property and continues past the Agricultural Learning Center along the property boundaries located near Highway 61 until connecting to the existing trails at Discovery Park. Figures 6.1. and 6.2. show the entire trail route and bridge locations.

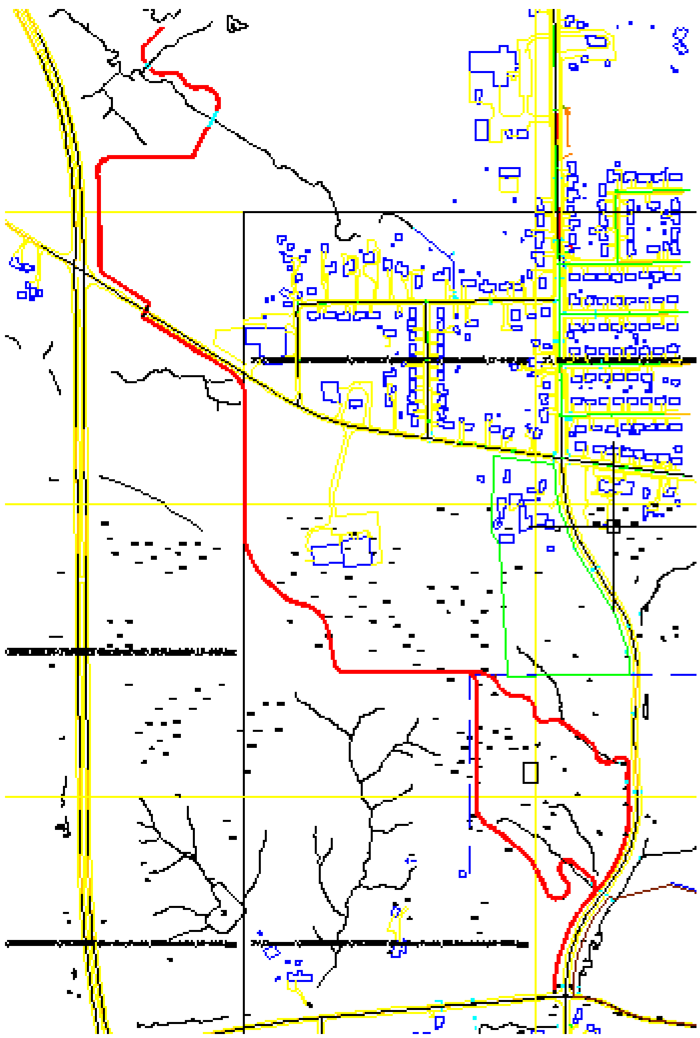

Figure 6.1: Recreational Trail System route.

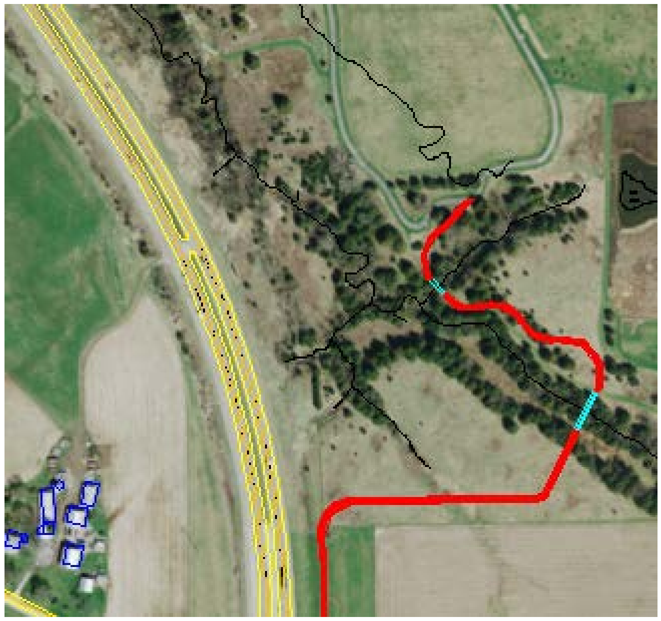

Figure 6.2: Trail connection at Discovery Park and location of bridges.

6.1. Trail Material

After the initial site visit with City Engineer John Lutz, we determined that asphalt, specifically warm-mix asphalt (WMA), was the best option for the trail material. The trail route runs through heavily-sloped areas and therefore requires a flexible material that will not crack. Additionally, WMA is simple to repair with minimal maintenance, thus rendering it more permanent. Asphalt resurfacing is scheduled every five years; however it should only be scheduled as needed. The smooth surface not only suits cyclists, runners, and pedestrians, but also adheres to ADA accessibility requirements.

Per the project timeline, asphalt paving will take place during the months of November and December. WMA has the ability to be paved at lower temperatures, therefore utilizing the colder months of winter by extending the paving season. Additionally, paving at reduced temperatures requires less energy and therefore decreases the fuel consumption and greenhouse gas emissions.

6.2. Cross Sections

Figure 6.2.1 displays the cross-sectional details of the trail design.

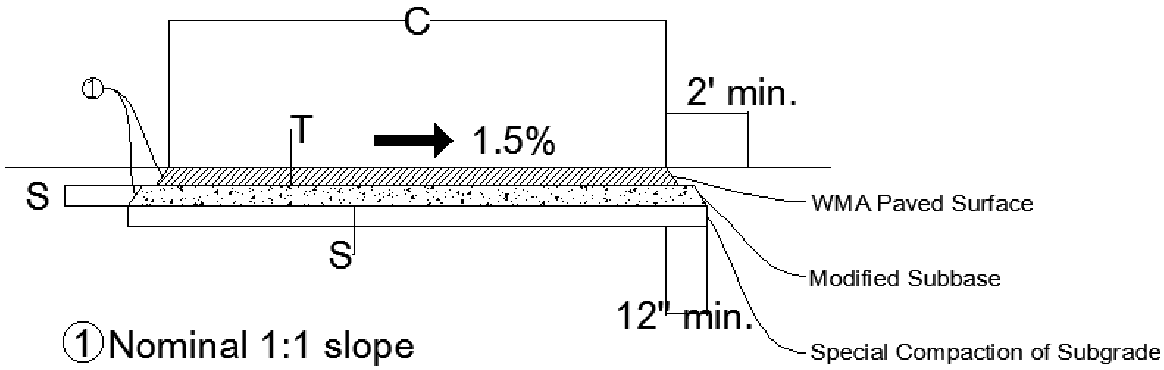

Figure 6.2.1: Trail cross section through unimproved land.

In accordance with the Iowa DOT and ADA accessibility standards, the paved trails will be 12 feet wide with a 5 inch thick WMA surface, 6 inch thick granular sub base with 6 inches of compacted soil underneath as a sub grade. The trail is designed to have a cross-sectional slope of 1.5%. Since the trail was constructed at least 5 feet away from Houser Street on its starting segment, safety barriers will not be necessary. The minimum vertical clearance to overhead obstructions, such as trees and brush, will be 10 feet and the minimum graded shoulder width and maximum shoulder area cross slope will be 2 feet and 6:1, respectively. Additional drawing of cross sections from different sections of the trail can be found in Appendix C.

6.3. Design Speed

According to the Iowa DOT, typical design speeds for bicyclists are between 20 and 30 miles per hour. We chose 25 miles per hour as an average.

6.4. Radius of Curvature

A preliminary trail drawing was first rendered with the appropriate curves. After determining that the minimum radius of curvature for a design speed of 25 miles per hour is 18.5 feet, each curve was then measured and checked to ensure that its radius exceeded 18.5 feet. The calculations for determining the minimum radius of curvature can be found in Appendix B.

6.5. Stopping Sight Distance

For a design speed of 25 miles per hour, the minimum stopping sight distance for a bicyclist is 103.65 feet. The necessary stopping sight distance equations and calculations may be found in Appendix C.

6.6. Bridge Foundations

A 100 foot long pedestrian bridge will be placed south of Discovery Park to cross the deep ravine and stream area. An additional 50 foot long pedestrian bridge will be installed to replace an existing 8 foot wide as the existing bridge is too narrow to support the desired shared-use trail activities. Both pedestrian bridges will be purchased and installed by Contech Engineered Solutions LLC. Contech provides the specifications for the bridge and design. The width of the pedestrian bridges will be 10 feet as it is the largest standardized size available through the subcontractor and both bridges will be designed in the style of the Connector Pedestrian Truss Bridge. Safety rails will be implemented into the bridge designs as vertical pickets with pipe handrails. The wood decking will give the bridge a natural and aesthetic appeal while the self-weathering steel will blend in with and adapt to the surrounding environment, thus requiring little maintenance. Figures 6.6.1, 6.6.2, 6.6.3, and 6.6.4 display general the designs of the bridges. Dimensioned drawings of the bridge foundations can be found in Appendix C.

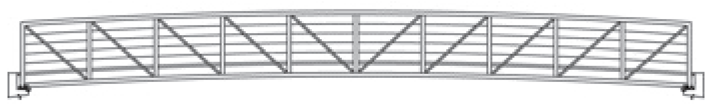

Figure 6.6.1: Design sketch of the Connector Pedestrian Truss Bridge.

Figure 6.6.2: Wood decking.

Figure 6.6.3: Vertical picket and pipe handrail.

Figure 6.6.4: Weathering steel.

Both bridges were designed with the same specifications.

According to Contech, the dead load on each foundation of the 100 foot bridge will be 21,000 pounds and the live load will be 43,570 pounds. The maximum LRFD factored loading will then be 94,912 pounds on each foundation. The foundations will be 11 feet long by 6 feet wide and 12 feet deep. All four foundations will have the same dimensions. Detailed design calculations for the bridge foundations can be found in Appendix B.

6.7. Signage

The Recreational Trail System incorporates three types of signs along the trail including mile marker posts, trail maps, and wayfinding signs. As the total length of the trail is 1.62 miles, six mile marker posts will be placed at quarter-mile intervals along the trail and one post will be placed at the start of the trail at the intersection of Hershey Avenue and Houser Street. Each of these seven posts will be 6 inches in both length and wide and 48 inches in height with two sides of text displaying the mileage and diagrams of the trail activities that are supported by the trail. Additionally, three trail maps and three wayfinding signs that exhibit the directions to the area's surrounding public spaces, will both be placed on the trail at the Houser Street and Hershey Avenue entrance, the Discovery Park entrance, and where the trail splits into two paths on the Welcome Center property. Figures 6.7.1., 6.7.2., and 6.7.3., display renderings of each type of sign.

Figure 6.7.1: Trail map sign.

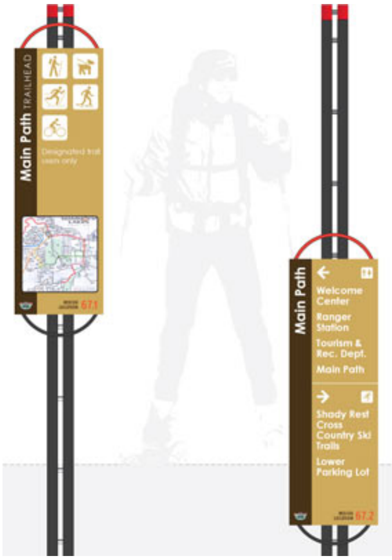

Figure 6.7.2: Wayfinding signs.

Figure 6.7.3: Two-sided mile marker posts.

6.8. ADA Ramps

To ensure that our trail design is ADA accessible, ADA ramps will be installed at all intersections including the trail entrance at Houser Street and Hershey Avenue and the Lucas Street crossing. The Lucas Street crossing will have two ADA ramps, one for each direction, and the trail entrance will have only one ramp. Renderings of the ramps are shown in Figures 6.8.1. and 6.8.2..

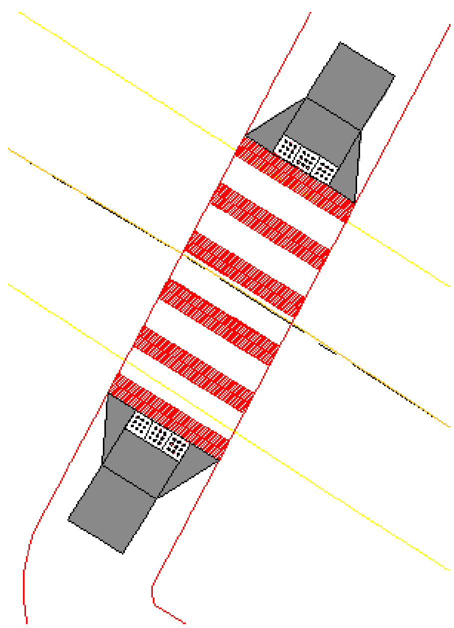

Figure 6.8.1: Cross walk at Lucas Street with ADA ramps.

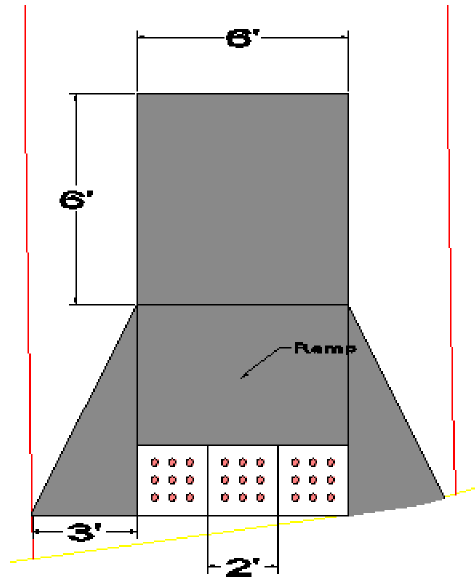

Figure 6.8.2: ADA ramp dimensions.

6.9. Vertical Slope

The Iowa DOT standards for shared-use path vertical slope grades are as follows:

- 8.3% for a maximum of 61.0 m (200')
- 10% for a maximum of 9.14 m (30')
- 12.5% for a maximum of 3.05 m (10')

Vertical slopes were measured at eight sections along the trail and only one section required excavation. A table and map of the vertical slopes is depicted in Appendix C.

6.10. HAWK Beacon

The HAWK beacon is a specialized hybrid beacon that is used to warn and control traffic at un-signalized locations and assist pedestrians in crossing a street or highway at a marked crosswalk. A beacon will be placed at the Lucas Street crossing in order to safely assist trail users to the other side of the street.

The beacon is activated when the pedestrian or cyclist presses a pushbutton. Flashing yellow lights caution on-coming traffic for seven seconds before turning a solid yellow for four seconds. Before the pedestrian or cyclist can cross the street, a red light is signaled for 3 seconds to ensure that no vehicles cross the crosswalk. The pedestrian or cyclist is then able to safely cross the street. When no pedestrians or cyclists are present, the beacon stays black so as not to disrupt traffic. Figure 6.10.1 displays the sequence of signals for both trail-users and motor vehicles.

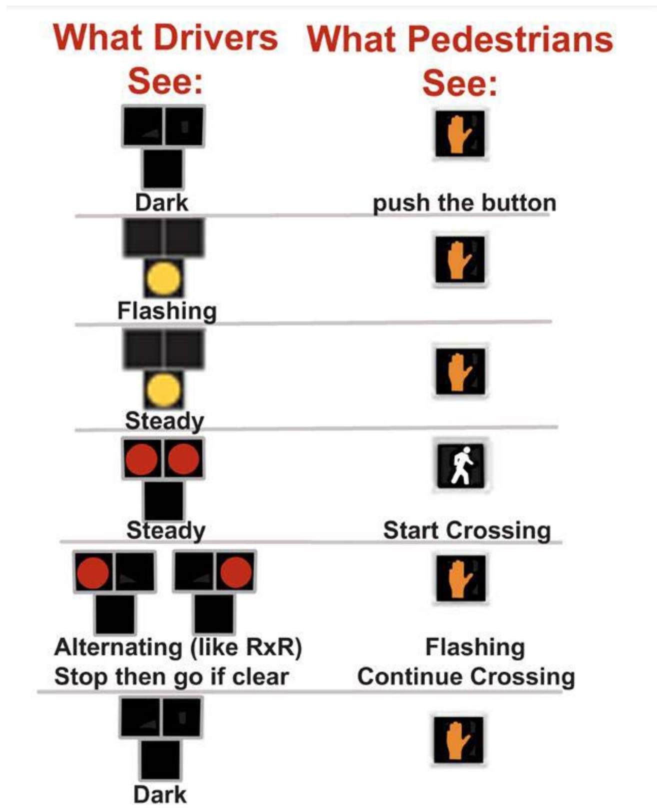

Figure 6.10.1: Sequence of HAWK Beacon signals.

7. Cost and Construction Estimates

Figure 7.1. displays the estimated timeline for the Recreational Trail System construction.

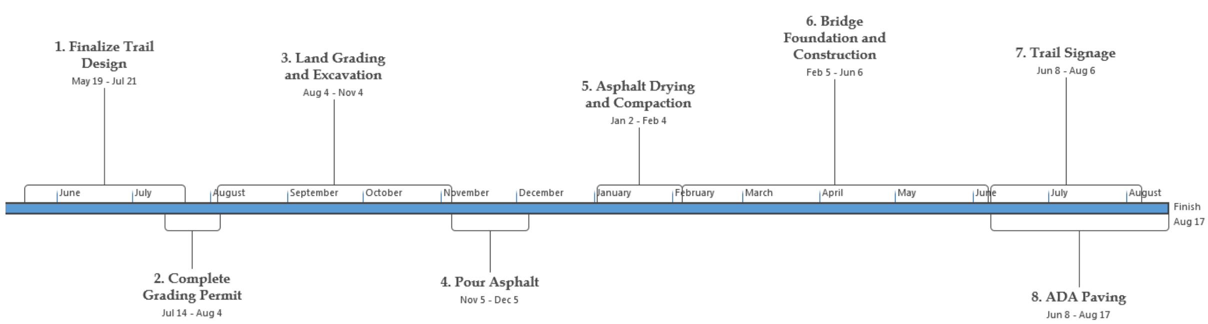

Figure 7.1: Construction Timeline

The design and construction costs considered for the Recreational Trail System include signage, materials and labor, and additional costs which comprise of the HAWK traffic signal, ADA ramps, and the two bridges. While the equipment rental and labor costs vary for each material due to the amount of energy and time required to pour, dry, and compact the asphalt, the excavation, labor, debris removal and disposal, and equipment rental and delivery costs were combined at a set price per cubic yard of material. It should be noted that during that material selection process, the varying costs of equipment rental and labor were considered for each alternative. The total cost of the project is $2,056,687. Detailed calculations and individual costs can be found in Appendix D.

8. Conclusions

The Recreational Trail System is an innovative solution to forger connections between the many parks and public spaces in Muscatine. The design of the trail is both challenging as it braves the curving and sloping landscape yet enjoyable for those looking for a more leisurely experience. Each design parameter of the trail system has been extensively thought-out to consider safety, accessibility, connectivity, surrounding societal impacts, and surrounding environmental impacts. While there are some challenges that must be faced in the completion of this project, including steep-sloping landscapes, possible interferences with traffic, and simultaneous construction with the Welcome Center, all challenges are met with inventive designs, dedicated for the greater good of the City of Muscatine.

9. Bibliography

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10. Appendix A—Permit Applications

GRADING PERMIT APPLICATION

CITY OF IOWA CITY

Application Date ____________________

1. Site Address: ____
   OR
   Lot & Subdivision: ____
   ____

2. Applicant: ____

   Address: ____

   City: ____________________ State __________ Zip ________

   Work Phone: ____________________ Home Phone: ____________________

3. Contractor: ____

   Address: ____

   City: ____________________ State __________ Zip ________

   Work Phone: ____________________ Home Phone: ____________________

4. Project Description: ____

5. Does this project involve grading of 500 cubic yards or more? _____Y _____N
   Grading of 500 cubic yards or more requires an engineered grading plan, prepared and certified by a civil engineer. At the completion of grading, the civil engineer preparing the plan must inspect and certify that the project is completed according to the grading plan.

Contact Person: ____

hisbldg/applicgrd.doc

11. Appendix B—Design Calculations

11.1. Radius of Curvature

The minimum design radius of curvature is derived from Equation 1

$$R_{min} = \frac{V^2}{15(e+f)} \quad (1)$$

where V is the design speed (mph), e is the rate of super elevation (ft/ft) (between +2% and +5%), and f is the coefficient of friction. According to the Iowa DOT, typical design speeds for bicyclists are between 20 and 30 miles per hour. Assuming a design speed of 25 miles per hour, a super eleveation of +2% and friction coefficient of 0.25, the minimum radius of curvature was calculated to be 18.5 feet.

$$\frac{25^2}{15(2+0.25)} = 18.5'$$

All trail curves are confirmed to have a radius greater than 18.5 feet.

11.2. Stopping Sight Distance

The stopping sight distance (ft) for a bicycle on the trail was determined from Equation 2

$$S = \frac{V^2}{30(f+/-G)} + 3.67V \quad (2)$$

where G is the grade of the trail. Assuming that the friction coefficient is 0.25, the design speed is 25 miles per hour, and the grade of the trail is 1.5%, the stopping sight distance was calculated to be 103.65 feet.

$$\frac{25^2}{30(0.25+/-1.5)} + 3.67(25) = 103.65'$$

The stopping sight distance was confirmed using Figure 11.2.1.

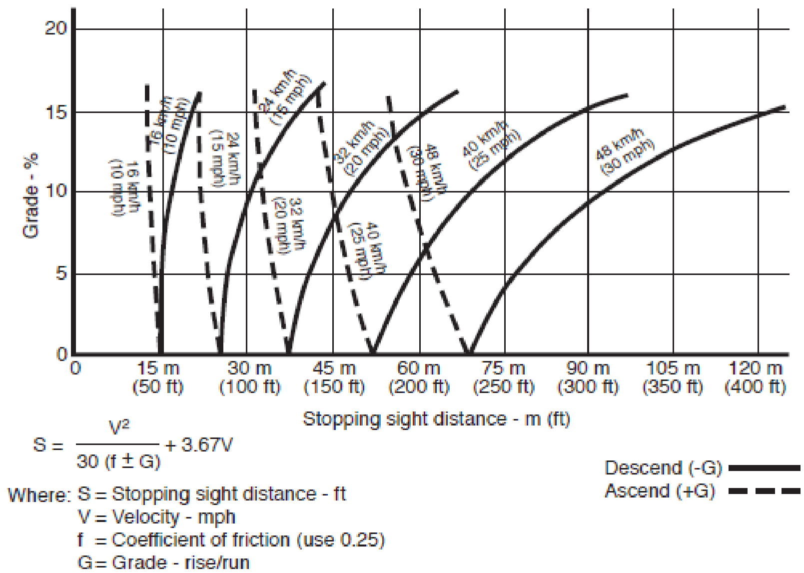

Figure 11.2.1: Stopping sight distances on bicycle paths.

11.3 Bridge Foundations

The effective stress, general bearing capacity, allowable load bearing capacity, and center settlements were calculated for each bridge foundation by assuming the following values.

Unit weight of soil, ϒ = 125 lb/ft³ (Down/ Tama soil)
Soil friction angle, φ' = 25°
Cohesion, c' = 80 lb/ft²
Factor of Safety, = 2
Modulus of Elasticity, Es = 292,320 lb/ft²
Water table is below foundation

First, the effective stress at the level of the bottom of the foundation was calculated using Equation 3.

$$q = \gamma D_f = 125 * 12\,ft = 1{,}500\,{}^{lb}/_{ft^2} \tag{3}$$

where ϒ is the unit weight of soil and D_f is the depth of the soil. The effective stress at the bottom of each foundation is 1,500 lb/ft². This values was then implemented into Equation 4 to find the general bearing capacity

$$q_u = c' N_c F_{cs} F_{ci} F_{cd} + q N_q F_{qs} F_{qi} F_{qd} + \frac{1}{2} \gamma B N_\gamma F_{\gamma s} F_{\gamma i} F_{\gamma d} \tag{4}$$

where c' is the cohesion, N_c, N_q, and N_γ, are dimensionless bearing capacity factors, B is the foundation width, F_{cs}, F_{qs}, and $F_{\gamma s}$ are shape factors, F_{ci}, F_{qi}, and $F_{\gamma i}$ are inclination factors, and F_{cd}, F_{qd}, and $F_{\gamma d}$ are depth factors. For a soil friction angle of 25°, the bearing capacity factors were found from a bearing capacity factor table.

N_c = 20.75
N_q =10.66
N_γ =10.88

To determine the shape factors, Equations 5, 6, and 7 were used.

$$F_{cs} = 1 + \left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right) \tag{5}$$

$$1 + \left(\frac{6}{11}\right)\left(\frac{10.66}{20.75}\right) = 1.28$$

$$F_{qs} = 1 + \left(\frac{B}{L}\right)\tan\emptyset' \tag{6}$$

$$1 + \left(\frac{6}{11}\right)\tan 25 = 1.25$$

$$F_{\gamma s} = 1 + 0.4\left(\frac{B}{L}\right) \tag{7}$$

$$1 + 0.4\left(\frac{6}{11}\right) = 1.218$$

Therefore, the shape factors are 1.28, 1.25, and 1.218. Next, the depth factors were calculated using Equations 8, 9, and 10.

$$F_{qd} = 1 + 2\tan\emptyset'\,(1 - \sin\emptyset')\tan^{-1}\left(\frac{D_f}{B}\right) \tag{8}$$

$$1 + 2\tan 25\,(1 - \sin 25)\tan^{-1}\left(\frac{15}{6}\right) = 1.37$$

$$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\emptyset'} \tag{9}$$

$$1.39 - \frac{1 - 1.39}{20.75\tan 25} = 1.43$$

$$F_{\gamma d} = 1.0 \tag{10}$$

Therefore, the depth factors are 1.37, 1.43, and 1.0. The inclination factors were found using Equations 11 and 12.

$$F_{ci} = F_{qi} = \left(1 - \frac{\beta}{90}\right)^2 \tag{11}$$

$$\left(1 - \frac{0}{90}\right)^2 = 1$$

$$F_{\gamma i} = \left(1 - \frac{\beta}{\emptyset'}\right) \tag{12}$$

$$\left(1 - \frac{0}{25}\right) = 1$$

The inclination factors all equal 1. These parameters were then used in Equation Y to determine the general bearing capacity.

$$q_u = 80 * 20.75 * 1.28 * 1.43 * 1 + 1500 * 10.66 * 1.25 * 1.37 * 1 + 0.5 * 125 * 6 * 10.88 * 1.218 * 1 * 1 = 35390.8\ {}^{lb}/_{ft^2}$$

The general bearing capacity of each foundation is 35,390.8 lb/ft^2.

Next, the allowable bearing load capacity of each foundation was to be 17,695.4 lb/ft^2 determined using Equation 13.

$$q_{all} = \frac{q_u}{FS} \tag{13}$$

$$\frac{35390.8\ {}^{lb}/_{ft^2}}{2} = 17695.4\ {}^{lb}/_{ft^2} \qquad \geq 1438.1\ {}^{lb}/_{ft^2}$$

Assuming a Poisson's ratio, μ_s, of 0.5 and I_f value of 0.79, the settlement at the center of each foundation was calculated using Equation 14

$$S_e = q_o(\alpha B')\frac{1-\mu_s^2}{E_s} I_s I_f \tag{14}$$

where q_o is the net applied pressure on the foundation, B′ is the half the width of the foundation, I_s a dimensionless shape factor, and I_f is a dimensionless depth factor.

$$q_o = 35390.8\ {}^{lb}/_{ft^2} \qquad \alpha = 4$$

$$m' = \frac{L}{B} = \frac{11}{6} = 1.833$$

$$n' = \frac{H}{{}^{B}/_{2}} = \frac{20}{3} = 6.67$$

I_s was calculated using Equation 15 and the parameters F_1 and F_2 were determined based on the values of m′ and n′. F_1 and F_2 are 0.566 and 0.0415 respectively.

$$I_s = F_1 + \frac{1-2\mu_s}{1-\mu_s} F_2 \tag{15}$$

$$0.566 + \frac{1-1}{1-0.5}0.0415 = 0.566$$

Finally, all parameters were implemented into Equation 14 to calculate a settlement of 5.85 inches.

$$S_e = 35390.8(4*3)\frac{1-0.25}{292320}*0.566*0.79 = 0.487 \rightarrow 5.85"$$

12. Appendix C – Additional Design Drawings

12.1. Cross Sections

Figure 12.1.1 exhibits the varying types of cross sections taken at different points along the trail with the corresponding gradation. Table 12.1.1 profiles the different cross slope types based on the path's slope and elevation from differing stations.

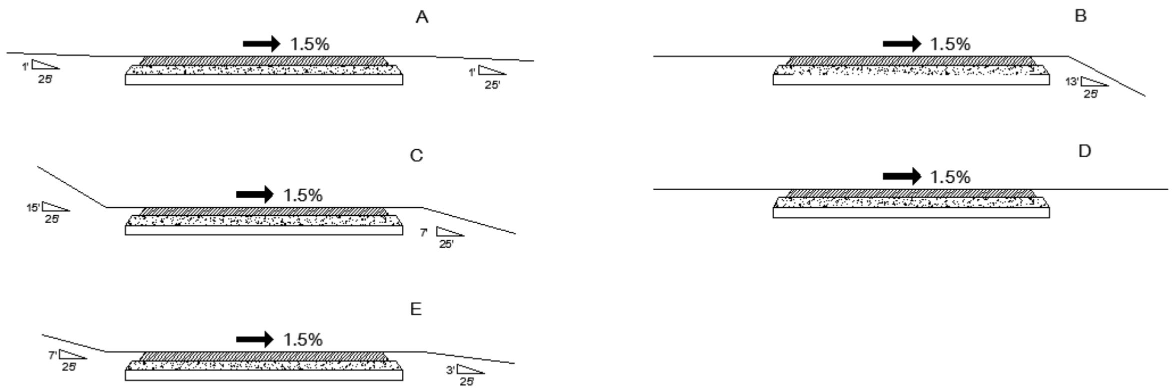

Figure 12.1.1: Varying types of cross slopes along trail.

Table 12.1.1: Cross slope profiling for different sections of the trail.

Cross Sections + Details								
	Section Type	Station to	Station	Length	Pavement Type	C	T	S
Houser Street	A	0+00	6+00	600	HMA	12'–0"	0'–5"	0'–6"
Houser Street	A	6+00	12+90	690	HMA	12'–0"	0'–5"	0'–6"
Path 2	B	12+90	15+90	300	HMA	12'–0"	0'–5"	0'–6"
Path 2	B	15+90	18+10	220	HMA	12'–0"	0'–5"	0'–6"
Path 2	C	18+10	21+10	300	HMA	12'–0"	0'–5"	0'–6"
Path 2	C	21+10	24+00	290	HMA	12'–0"	0'–5"	0'–6"
Welcome Center	D	14+87.38	16+06.47	119.0900	HMA	12'–0"	0'–5"	0'–6"
Welcome Center	D	16+06.47	24+19.73	813.2600	HMA	12'–0"	0'–5"	0'–6"
Path 1	E	0+00	2+39.2	239.2000	HMA	12'–0"	0'–5"	0'–6"
Path 1	E	2+39.2	14+87.38	1248.1800	HMA	12'–0"	0'–5"	0'–6"
To Discovery Park	A	24+00	60+26.27	3626.2700	HMA	12'–0"	0'–5"	0'–6"
			Total =	8446.0000				

12.2. Vertical Slopes

The Iowa DOT standards for shared-use path vertical slope grades are as follows:

- 8.3% for a maximum of 61.0 m (200')
- 10% for a maximum of 9.14 m (30')
- 12.5% for a maximum of 3.05 m (10')

Vertical slopes were measured at eight sections along the trail and only one section required excavation, Section 4. Table 12.2.1 displays the slopes at each section and Figure 12.2.1 shows where each vertical slope was measured along the trail.

Table 12.2.1: Vertical Slope Grades

Number	Length (ft)	Slope (◦)
1	8442	1.4
2	1079	0.3
3	158	7.2
4	68	-12.5
5	752	2.7
6	655	1.4
7	636	-0.5
8	251	0.5

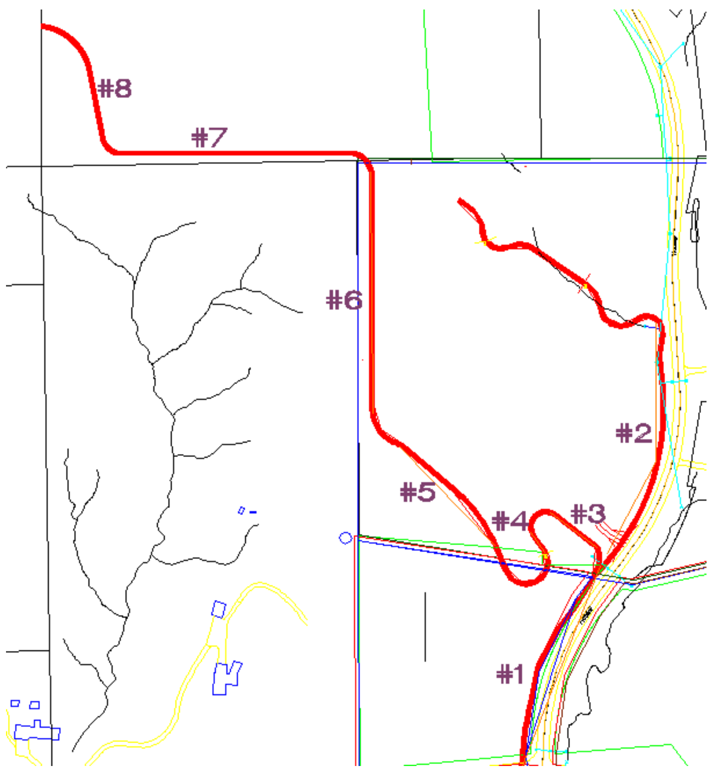

Figure 12.2.1: Map of vertical slope sections.

12.3. Bridge Foundations

Figure 12.3.1 displays the dimensioned plan and side views for the concrete bridge foundations. Figure 12.3.2 illustrates a three-dimensional model of the foundation.

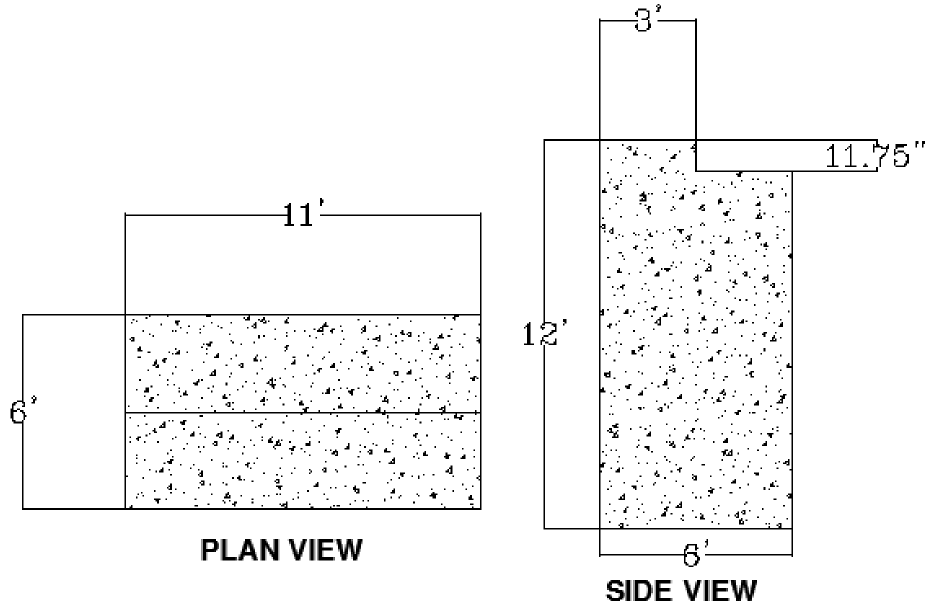

Figure 12.3.1: Plan view and side view of bridge foundations.

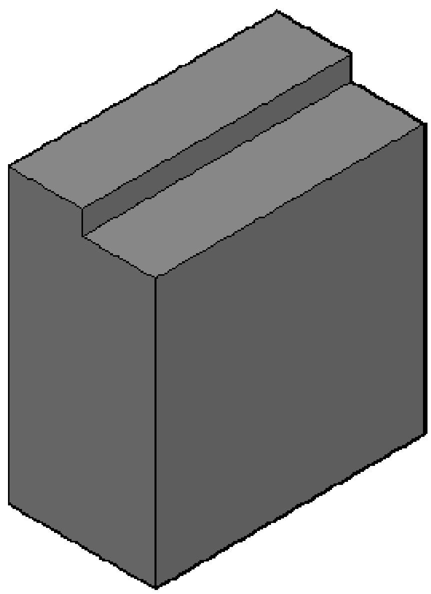

Figure 12.3.2: 3-D bridge foundation model.

13. Appendix D—Cost and Construction Calculations

The total cost of the entire project is estimated at $2,056,687. Individual costs for signage, materials and labor, and additional costs that include ADA ramps, bridges, and the HAWK signal, were calculated based on assumed average cost values and are summarized in Table 13.1.

Table 13.1: Project cost summary.

Cost Consideration	Total Cost
SIGNAGE	
Mile Marker Posts	$1,722
Trail Head Map	$1,500
Wayfinding	$450
MATERIALS/LABOR	
Asphalt	$388,275
Sub Base	$436,260
Maintenance	$2,430
Resurfacing	$24,300
Labor, Excavation Debris Removal, Equipment, Delivery	$925,750
Bridge Foundation Concrete	$10,000
ADDITIONAL	
Hawk Signal	$80,000
ADA Ramps	$6,000
Bridge	$180,000
TOTAL	$2,056,687

13.1 Signage Costs

Three different types of signs were implemented into the design of the trail system including mile marker posts, trail maps, and wayfinding signs. As the total length of the trail is 1.62 miles, six mile marker posts will be placed at each quarter-mile interval including a post at the start of the trail, thus totaling seven posts. Each post will be 6 inches in both length and width and 48 inches in height with two sides of text indicating the mileage and which activities are supported by the trail. The estimated cost to put two sides of text on a 6" x 6" post is $36 and the cost of 6" x 6" x 48" post is $210.

$$\$36 * 7 = \$252$$

$$\$210 * 7 = \$1,470$$

$$\$252 * 1470 = \$1,722$$

By summing the text and post costs, the total cost for mile marker posts is $1,722.

Three trail maps and three wayfinding signs that indicate the directions to the area's surrounding public spaces will both be placed on the trail at the Houser Street and Hershey Avenue entrance, the Discovery Park entrance, and where the trail splits into two paths on the Welcome Center property. The estimated cost for one trail map sign is $500 and the estimated cost for one wayfinding sign is $150.

$$\$500 * 3 = \$1,500$$

$$\$150 * 3 = \$450$$

The total cost for trail map signs is $1,500.00 and the total cost for wayfinding signs is $450.00.

$$\$1,722 + \$1,500 + \$450 = \$3,672$$

By summing up the costs of each sign type, the total projected cost of trail signage is $3,672.

13.2 Material and Labor Costs

In order to determine the total estimated cost of each material, the volume of the trail was first calculated using Equation 16.

$$Volume = Area * Thickness \tag{16}$$

The designed trail route is roughly 170,000 square feet and the thickness of the asphalt surface is 5 inches. Using Equation 16 and converting the thickness units to feet, the total volume of the asphalt paving was calculated to be 71,400 cubic feet.

$$5\ in * \frac{1\ ft}{12\ in} = 0.42\ ft$$

$$170,000\ ft^2 * 0.42\ ft = 71,400\ ft^3$$

As most paving materials are priced by the ton, the weight of each material was calculated using Equation 17.

$$Weight = Volume * Density \tag{17}$$

The volume of the asphalt surface stays constant for each alternative; however the average compacted density of each material varies. It was assumed that the average compacted densities for HMA, WMA, and Porous Asphalt are 145 pounds per cubic foot, 145 pounds per cubic foot, and 120 pounds per cubic foot, respectively. The weights for each material were calculated in feet then converted to tons.

$$71,4000\ ft^3 * 145\ \frac{lb}{ft^3} = 10,353,000\ lb$$

$$10,353,000\ lb * \frac{1\ ton}{2,000\ lb} = 5,177\ tons$$

$$71,4000\ ft^3 * 120\frac{lb}{ft^3} = 8,568,000\ lb$$

$$8,568,000\ lb * \frac{1\ ton}{2,000\ lb} = 4,284\ tons$$

Therefore, 5,177 tons of HMA and WMA are needed for paving and 4,284 ton of Porous Asphalt are needed. Next, the price of each material was calculated by assuming an average price of $69 per ton for HMA, $75 per ton for WMA, and $125 per ton for Porous Asphalt.

$$5,177\ tons * \frac{\$69}{ton} = \$357,213$$

$$5,177\ tons * \frac{\$75}{ton} = \$388,275$$

$$4,284\ tons * \frac{\$125}{ton} = \$535,500$$

The final material costs for HMA, WMA, and Porous Asphalt were calculated as $357,213, $388,275, and $535,500, respectively. Table 12.2.1 depicts a summary of each material's volume and cost.

Table 13.2.1: Estimated material cost for each asphalt alternative.

Asphalt Type	Weight (tons)	Cost Per Ton	Total Paving Cost
Warm-Mix	5,177	$69	$357,213
Hot-Mix	5,177	$75	$388,275
Porous	4,284	$125	$535,500

The total estimated cost for the granular sub base was found in a similar manner as the asphalt cost. Since the thickness of the sub base is 6" and the area of the trail is 170,000 square feet, the volume of the sub base was calculated using Equation 16.

$$6\ in * \frac{1\ ft}{12\ in} = 0.5\ ft$$

$$170{,}000\ ft^2 * 0.5\ ft = 85{,}000\ ft^3$$

The granular sub base was assumed to have a compaction density of 135 pounds per cubic foot and by implementing this value into Equation 17, the weight of the sub base was calculated.

$$85{,}0000\ ft^3 * 135\ \frac{lb}{ft^3} = 11{,}475{,}000\ lb$$

$$11{,}475{,}000\ lb * \frac{1\ ton}{2{,}000\ lb} = 5{,}738\ tons$$

Therefore, 5,738 tons of granular sub base is needed for the entire trail. The total cost of the sub base was determined by assuming an average price of $77 per ton.

$$5{,}738\ tons * \frac{\$77}{ton} = \$436{,}260$$

The final cost of the granular sub base is $436,260.

According to the Iowa DOT, yearly maintenance costs for the trail can be estimated at $1,500 per mile. Routine maintenance includes, but is not limited to, yearly facility evaluation to determine the need for minor repairs, mowing, tree and brush clearing, and signage updates.

$$\$1{,}500 * 1.62\ miles = \$2{,}430$$

The cost of yearly trail maintenance amounts to $2,430. Additionally, the cost of asphalt resurfacing was considered in the final cost estimate. The Iowa DOT recommends trail resurfacing every five years. For a 12 foot wide trail, the resurfacing cost is $15,000 per mile.

$$\$15{,}000 * 1.62\ miles = \$24{,}300$$

The cost of asphalt resurfacing once every five years is $24,300. Next, the labor, excavation, debris removal and disposal, and equipment rental and delivery costs were combined and calculated at an assumed average price of $350 per cubic yard of material.

$$71{,}400 ft^3 * \frac{1\ yd}{27 ft^3} = 2{,}645\ yd^3$$

$$\$350 * 2{,}645\ yd^3 = \$925{,}750$$

The total combined cost of labor, excavation, debris removal and disposal, and equipment rental and delivery amounts to $925,750.

Lastly, an assumed average of $75.00 per cubic yard of concrete was used to determine a rough estimate of $10,000.00 for the bridge foundations.

13.3 Additional Costs

The HAWK traffic signal that is to operate at the Lucas Street crossing will comprise of two traffic signals, one for each direction. One traffic signal is priced at approximately $40,000 which makes for a total of $80,000.

ADA ramps will be installed at all intersections including the trail entrance at Houser Street and Hershey Avenue and the Lucas Street crossing. The Lucas Street crossing will have two ADA ramps, one for each direction, and the trail entrance will have one ramp totaling three that are priced at $2,000 per ramp. The total cost for three ADA ramps is $6,000.

As specified by Continental Bridge, each 10 foot wide pedestrian bridge costs $1,200 per foot to construct. A 100 foot long pedestrian bridge will be placed south of Discovery Park in order to cross the deep ravine and stream area. An additional 50 foot long pedestrian bridge will be installed to replace an existing 8 foot wide bridge.

$$(100\ ft + 50ft) * \$1{,}200 = \$180{,}000$$

The total cost for both bridges is $180,000.