The University of Iowa
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

FINAL DELIVERABLE

Title	Cedar Prairie Pedestrian Bridge Replacement in Waterloo
Completed By	Lucy Dent, Michelle Nitschke, Dalton Hart, Collin Furlong
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UI Department	Department of Civil & Environmental Engineering
Course Name	CEE:4850:0001 Project Design & Management
Instructor	Christopher Stoakes
Community Partners	City of Waterloo

This project was supported by the Iowa Initiative for Sustainable Communities (IISC), a community engagement program at the University of Iowa. IISC partners with rural and urban communities across the state to develop projects that university students and IISC pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.

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Cedar Prairie Trail Bridge Replacement

City of Waterloo, IA

Proposal: February 12, 2021

Section I: Executive Summary

The University of Iowa engineering project team is a civil and structural engineering group comprised of senior civil engineering students focusing on both civil practice and structural engineering. Our team has developed its education and experience through various courses such as Introduction to Bridge Engineering, Principles of Structures, and Design of Transportation Systems. These courses and others have given the project team the necessary experience to work on the Trail Bridge Replacement Project for the City of Waterloo, Iowa.

The City of Waterloo hopes to replace two pedestrian bridges along the Cedar Prairie Trail that cross Black Hawk Creek. Both existing bridges are located south of Ranchero Road. The northern bridge spans approximately 250 feet and the southern bridge spans approximately 150 feet. The existing bridges were built on top of an old railroad track and are thus elevated by existing railway embankments. The two existing bridges are currently experiencing severe deterioration such as corrosion, dry rot, and broken cross bracing, as well as significant debris in the waterway. This damage can be demonstrated in Appendix E through the 2019 inspection report of the northern bridge. These issues pose a threat to the safety of the people using the bridges, which is the main motivation for their replacement. Additionally, the City of Waterloo would like to create more aesthetically pleasing bridges along the Cedar Prairie Trail. The engineering team began by proposing five alternatives for the alignment of the bridges and trail, with several design alternatives for the bridges themselves. After meeting with our clients, we determined to pursue preliminary designs for two alignment alternatives, with a constructed bridge made of steel framing with a wood deck for one alternative and a prefabricated steel bridge for the second alternative. Additionally, it was decided to consider removing the existing railway embankments as a secondary phase for the project.

The first proposed alternative was to keep the current alignment of both the northern and southern bridges but replace the bridge superstructures. This would alleviate the need to realign any of the existing trail but would leave the failing substructure and debris blockage unresolved. The second alternative would have been to keep the southern bridge's alignment and replace and redesign that bridge since this bridge is mostly out of the creek, but crosses on top of the east bank of the creek. However, it would have realigned the northern bridge to create a shorter span that is perpendicular to the creek. This would also necessitate realignment of the trail on both sides of the northern bridge. The third alternative removed both bridges and replaced them with a singular bridge further south across the creek. The singular bridge would be aligned perpendicular to the creek to allow for a shorter spanning bridge, as well as less maintenance since there is only one bridge to care for. This would require realignment of the trail on both sides of the bridge as well. The fourth alternative design realigned the northern bridge and completely removed the southern bridge since as mentioned before the southern bridge is not completely crossing the creek, a simple realignment of the trail would be enough to replace the bridge. The final alternative realigned the trail across Black Hawk Creek using the bridge across Ranchero Road and then south through the Robinson Bird Sanctuary. This alignment would cross the smaller creek, Prescott's Creek as opposed to Black Hawk Creek.

Of the proposed alignments, two were chosen for a preliminary design. The first of the two alignments chosen was the third alternative, which replaces both bridges with one bridge further south and which will now be referred to as the Western Trail Alignment. The trail realignment is approximately half a mile long and the bridge crosses Black Hawk Creek with a span of 130 feet.

The trail realignment began where the existing northern bridge began and goes south along the west bank of Black Hawk Creek. The alignment goes into existing farmland west of the creek, which is owned by the city, and we took care to avoid the existing powerlines. After crossing Black Hawk Creek, the realignment quickly reconnects with the existing trail. This trail was designed to meet the standards for a type 3 shared use path according to the Iowa Statewide Urban Design and Specifications (SUDAS).

The second alternative chosen was the fifth alternative that went east of the creek through Robinson Bird Sanctuary, which will now be referred to as the Eastern Trail Alignment. The trial realignment is also approximately half a mile, and crosses Prescott's Creek with a span of 38 ft. The trail starts north of Ranchero Road on the existing trail and meets the road at the existing crossing. It then follows the bridge on Ranchero Road across Black Hawk Creek, and then goes south off the road and down through the Robinson Bird Sanctuary that is east of Black Hawk Creek. It crosses Prescott's Creek as it continues south through the bird sanctuary before it meets up with the existing trail. This trail was also designed to meet the standards for a type 3 shared use path according to SUDAS.

For all five alternatives, similar designs and design materials were considered. For the deck, the team considered the use of both concrete and wood. Concrete would be a more durable and longer lasting alternative that would provide a smooth riding surface to potential bikers; however, it would be the more expensive option compared to wood. A wood deck would be long lasting and durable as well but would require more potential maintenance and would potentially be less pedestrian-friendly. For the other structural elements, metal and wood were considered using the same reasoning as the decking. Metal being the more durable and low-maintenance option, however more expensive initially. Additionally, prefabricated bridges were considered to alleviate the construction impacts and costs, as well as simplify the design process.

For the Western Trail Alignment, the engineering team designed the bridge to cross Black Hawk Creek with a span of 130 ft. The bridge was designed with steel framing and a wood deck. For framing, a truss was designed using the steel to match the aesthetic of another existing bridge further north on the creek. A truss was chosen to help increase the support of the bridge over the long span. The depth of the truss was selected to be 12 ft to decrease the deflection of the bridge as well as allow for enough clear space for people and bike riders to use the bridge without any difficulties. The truss was designed with 10 panels at 13 ft for a symmetric truss and a reasonable panel size to keep the size of the individual components in the truss down. The bride is 12 ft wide to account for the potential use of maintenance vehicles and opposing traffic for pedestrians. For the Eastern Trail Alignment, a prefabricated bridge was chosen for both the ease of construction in the bird sanctuary and the short length of the crossing over Prescott's Creek. The prefabricated bridge was chosen from Contech Engineering Solutions. The Link Truss Pedestrian Bridge was chosen because it also matches the aesthetic of the existing bridge further north on Cedar Prairie Trail.

Throughout this design process, potential challenges and constraints were considered for both alternatives. Black Hawk Creek is prone to significant flooding. Therefore, existing flood reports were studied, and a hydraulic assessment was conducted to assess the impact of any topographic changes. Additionally, there is an overhead powerline that follows along the west bank of Black Hawk Creek that was avoided in the proposed alignments. This powerline also requires that city work vehicles can travel along any bridges designed, so they would need to be designed to account for the size and load of maintenance and emergency vehicles. There is also a bird sanctuary on the east side of the creek and trail that would need to be protected from construction impacts through the design process.

The cost of both alternatives was estimated using RSMeans online estimating tool and a representative of Contech Engineered Solutions. The Western Trail Alignment was estimated to be $521,500. The Eastern Trail Alignment was estimated to be $209,500. The removal of the railway embankments was estimated to be $78,500. The detailed estimation can be seen in Section VII of the report.

Based on the challenges and constraints of the project, the two alternatives were evaluated to determine the recommended preliminary design of the project. The engineering team recommends designing the Eastern Trail Alignment. This alternative is recommended for its ease of construction, more cost-effective design, and more unique experience for pedestrians using the trail. The two main cons of this design would be the flooding and the construction impacts on the bird sanctuary. However, this design has an easy alternative route to bypass the flooding either by following Ranchero Road to Sergeant Road Trail, or through the smaller trails throughout the bird sanctuary. As for the construction impacts, these could be mitigated in a multitude of ways such as replanting new trees to replace those removed and/or performing construction during a certain window to avoid disrupting the birds and other wildlife living in the sanctuary.

Contents

Section II: Organization, Qualifications, and Experience

1. Organization and Team Description

The engineering project team is comprised of students completing a capstone design course at the University of Iowa. For the Trail Bridge Replacement Project, the project manager is Lucy Dent. Miss Dent is studying Civil engineering practice but will pursue structural engineering for her master's degree. The co-editors for the project are Michelle Nitschke, who is specializing in structural engineering, and Dalton Hart, who is specializing in civil engineering practice. Technical support will be provided by Collin Furlong who has a focus in structural engineering.

2. Description of Experience with Similar Projects

The members of the engineering team have extensive experience in Civil Engineering. Each team member will be able to add expertise in different areas pertaining to the project.

Lucy Dent has gained valuable experience and knowledge throughout her four years at the University of Iowa, as well as through an internship with the City of Aspen Engineering Department that gives her the necessary background to be project manager for the trail bridge replacement project. Throughout her time at the University of Iowa, she has taken several relevant courses such as Introduction to Bridge Engineering, Design of Transportation Systems, Principles of Structural Engineering, Structural Modeling and Health Monitoring, Design of Concrete Structures, and Design of Steel Structures. All courses have given her background in designing trails and bridges that are safe and structurally sound, as well as designing with the same materials considered and used for the project. Additionally, throughout her time in school, Lucy has been a teaching assistant for Engineering Problem Solving I, Statics, Dynamics, Fluid Mechanics, and Resilient Infrastructure & Emergency Response; she has also held multiple positions on the executive board for both Chi Epsilon Honor Society and Eat & Treats, including the role of president for both. This has given her the experience to lead a group, help others, and manage her time in a way that is needed of a project manager. In addition, she worked as an engineer intern in a public works department that gave her experience in managing projects such as overseeing construction work in the right of way and inspecting sidewalks. This internship also contributed to her knowledge of the design process and the requirements of a multitude of design standards that contribute to the safety of the public using these facilities.

Michelle Nitschke has taken several courses at the University of Iowa that have given her the knowledge needed to contribute to the design of the trail bridge replacement project. In particular, she has taken an Introduction to Bridge Engineering course; this has given Michelle experience in designing and analyzing many different components of bridges. To support Michelle's general structural knowledge, she has taken Principles of Structural Engineering which helped provide the fundamentals to properly design safe structures. Michelle is also qualified to help design stable foundations for the bridges as she has taken a Foundations of Structures course as well. As for knowledge in the trail design, Michelle has taken a Design of Transportation Systems course; in this class, Michelle had the opportunity to create her own bike path using the knowledge she learned throughout the semester.

Dalton Hart has taken several hydraulics and water resources courses at the University of Iowa which directly relate to his work on this project. He designed an emergency spillway for a dam in Missouri as part of Water Resources Engineering. In Water Resources Design, he used HEC-

HMS and HEC-RAS to determine the flow characteristics and storage requirements for a reservoir in southern Iowa and designed both the primary and emergency spillways.

Collin Furlong has completed several courses as a student at the University of Iowa that have provided necessary experience to design a new bridge and trail. Specifically, Collin has taken Introduction to Bridge Engineering, Design of Steel Structures, Design of Concrete Structures, Foundations of Structures, as well as other course such as Principles of Structures that provide the basic knowledge that is the basis of these more advanced courses. Collin also has taken a Design of Transportation course which provided the knowledge used in the trail design.

Section III: Proposed Services

1. Project Scope

The City of Waterloo desires to improve the safety and quality of the Cedar Prairie Trail with this project. Currently, the existing bridges are old railroad bridges that are experiencing structural deterioration. Both bridges have moderate to severe deterioration and splitting of the stringers, significant deterioration of piles and pile caps, severe decay and section lass in several caps, severe dry rot, decay, crushing, and section loss in most of the timber piles. Additionally, the southern bridge's northeast wingwall is tipping and the north abutment is undermined. The north bridge has locations which have suffered collision and fire damage that can be seen in the bridge inspection report in Appendix D. The Trail Bridge Replacement Project consists of removing, replacing, and redesigning the two existing pedestrian bridges along the Cedar Prairie Trail that cross Black Hawk Creek. The main site design, as well as the design of the pedestrian bridges included the site location and construction boundaries, existing and future utility locations, existing and final grading, design of all elements of the bridge or bridges, pedestrian facilities, design of expansion joints and deck drains, and the realignment of the trail and bridges. Additionally, a hydraulic analysis of Black Hawk Creek was conducted, and the potential removal of the existing railway embankments was considered.

2. Work Plan

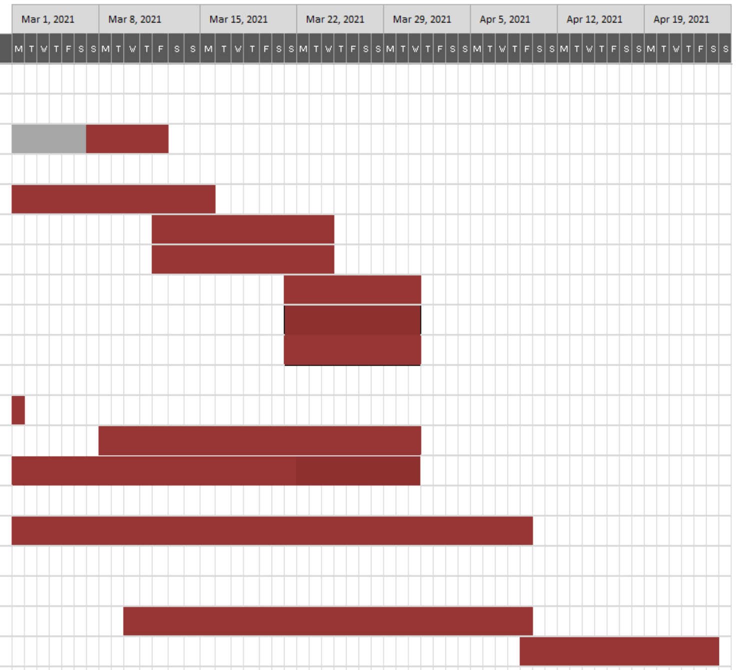
The Trail Bridge Replacement Project took place over the span of approximately two and a half months. The project was finalized on May 7th, 2021. Our design work consisted primarily of alignment/site design, design of the bridges, hydraulic analysis, and compliances with design standards, all of which was worked on concurrently throughout the project after the alternative was chosen one week following the proposal presentation. The design of phase 2, the removal of the existing embankments, was performed after phase 1 was finalized. The breakdown of time spent on each task can be seen below in Table 1.

Table 1: Gantt chart of proposed Work Plan for Cedar Prairie Trail Bridge Replacement Project

MLDC Engineering Co.
Lucy Dent

Project Start: Tue, 1/26/2021
Display Week: 6

TASK	ASSIGNED TO	PROGRESS	START	END
Alignment(s)	Michelle Nitschke			
Solidify Proposal		100%	2/15/21	2/24/21
Develop Alignment(s)		65%	2/24/21	3/12/21
Bridge Design	Lucy Dent			
Decide on Style/Materials			2/24/21	3/15/21
Superstructure Design			3/12/21	3/24/21
Substructure Design			3/12/21	3/24/21
AutoCAD Design			3/21/21	3/31/21
Robot Analysis			3/12/21	3/24/31
Revit Model			3/21/21	3/31/21
Hydraulic Analysis	Dalton Hart			
Study Existing Flood Report			2/24/21	3/1/21
Develop Channel Model (existing + alternatives)			3/8/21	3/31/21
HEC-RAS Floodplain + Backwater Analysis			2/24/21	3/21/21
Confirm Code and Standards Compliance	Collin Furlong			
All Codes and Standards			2/12/21	4/9/21
Presentation and Report				
Proposal Report and Presentation		100%	1/28/21	2/12/21
"Draft" Final Report			3/10/21	4/9/21
Final Report and Presentation			4/9/21	5/7/21



Section IV: Constraints, Challenges, and Impacts

1. Constraints

The final design needed to be completed and submitted by Friday, May 7th, 2021, which created a short design period. This will be one of the larger constraints of the project. Additionally, budget will be the other significant constraint for the project. While having no defined limit, the City of Waterloo's budget was a deciding factor in the project's viability. The team needed to try to minimize the project construction cost. Other constraints included the physical boundaries created by Black Hawk Creek and the neighboring powerline.

2. Challenges

The current bridge alignments are at a significant skew to Black Hawk Creek, increasing the span length of both crossings. This causes a challenge in providing a bridge that will span the length of the creek without needing additional support to prevent failure of the bridge. Additionally, this alignment skew is contributing to a second challenge which is debris blockage. The debris blockages can be pictured below in Figure 1. The chosen alignments were selected in part for their realignment of the bridges and trail to avoid causing a similar issue.

Figure 1: Debris blockage on the northern bridge during flooding

This provides a challenge as to make sure we abide by clear zone requirements and account for the safety of pedestrians using the trail. Additionally, this means that there will need to be maintenance vehicles around the trail, and so the redesigned bridges would have to account for the space to drive on the trail and bridges, as well as having the bridge support the load of the vehicle.

The site is a bird sanctuary and is a popular recreation area for cyclists, hikers, and birdwatchers. Therefore, the aesthetic and environmental impact of the bridge, as well as any site alterations, must be carefully considered. It is expected that any destruction of natural habitat would result in a negative reaction from the community.

3. Societal Impact

This project will have a few significant impacts on society. The existing bridges are on a recreational trail through a bird sanctuary and already have steady pedestrian traffic. The replacement of these bridges will improve the safety of the trail so that the trail will likely experience increased usage by pedestrians, especially among families, once the project is complete. Part of the site location is currently farmland that is owned by the client, the City of Waterloo. Depending on the design alternative chosen, this land would be transformed into trail space as well. This farmland is currently within the flood zone and turning it into the trail space could be an advantage. Finally, improving the trail would have positive economic impacts through multiple ways such as improving the quality of life of the residents and increasing tourism especially with the Robinson Bird Sanctuary.

Section V: Alternative Solutions That Were Considered

The first design solution was to leave the two bridges in the same location as they currently stand but to replace both bridge superstructures. The locations of the current bridges are depicted by the red lines in Figure 2 below. Leaving the bridges in the same location would have allowed the team to focus fully on the design of the bridge itself and allocate all resources to the bridge design. With this, the team could have created a design with a material that would be of very high quality that was more expensive. This would have been beneficial as that would increase the safety of the bridge as well as decrease future maintenance on the bridge. However, the current locations of the bridges are not ideal and moving the bridges were going to be more valuable than solely focusing on the bridge design and materials.

Figure 2: Alternative 1

For the second alternative solution, the design was to leave the south bridge in the same location but replace the bridge’s superstructure. The north bridge, however, would have been removed and relocated but left in the same relative location. The north bridge would be realigned so that the span length is smaller, and the bridge has less skew in relation to the creek. In Figure 3 below, the yellow line depicts the realignment of the trail and north bridge. The red circle shows the general area where the north bridge would be located, and the red line depicts the south bridge staying in its same location. Shortening the span of the bridge helped make this design more intriguing, but it still left the community with two bridges which was not as ideal. It may have saved money up front to only replace one bridge, but in the long run it would add cost and required maintenance since the city would have to keep up with two bridges. Another downside to this alignment is its placement in relation to the 2-year floodplain. Going around the east side of the creek places the trail through more of the 2-year floodplain which would increase the trail's risk of frequent flooding.

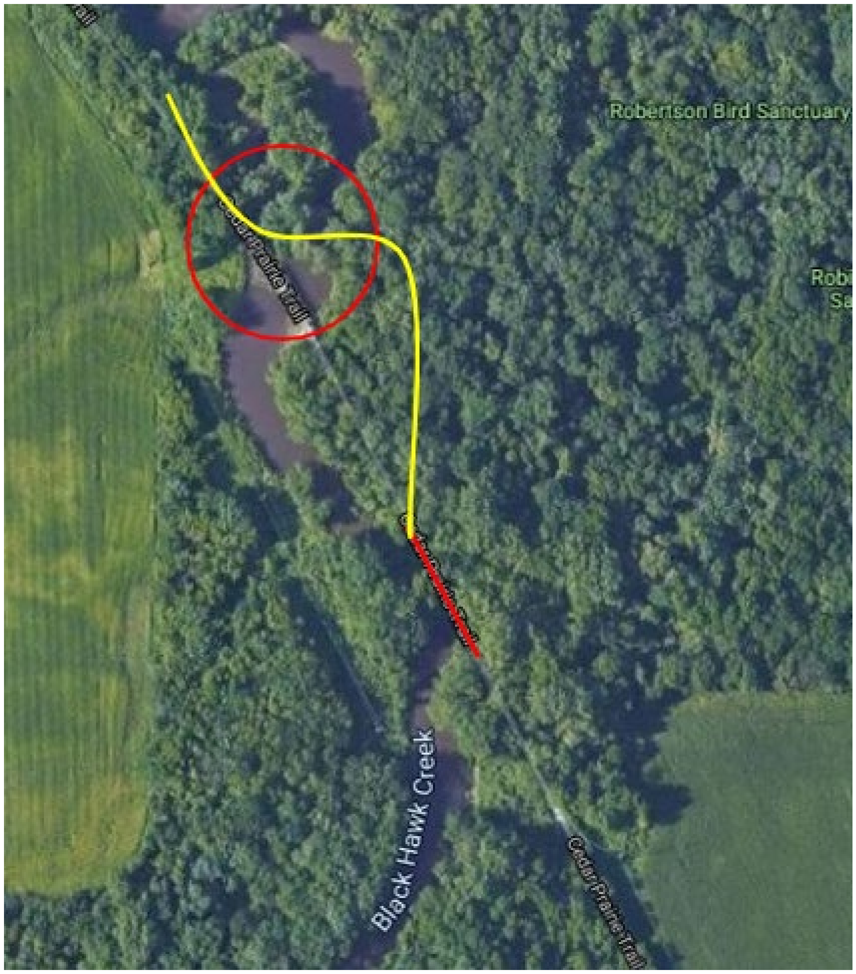


Figure 3: Alternative 2

For the third design alternative, both bridges would be removed completely. The trail would then be realigned so that the path would only require one bridge. This one bridge would be located to the south of the current crossings, as shown in the red circle in Figure 4 below. The yellow line identifies the relative location of the new trail route that stays left of the creek and crosses further south to then meet back up with the existing location of the trail. Since the team would be able to pick a new location for the bridge, they would be able to choose a location that leads to a much smaller span length that would not require any piers. This would lessen the cost of materials being used. It would also reduce future maintenance, as the city would not have to worry about piers deteriorating from debris and flooding like the current arrangement. Having only one bridge would reduce the cost of the project both up front and in the future. This also means that the team would be able to focus resources and time towards designing only one bridge rather than two. Therefore, more expensive materials and designs could be used which would increase the bridge's efficiency and safety. In addition, with one less bridge and nicer materials, there would be less maintenance in the future. Lastly, going around the west side of the creek does put the trail in less of the 2-year floodplain which would lessen the trail's flood risk. The downside to this design, however, is the large realignment of the trail. This would increase work and cost.

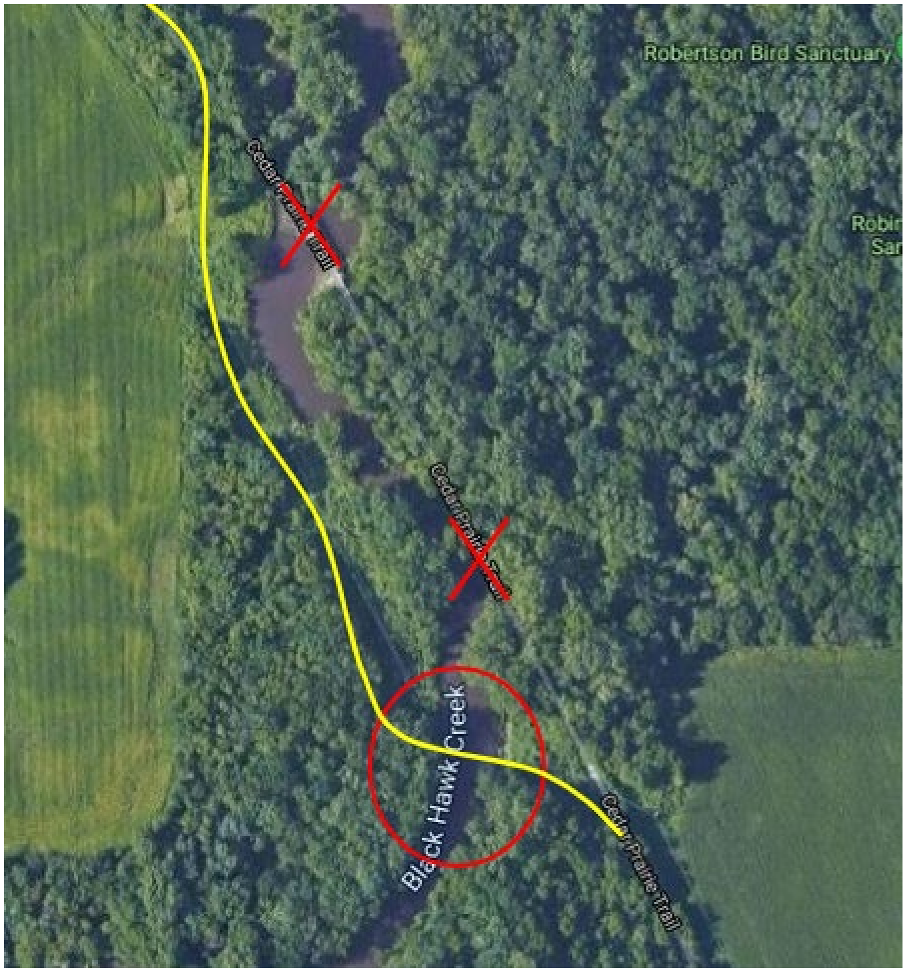


Figure 4: Alternative 3

Another design solution we considered was to remove both bridges but to replace only the north bridge. The north bridge would be slightly repositioned to lessen skew and span length but left in the same vicinity as shown by the red circle in Figure 5. With the complete removal of the south bridge, the trail would have to be realigned so that the south bridge is no longer needed. This route change is portrayed by the yellow line in Figure 5 as well. With this alternative, having only one bridge would save time and money up-front and in the future. The city would only have to pay for one bridge, and they would only have to maintain one bridge. This was a very intriguing solution for these reasons; however, this solution's realignment of the trail would create much more earthwork as it goes through a lot of trees and wooded area. As stated earlier, going along the east side of the creek places the trail through more of the 2-year floodplain which would put the alignment at a higher risk of frequent flooding.

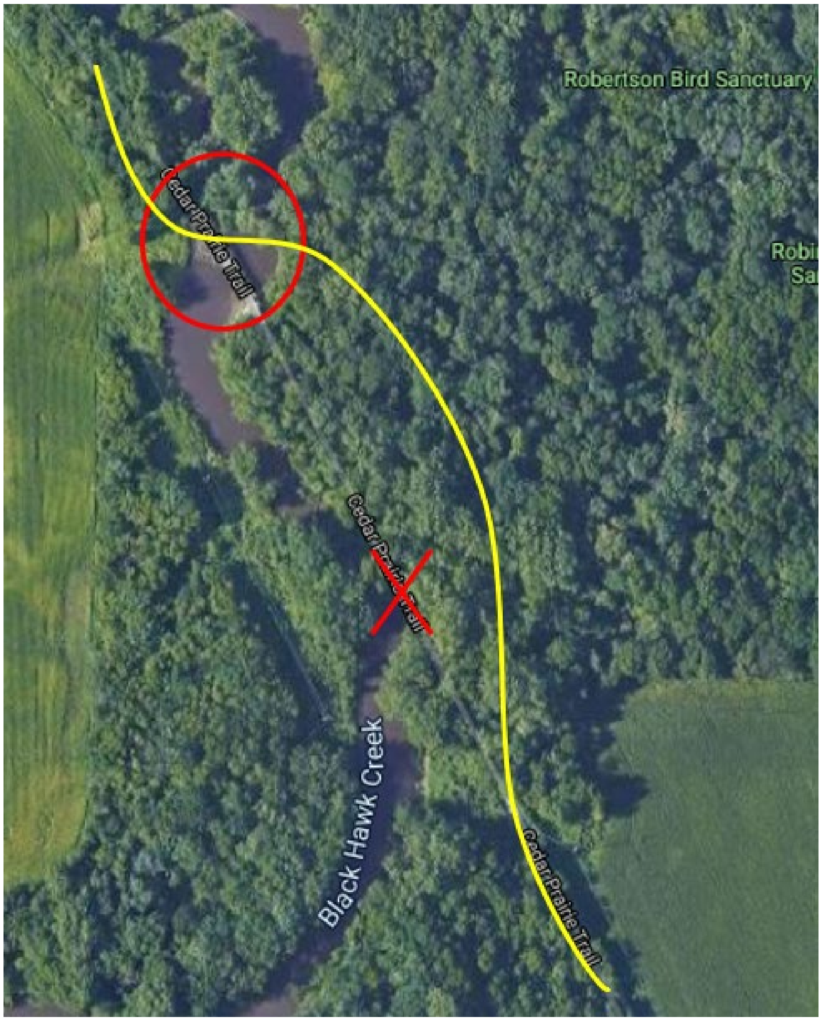


Figure 5: Alternative 4

The final design alternative considered was a complete realignment of the trail across Ranchero Road and down south through the Robinson Bird Sanctuary. This involved removing both bridges across Black Hawk Creek and placing a smaller bridge across Prescott's Creek. In Figure 6, the realignment of the trail is portrayed by the yellow line and the red circle signifies the general location of the new bridge. The main advantage of this alternative was that Prescott's Creek is much thinner in comparison to Black Hawk Creek, and would require a smaller, less costly bridge. A smaller crossing would also allow for a prefabricated bridge to be used which would make construction very easy and decrease the time spent completing this project. The smaller crossing would also require much less material which would help limit costs. Along with this, having only one much smaller spanned bridge would minimize required maintenance in the future. Additionally, the new trail alignment would go through the bird sanctuary, which would create a fun recreational trail for pedestrians. However, this design would involve a total realignment of the trail with the removal of a lot of the existing trees and plants currently in the sanctuary. The work this creates would increase cost and time on the project. This alignment would also go through more of the 2-year floodplain in comparison to staying on the west side of the creek.

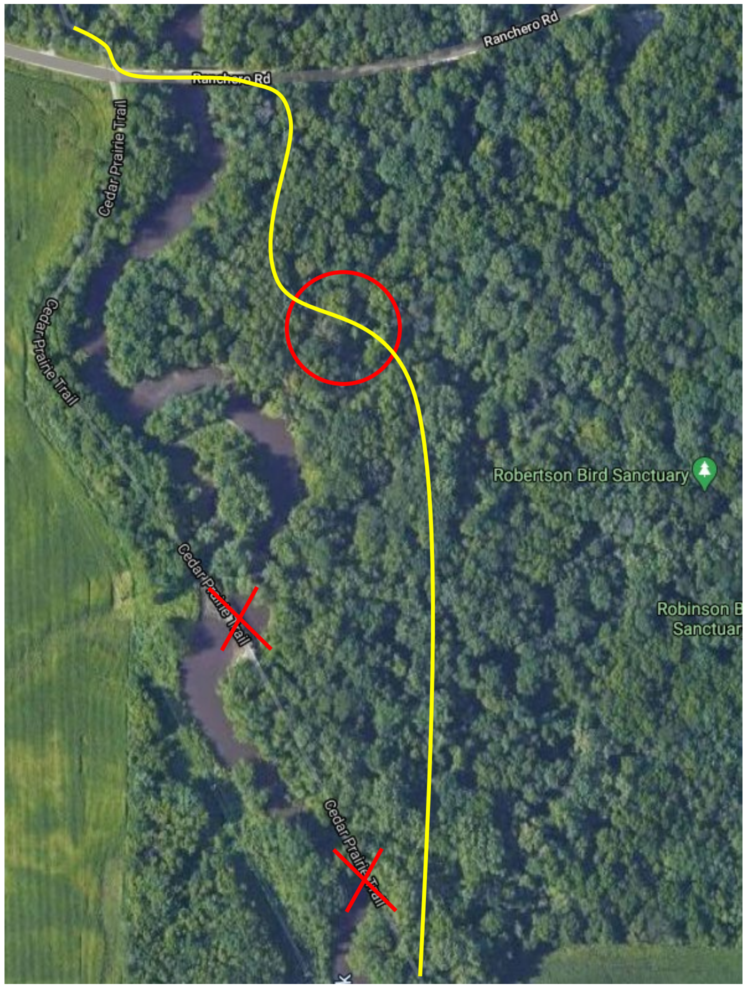


Figure 6: Alternative 5

When it comes to the specific design of the bridge, the best suited design would depend on the chosen alignment for the trail and bridge. As for the truss design of the bridge, we explored several different options in both material and shape. One option we considered was a prefabricated steel truss. This would include a quick installation which helps reduce construction time and cost. Since prefabricated trusses are built with steel, the bridge would have a sleek design while also providing great durability. Steel is a satisfactory choice in terms of long-term maintenance. Another option was to use steel for the truss, but to create a custom design. Another suitable material for the truss design is wood. When comparing wood and steel, both provide their own advantages and disadvantages. First of all, steel framing in general provides a greater strength-to-weight ratio compared to wood. A steel truss would also have a better long-term performance as it is more durable than wood. Steel does corrode, but there are certain mitigation measures that can be taken, giving it a favorable design life. Wood, on the other hand, can rot, split, and crack which makes it less than ideal when considering longevity and maintenance. Therefore, we consider steel to be the better option to minimize maintenance requirements. As for the benefits of a wood truss, the main advantage is its lower cost. As discussed, wood is not as durable as steel, but it still would prove a suitable material for the truss.

The shape of the truss design was highly dependent on our choice of material and the span length of the bridge. Some prefabricated designs that the team considered were a keystone truss, a link truss, and a capstone truss. Each of these designs is depicted in Figures 7, 8, and 9, respectively. If it is decided to design a truss and forgo the prefabricated option, these three truss designs can still be used as foundational ideas for the team.

Figure 7: Keystone Truss Bridge

Figure 8: Link Truss Bridge

Figure 9: Capstone Truss Bridge

For the decking, the team looked into using either a concrete deck or a wood deck. Concrete would provide a very nice, smooth surface; it would also be an effective long-term option as it is durable. With its durability, it would also require less maintenance in the future. If the design were to use wood decking, however, the cost would be much lower. Even though wood is not as durable and will require periodic maintenance, it would still provide sufficient decking for pedestrians and cyclists.

As the bridges currently stand, the northern bridge is approximately 250 ft long while the southern bridge has a span length of about 150 ft. Whether the south bridge is realigned or not, it will be able to have a design of any three of these trusses. Since the north bridge is much longer, however, it may not be able to use just any design. If the north bridge remains the same length, only a keystone truss or a capstone truss would be acceptable. If it is chosen to realign the north bridge or create a completely new bridge, any of the three trusses would be satisfactory as the team wants to limit the span length. Limiting the span will be accomplished by choosing a location along the creek where the creek is narrow and a bridge can perpendicularly cross it. This will give the team the shortest possible span and allow for any type of truss design as discussed. In addition to the prefabricated truss designs, other design inspirations can be seen in Figures 10-12 below.

Figure 10: Design Inspiration 1

Figure 11: Design Inspiration 2

Figure 12: Design Inspiration 3

Section VI: Final Design Details

After discussing all the possible solutions and weighing the pros and cons, the team decided to proceed with a preliminary design to further investigate the options. The team chose to design two of the alignments and therefore two bridges.

1. Western Trail Alignment

One final design will consist of the third trail alignment with one new bridge at a location further south along Black Hawk Creek. This solution will be referred to as the Western Trail Alignment.

Contours

Once the team had brainstormed the more specified design in ArcGIS, contours were overlayed on a road map. The contour was then clipped down just to cover the space being considered for the trail. Once in State Plane Coordinates, the contour could be opened in Civil 3D to proceed with the rest of the design.

Alignments

Once the contour surface was developed in Civil 3D, the chosen path was drawn out to create the horizontal alignment. Once this was done, the curves were evaluated to make sure that the minimum radius at each curve was met. This was accomplished by first determining the design speed. The team chose a design speed of 25 mph as it is a shared use path. With this value, a minimum radius of 115 ft must be met according to the Iowa DOT Design Manual. Each radius along the trail came out to be 200 ft and thus satisfies this requirement. The total length that would be added to the existing trail to go along the west side of the creek came out to be about 0.46 miles. This final trail realignment can be seen in Figure 13 below.

The vertical alignment was then created to analyze the vertical curvature of the path. From the design manual, it was decided that the grade be no more than 5.00%. In addition, each crest and sag curve had to meet a minimum rate of curvature of 12 and 26, respectively. The team was able to satisfy these criteria with the chosen design while smoothing out the elevations to allow for a more user-friendly path.

Figure 13: Alignment for the Western Trail Alignment in Civil 3D

Pavement Cross Section

An assembly was then built to analyze the cross section of the trail. The assembly was designed to have an asphalt pavement to match the current trail material. The asphalt was made to have a thickness of 5 inches which is recommended by the Iowa DOT Design Manual. Also based on the design manual, the trail was designed to be 12 ft wide to accommodate two-way traffic. Two-foot-wide shoulders were also added on each side to account for the clear space needed. This also met the Iowa DOT requirements of having a minimum shoulder of 2ft. This part of the assembly, however, will consist of soil and grass. Lastly, the trail path will have a small slope of 1.5% down toward Black Hawk Creek for drainage purposes. The finalized pavement cross section can be seen in Figure 14.

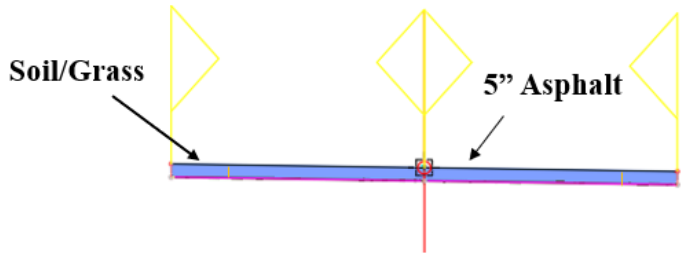


Figure 14: Western Alt. Pavement Cross-section

Material Volumes
Using the built-up assembly, a corridor was built. With the corridor, a corridor surface was built along the length of the trail in the horizontal alignment. With this completed, material volume tables could be created to analyze the cross-sectional volume of the pavement at various stations along the path. In addition to the tables, cross-sectional views were generated at multiple stations along the path to better visualize the cut and fill of the vertical profile. These tables and graphs can be seen in section VIII of the report under the Western Trail Alignment portion.

Cut and Fill

To better the design of the trail, the total cut and fill volumes along the path were estimated. From here, the team was able to adjust the vertical profile to balance out the cut and fill as much as possible while maintaining the necessary grades and curvature. Once finalized, the net cut and fill came out to be 0.01 cy with a little bit of excess cutting. This was determined to be satisfactory, and the trail alignment design could be completed.

Bridge Design
For the Western Bridge design, both the superstructure and substructure were designed by our team. The bridge spans Black Hawk Creek at 130 ft, so a steel truss framing system was decided on for the durability and less corrosive nature in water compared to wood framing. However, a wood deck was still chosen to help mediate costs. The bridge has a cross section of 12 ft to account for any maintenance and emergency vehicles, as well as providing enough room for opposing pedestrian traffic. A final design rendering of the Western Bridge is shown in Figure 15.

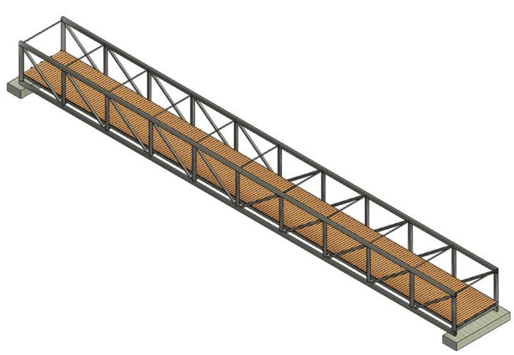


Figure 15: Full bridge design for the Western Trail Alignment

As for the foundation design for the Western Bridge, the team used a pile group design spreadsheet from the Iowa DOT to calculate the load carrying capacity of the pile group. The soil type around the new bridge's location was found to be primarily Spillville-Coland-Shandep complex, which is composed of clay loam and sandy loam, from the USDA web soil survey. This information was used in the spreadsheet along with the team's chosen pile shape. After evaluating the data and finalizing the design, the team came up with a pile group design that contains 10 piles of HP10x57 in the layout shown below in Figure 16. The pile lengths would be 35 ft deep.

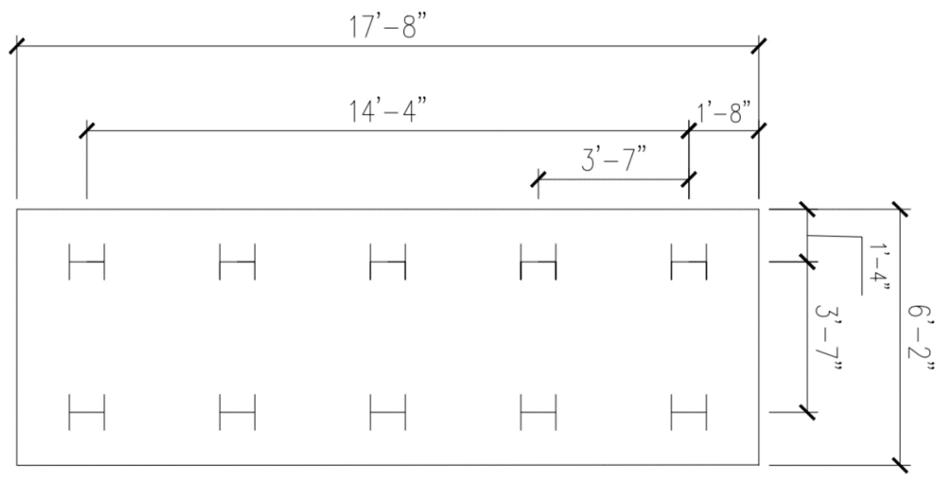


Figure 16: Pile Group Design

Hydraulic Analysis

Results of the hydraulic analysis for the Western Trail Alignment are summarized in Table 2 and Figures 17-19. The contraction scour depth in the 100-yr event was 5.4 ft, and the peak velocity immediately downstream of the crossing was about 5.9 ft/s for phase 1 and 5.7 ft/s for phase 2. At the far upstream end of the model, we found reduction of water surface elevation of about 1 ft for both phase 1 and 2. This is approximately 1000 ft upstream of the western bridge location. These results were obtained using the methods outlined in Section 3. Note that in the 100-yr flood event, the western crossing exceeds the SUDAS limit of 5 ft/s for a stiff clay streambed, indicating a need for channel protection measures. More detailed results are provided in Appendix G.

Table 2: Results of hydraulic analysis - west alternative

West Alternative				
Event	Depth, Upstream, ft	Velocity US, ft/s	Velocity DS, ft/s	Scour Depth, y_s, ft
2 year	11.7	3.64	3.86	-1.17
10 year	13.3	4.04	4.33	-2.50
100 year	15.6	4.4	4.3	-5.37
500 year	15.7	4.78	5.3	-4.30

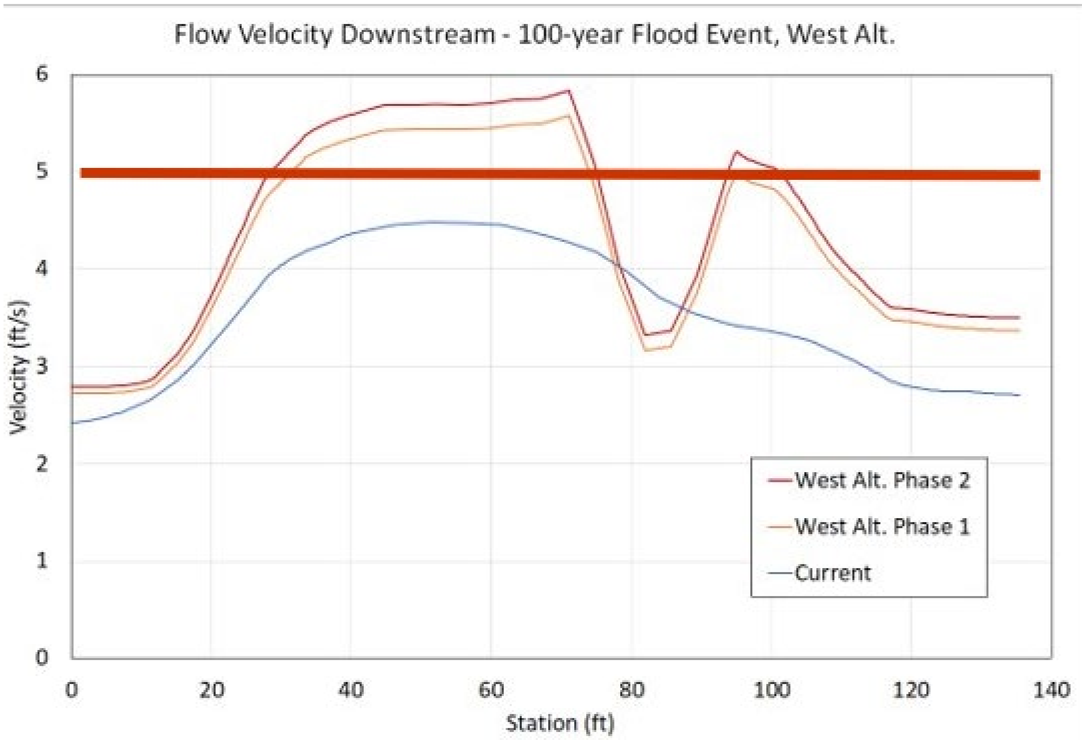


Figure 17: Velocity results downstream of the western crossing. Note the red line, indicating the SUDAS limit of 5 ft/s for a stiff clay streambed.

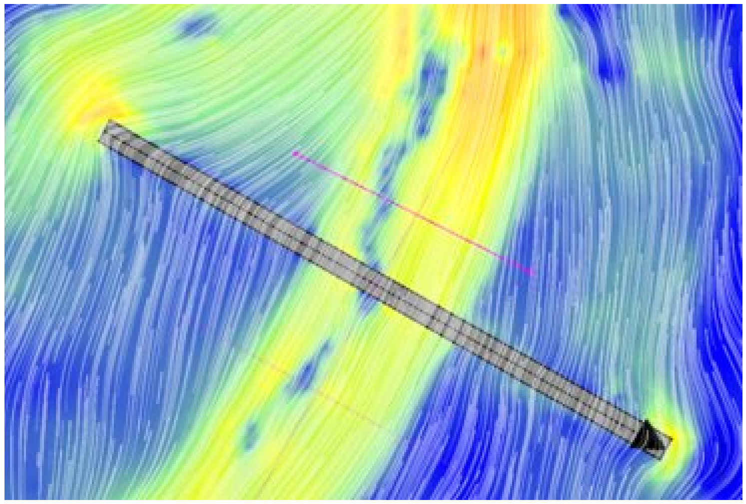


Figure 18: Cross-section at which velocity measurements were taken.

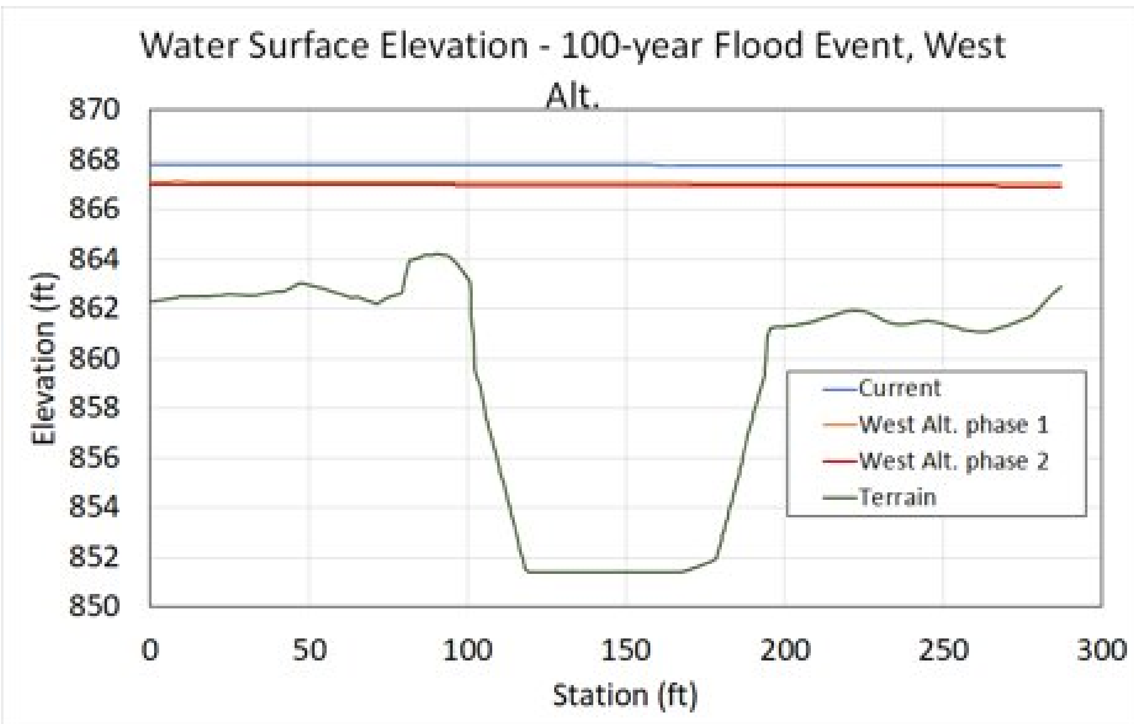


Figure 19: Water surface elevation as measured at the mouth of our hydraulic model.

2. Eastern Trail Alignment

The second final design will consist of the trail alignment passing through the bird sanctuary with one shorter bridge crossing Prescott's Creek. This solution will be referred to as the Eastern

Trail Alignment. A very similar process as the Western Trail Alignment was taken for this trail design.

Contours
The team created the initial alignment in ArcGIS and the contours were overlayed on a road map. The contour was then clipped down just to cover the space being considered for the trail. Once in State Plane Coordinates, the contour could be opened in Civil 3D to proceed with the rest of the design.

Alignments
Once the contour surface was developed in Civil 3D, the chosen path was drawn out which created the horizontal alignment. The radius of each curve along the path was adjusted to meet the 115 ft minimum from the Iowa DOT Design Manual. The total length that would be added to the existing trail to go along the east side of the creek came out to be about 0.44 miles. The final trail alignment can be seen in Figure 20 below.

The vertical alignment was then created to analyze the vertical curvature of the path. The team satisfied the grade criteria of being under 5.00%. In addition, each crest and sag curve had to meet a minimum rate of curvature of 12 and 26, respectively. This was accomplished and the vertical alignment was thus completed.

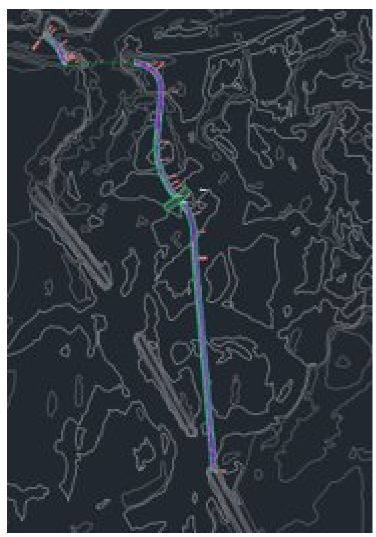


Figure 20: Alignment for Eastern Trail Alignment

Pavement Cross Section
An assembly was then built to analyze the cross section of the trail. The assembly was designed to have an asphalt pavement to match the current trail material. The asphalt pavement was chosen to be 5 in thick and the trail was made to be the recommended width of 12 ft. Two-foot-wide shoulders were also added on each side to account for the clear space needed. This part of the assembly, however, will consist of soil and grass. Lastly, the trail path will have a small slope of 1.5% down toward Black Hawk Creek for drainage purposes. The finalized pavement cross section can be seen in Figure 21.

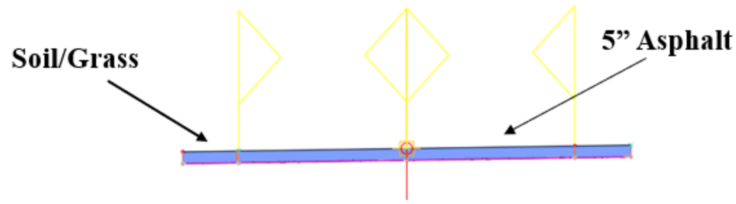


Figure 21: Eastern Alt. Pavement Cross-section

Material Volumes
Using the built-up assembly, a corridor was built. With the corridor, a corridor surface was built along the length of the trail in the horizontal alignment. With this completed, material volume tables could be created to analyze the cross-sectional volume of the pavement at various stations along the path. In addition to the tables, cross-sectional views were generated at multiple stations along the path to better visualize the cut and fill of the vertical profile. These tables and graphs can be seen in section VIII of the report under the Eastern Trail Alignment portion.

Cut and Fill
The total cut and fill volumes along the path were then estimated. From here, the team was able to adjust the vertical profile to balance out the cut and fill as much as possible while maintaining the necessary grades and curvature. Once finalized, the net cut and fill came out to be 185.26 cy with excess filling. This was determined to be the best net cut and fill that could be achieved due to the end of the new trail section needing to be raised up to the existing elevation of the current trail. The trail alignment design could then be completed.

Bridge Design
For this alternative, a prefabricated bridge was chosen for the simplicity and cost benefit given the short crossing over Prescott's Creek. The prefabricated bridge chosen is from Contech Engineered Solutions, and it is their Link Truss Pedestrian Bridge. The bridge will span 38 ft and be comprised of steel framing and a wood deck. The steel will be weathering steel to contribute to the rustic aesthetic. To contribute to the ease of construction, there will be precast concrete abutments. The design of the bridge can be seen below in Figure 22. The foundation design for this bridge can be seen in Figure 23.

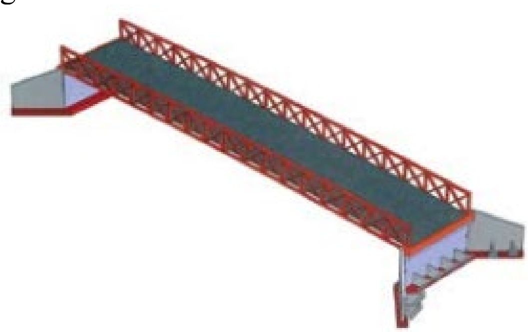


Figure 22: Eastern Bridge Design (courtesy Contech Bridge Solutions)

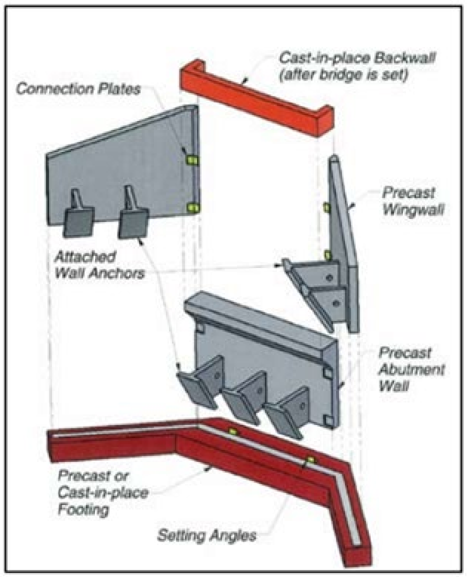


Figure 23: Eastern Bridge Foundation (courtesy Contech Bridge Solutions)

Hydraulic Analysis

The hydraulic analysis was carried out in the same manner as for the Western Trail Alignment and the results are summarized in Table 3 and Figures Figure 24 and Figure 26. The contraction scour depth in the 100-yr event was 5.9 ft, and the peak velocity immediately downstream of the crossing was about 4.2 ft/s for both phases 1 and 2. We found reduction of water surface elevation of about 1 ft for both phase 1 and 2. Again, this is approximately 1000 ft upstream of the western bridge location. In comparing these results, we see that, especially in higher frequency flood events, the western location is less susceptible to scour, while the eastern location has lower overall velocity. Because the smaller bridge of the eastern alternative is less costly, this alternative may still be the more economical, despite suffering deeper scour.

Table 3: Results of hydraulic analysis – Eastern Trail Alignment

East Alternative				
Event	Depth, Upstream, ft	Velocity US, ft/s	Velocity DS, ft/s	Scour Depth, y_s, ft
2 year	11.1	0.65	0.49	-4.68
10 year	12.2	2.23	1.99	-4.68
100 year	14.2	4.4	4.3	-5.90
500 year	14.4	3.96	3.88	-6.06

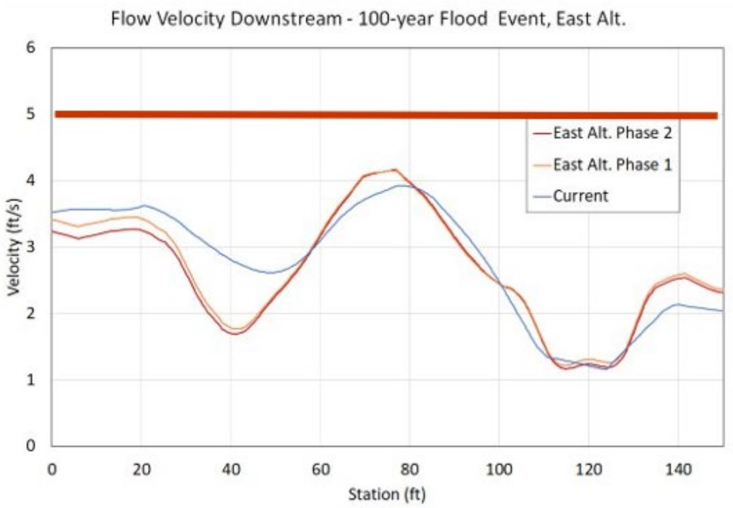


Figure 24: Velocity results downstream of the eastern crossing. Note the red line, indicating the SUDAS limit of 5 ft/s for a stiff clay streambed.

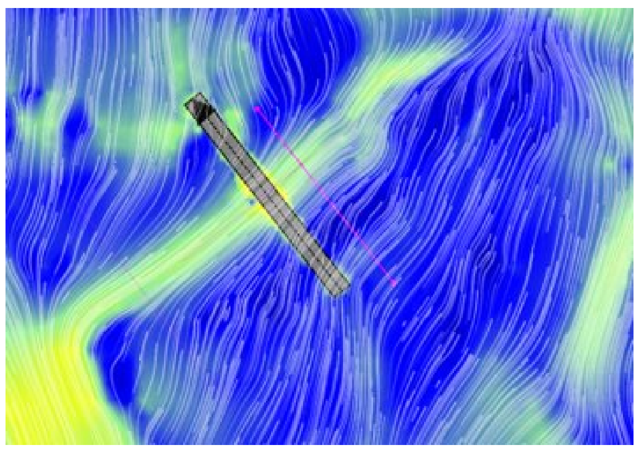


Figure 25: Cross-section at which velocity measurements were taken.

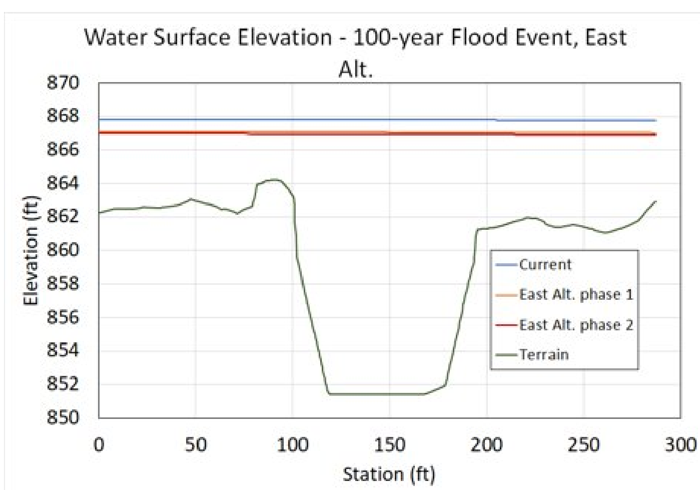


Figure 26: Water surface elevation as measured at the mouth of our hydraulic model.

3. Hydraulic Analysis

The hydraulic analysis was carried out in HEC-RAS in order to ascertain how this project will respond to flooding, which is common in the area. Two separate models were developed for both design alternatives that we chose to explore, one each for phase I and phase II, as well as a fifth model of the current conditions. It is important to note that this is only a preliminary analysis. The client acknowledged that they would need a FEMA flood assessment before building this project, so our analysis is purely exploratory, for the purpose of comparing our designs with the bridges to be replaced.

We have made several assumptions and approximations which, while necessary, do limit its utility. The model was developed as follows. First, a projection of the project area was obtained from ESRI (Spatial Reference, 2021). Elevation data from the Iowa HUC12 2m DEM database was obtained via Iowa State's online repository (USDA/ARS National Laboratory for Agriculture and the Environment, 2016). This was used to build a terrain model in HEC-RAS. The dataset did not include bathymetry. However, the flood assessment provided by the client did include streambed elevations along the length of both Black Hawk and Prescott's Creeks (Appendix G: Hydraulic Analysis Details). We used this elevation profile as the thalweg to develop a series of trapezoidal cross-sections for both creeks using the channel modification tool in HEC-RAS. These cross-sections were estimated using a combination of satellite photography from Google Maps and drone video footage provided by the client. From these cross-sections, we created an interpolated surface which was then combined with the DEM data to create a new terrain.

A land use map was obtained from the state of Iowa (State of Iowa Office of the Chief Information Officer, 2009). This was overlaid on the terrain and Manning's n values were assigned to each land use category using data from Open Channel Hydraulics by V.T. Chow (1959), supplemented where necessary by an NRCS handout by Curtis Janssen, SCE (2016). Using all of this information, a 1D steady-flow analysis was performed in order to obtain slopes for the Energy Grade Line to be used in boundary conditions for 2D analysis. A computational mesh was created using a 10 ft. grid spacing for the channel, 20 ft. for the overbanks and 75 ft. for the floodplain (Figure 28). Additional refinement was added to the model along sharp features such as the existing trail embankment by the use of breaklines.

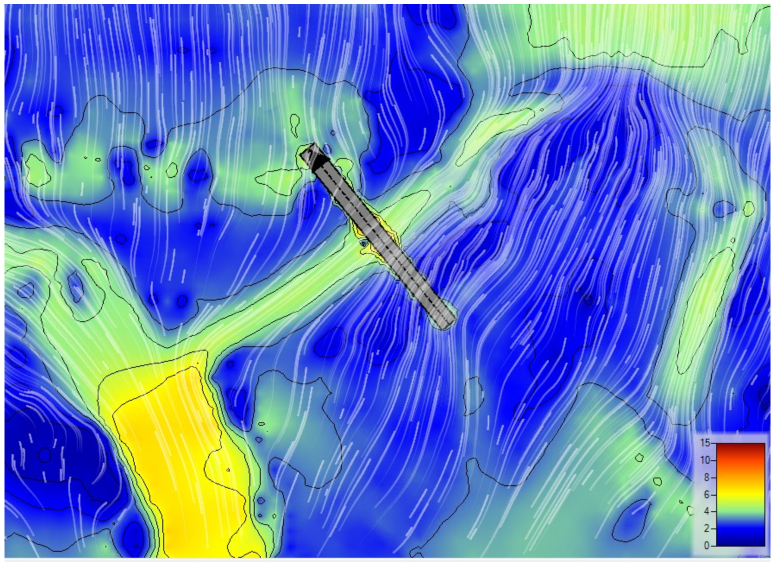


Figure 27: Velocity heatmap with streamlines for East alternative from 100-year flood event (ft/s).

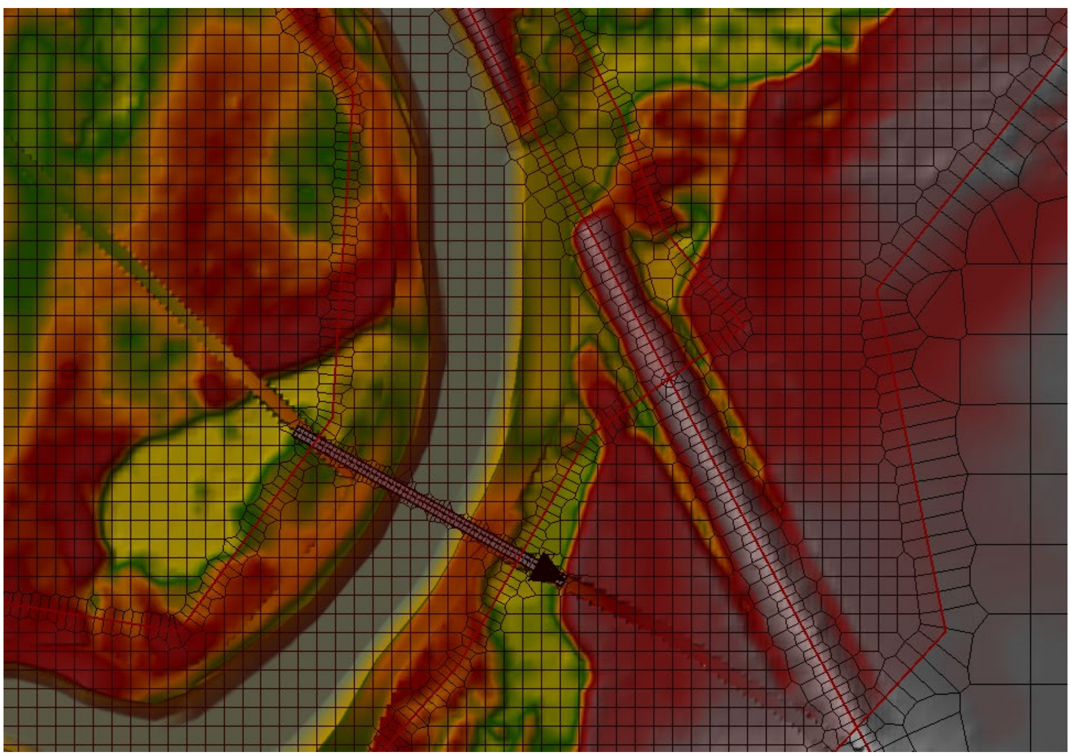


Figure 28: Western Trail Alignment showing computational mesh.

Input boundary conditions were applied at the upstream intersections of the flow area with Black Hawk and Prescott's Creeks. A normal depth output boundary condition was applied at the crossing of Ranchero Road over Black Hawk Creek. Additional normal depth output boundary conditions were applied along Ranchero Road to the north and also along Sergeant Road to the east. Peak flow statistics were found using USGS StreamStats (United States Geological Survey,

2021) for 2, 10, 100, and 500-year recurrence intervals. A 2D steady flow analysis was then performed using these peak flows. From these analyses, velocities were measured at the proposed bridges and then used to calculate contraction scour using the methods outlined in HEC18 (U.S. Department of Transportation Federal Highway Administration, 2012). Contraction scour was calculated for the 100- and 500-year events per NCHRP Report 516 (National Academies of Sciences, Engineering, and Medicine, 2004) and AASHTO (American Association of State Highway and Transportation Officials, 2012). Soil characteristics were estimated using the custom soil survey maps provided by NRCS (National Resources Conservation Service, 2021), an estimation of D_{50} for scour calculation was made using Table 1 in “An approach for using soil surveys to guide the placement of water quality buffers” by Dosskey et al. (2006). In the implementation of the model bridges, we used HEC-RAS' default 2:1 expansion ratio and 1:1 contraction ratio. Sloping abutments were not used and we specified a weir coefficient of 2.7.

Local scour at the abutments was not calculated. This is because local scour is highly dependent on a number of design details which are not specified in this preliminary analysis and streambed conditions which are difficult or impossible to determine without an in-person site visit. Additionally, HEC-RAS can currently only calculate local scour in 1D models. Backwater elevations for both alternatives were compared with our model of the existing conditions.

Caution should be exercised when interpreting these results. A number of assumptions were made while performing this analysis. Because we could not make an in-person site visit, we were unable to conduct any kind of soil analysis and needed to rely on maps of soil groups, the characteristics of which are highly variable. Additionally, we were not able make any measurements of the channel, the crossings, or the existing bridges. The information provided by the clients was invaluable, but still could not compare to visiting the site ourselves, and necessitated we take several liberties in our analysis. These limitations contributed to our decision to perform only a preliminary analysis of multiple alternatives. In calculating the scour depth, the top width of the channel was used rather than the bottom. HEC18 states that this is permissible in many cases.

Using this model, we were able to calculate water surface elevations and flow velocities at the proposed crossings, to provide a preliminary approximations of our models’ respective impacts on the area.

Section VII: Engineer’s Cost Estimate

Cost Estimates were developed for both the Western Trail Alignment and the Eastern Trail Alignment. Both trail alignment costs were estimated using the RSMeans online data estimating service (Gordion, 2021). The Eastern Trail Alignment cost estimate also considered the estimate given by Contech Engineering Solutions for the prefabricated bridge. Finally, a cost estimate was made for the removal of the railway embankments. The unit costs include overhead and labor costs.

The Western Trail Alignment Project is estimated to be $521,500. This comes from the realignment of the trail, which was estimated to be approximately $91,000, and the cost of designing and constructing the bridge which is estimated to be approximately $310,000. Where these estimations came from can be viewed in Table 4 below.

Table 5: Detailed cost estimate for Western Trail Alignment

Item	Unit	Unit Cost	Quantity	Extended Cost
Trail				
Clearing and Grubbing	acre	$ 6,000.48	0.89	$ 5,350
Cut/Fill	CY	$ 5.56	24.28	$ 135
Soil Compaction	CY	$ 0.43	539.64	$ 230
5" asphalt	SY	$ 24.93	3237.87	$ 80,500
Top soil	CY	$ 8.37	449.70	$ 3,775
Seeding	Acre	$ 914.42	0.67	$ 610
Bridge				
4" x 8" Lumber	LF	$ 15.30	2532.00	$ 38,700
Pile Caps	CY	$ 786.69	31.80	$ 25,000
Steel Piles HP 10x57	VLF	$ 121.47	700.00	$ 85,000
Bearings	Ea.	$ 1,245.00	4.00	$ 4,975
HSS4-1/2X4-1/2X5/16	Ea.	$ 861.69	11.00	$ 9,475
HSS6X4X5/16	Ea.	$ 1,390.74	20.00	$ 27,800
HSS8X6X5/16	Ea.	$ 2,230.65	18.00	$ 40,200
HSS10X6X3/8	Ea.	$ 3,057.93	4.00	$ 12,200
HSS12X6X3/8	Ea.	$ 4,021.56	4.00	$ 16,100
W8x10	LF	$ 63.57	650.00	$ 41,300
W10x12	LF	$ 70.44	132.00	$ 9,300
Trail				$ 91,000
Bridge				$ 310,000
Cont -- 10%				$ 40,100
Admin & Engineering -- 20%				$ 80,200
			Total	**$ 521,500**

The Eastern Trail Alignment Project is estimated to be $209,500. This comes from the realignment of the trail, which was estimated to be approximately $88,000, and the prefabricated bridge which was estimated to be $95,000. Where these estimations came from can be viewed in Table 5 below.

Table 6: Detailed cost estimate for Eastern Trail Alignment

Item	Unit	Unit Cost	Quantity	Extended Cost
Trail				
Clearing and Grubbing	acre	$ 6,000.48	0.85	$ 5,125
cut/fill	CY	$ 5.56	185.26	$ 1,025
Soil Compaction	CY	$ 0.43	516.27	$ 220
5" asphalt	SY	$ 24.93	3097.60	$ 77,000
Top soil	CY	$ 8.37	430.22	$ 3,600
Seeding	Acre	$ 914.42	0.64	$ 585
Bridge				
Link Truss Pedestrian Bridge	Ea.	$ 60,000.00	1.00	$ 60,000
Pre-cast abutments and foundation	Ea.	$ 17,500.00	2.00	$ 35,000
Trail				$ 88,000
Bridge				$ 95,000
Cont -- 10%				$ 8,800
Admin & Engineering -- 20%				$ 17,600
			Total	**$ 209,500**

The cost for removing the existing railway embankments is estimated to be $78,500 for both embankments. This estimate was looked at separately from the two design alternatives because the removal of the railway embankments was to be considered a secondary phase of the design.

Table 7: Detailed cost estimate for Railway Embankment Removal

Item	Unit	Unit Cost	Quantity	Extended Cost
Embankment 1 Removal	CY	$ 5.56	5285.35	$ 29,400
Embankment 2 Removal	CY	$ 5.56	5560.2	$ 30,900
Removal of Embankments				$ 60,500
Cont -- 10%				$ 6,050
Admin & Engineering -- 20%				$ 12,100
			Total	**$ 78,500**

Recommended Design

After the preliminary design of the western and eastern trail alignments and the hydraulic analysis was complete, both alternatives were compared to determine the best design for the project. A decision matrix was created that included multiple criteria that were of importance to the project. Those criteria were cost, flooding, removal of trees, ease of construction, pedestrian experience, and client preference. These criteria were given a weight on a scale of 0-1 to how important they were to the project. After this was developed, the Western Trail Alignment and

Eastern Trail Alignment were ranked on a scale of one to five, five being the optimal conditions and one being suboptimal, on how well they met the criteria. From this, it was determined the Eastern Trail Alignment would be the best design option to pursue for the Cedar Prairie Trail Bridge Replacement Project.

Table 4: Decision Matrix for Project

Evaluation Criteria	Weight	Western Alignment	Eastern Alignment
Cost	**0.7**	**2**	**5**
Flooding	**0.5**	**2**	**1**
Removal of Trees	**0.2**	**3**	**1**
Ease of Construction	**0.5**	**4**	**4**
Pedestrian Experienc	**0.3**	**3**	**4**
Client Preference	**0.4**	**4**	**5**
Weighted Total		**7.5**	**9.4**

Section VIII: Appendices

Appendix A: Task Form

UNIVERSITY OF IOWA
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
Project Design & Management
(CEE:4850:0001)

RFP # 02-spring2021

Trail Bridge Replacement

Tasks Form

Bidder's Organization Name:
MLDC Engineering Co.

Task Description	Task Hours
Task 1: Decide Alternative	8.8
Task 2: Alignment / Site design	39.6
Task 3: Bridge design	176
Task 4: Hydraulics	96.8
Task 5: Confirm code and standards compliance	52.8
Task 6: Remove embankments / abutments if needed	26.4
Task 7: Report and presentation preparation	22
Task 8: Meetings	17.6
TOTAL BILLABLE HOURS	440

Appendix B: Cost Form

UNIVERSITY OF IOWA
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
Project Design & Management
(CEE:4850:0001)

RFP # 02-spring2021

Trail Bridge Replacement
Cost Form

Bidder's Organization Name:
MLDC Engineering Co.

Budget Summary					
Task	**Hours**	**Hourly Salary**[a]	**Multiplier for overhead and profit**[b]	**Total**	
Decide Alternative	8.8	$29.26	2.5	$643.62	
Alignment / Site design	39.6	$29.26	2.5	$2,896.27	
Bridge design	176	$29.26	2.5	$12,872.33	
Hydraulics Analysis	96.8	$29.26	2.5	$7,079.78	
Confirm code and standards compliance	52.8	$29.26	2.5	$3,861.70	
Remove embankments / abutments if needed	26.4	$29.26	2.5	$1,930.85	
Report and presentation preparation	22	$29.26	2.5	$1,609.04	
Meetings	17.6	$29.26	2.5	$1,287.23	
				$32,180.82	Sub-total
				$0.00	Travel, Materials and Supplies
	440			$32,180.82	Total Cost

[a]Direct Costs is broadly defined as any cost that can be assigned to a specific task in an accurate way, such as wages, fringe benefits, materials, and supplies.
[b]Indirect Costs include overhead costs of maintaining a design firm that cannot be accurately attributed to given tasks and profit margin.

Appendix C: North Bridge Inspection Report

Pictures			
NBI Number:	14870	Bridge ID:	0704.7S934
Facility Carried:	UNIVERSITY AVE	Feature(s) Intersected:	ABANDONED RR

Photo Number: 47 Photo Taken: 07/09/2019

Exposed abutment cap underside at south end of East Abutment

Photo Number: 48 Photo Taken: 07/09/2019

Exposed timber pile at south end of East Abutment cap

927

Office of Bridges and Structures
Bridge Maintenance and Inspection Unit

Bridge Condition Report

Bridge ID: NORTH TRAIL BRIDGE NBI Number:
District: Inspection Group: AECOM
Inspection Type: Routine
Inspection Date: 7/12/2019
Carrying: CEDAR PRAIRIE TRAIL
Location: OVER BLACK HAWK CREEK
Approved By: 7/12/2019

928

IOWADOT

FIELD DATA COLLECTION FORM

90 Inspection Date: 7/12/2019

Bridge Name: NORTH CEDAR PRAIRIE TRAIL BRIDGE   Bridge ID:

43 Main Structure Type: TIMBER TRESTLE BRIDGE   90 Inspection Date: 7/12/2019

FHWA No. :   6 Feature Intersected: BLACK HAWK CREEK   Inspector: 7/12/2019 ael

Report Type: ☑ Routine ☐ In-Depth ☐ Fracture Critical Details ☐ Underwater Insp. ☐ Special Insp.   Consulting Firm: AECOM

9 Location: CITY BRIDGE   3 County: Black Hawk   City: WATERLOO   22 Owner: City or Municipal Highway Agency

Est. Remaining Life: ____ Yrs.   Fracture Critical: ☐   29 ADT: ____   113 Scour Critical: ____   27 Yr. Built: ____   106 Yr. Reconst.: ____

LOAD POSTING TABLE

Type	Recommended Tons	Actual Tons

APPROACH	COND. RATING	REMARKS
1. Approach Slab	7	Minor cracking
2. Relief Joints		NA
3. Approach - Guardrail		NA
Embankment	7	Minor erosion

ITEM 72 APPROACH ROADWAY ALIGNMENT: 7

LOAD POSTING REMARKS

SIGNING

Type	Legibility	Visibility	Remarks
Posted Loads			
Narrow			
One Lane			
Object Markers			

DECK ITEM	CONDITION RATING	REMARKS
1. Wearing Surface		
2. Deck - Structural Condition	7	Minor deterioration of timber planks
3. Curbs		
4. Median		
5. Sidewalks		
6. Railings	7	Damage to Fence at east.
7. Paint		
8. Drains		
9. Utility Connections		
10. Joint Leakage		
11. Expansion Joints and Devices		
General Comments		

ITEM 58 DECK CONDITION RATING: 7

929

IOWA DOT

FIELD DATA COLLECTION FORM

Bridge ID: North Cedar Prairie Trail Bridge over Black Hawk Creek 8 FHWA No.: NA 90 Inspection Date: 7/12/2019

SUPERSTRUCTURE	CONDITION RATING	REMARKS
1. Bearing Devices		
2. Stringers	4	Moderate deterioration and splitting of timber stringers. Moderate corrosion on steel beam stringers.
Lateral Supports ( )		
3. Girders/Beams		
Lateral Supports ( )		
4. Floor Beams		
Lateral Supports ( )		
5. Trusses - General		
Portals		
Bracing		
6. Paint		
7. Rivets or Bolts		
8. Welds - Cracks		
9. Rust		
10. Timber Decay		
11. Concrete Cracking		
12. Collision Damage		
13. Deflection Under Load		
14. Alignment of Members		
15. Vibration Under Load		

General Comments

ITEM 59 SUPERSTRUCTURE CONDITION RATING: 4

Additional Structure Details:

930

IOWADOT

FIELD DATA COLLECTION FORM

Bridge ID: North Cedar Prairie Trail Bridge over Black Hawk Creek 8 FHWA No.: NA 90 Inspection Date: 7/12/2019

1. Abutments - Caps		3	Severe decay and section loss in several caps. See tables in inspection report for locations.
~~MARKS	Wings		
	Backwall	5	Some deterioration of timber planks.
	Footing		
	Piles	3	Severe dry rot, decay, and section loss in most piles. See tables in inspection report for locations.
	Erosion		
	Settlement		
2. Piers or Bents - Caps		3	Severe decay and section loss in several caps. See tables in inspection report for locations.
	Columns		
	Footings		
	Piles	3	Severe dry rot, decay, crushing and section loss in most piles. See tables in inspection report for locations.
	Scour		50% to 80% section loss in multiple piles. Some piles are missing. Some piles have failed.
	Settlement		Broken cross bracing.
3. Concrete Cracking			
4. Steel Corrosion			
5. Timber Decay		3	Timber caps and piles have severe decay. Fire damage is also present.
6. Debris on Seats			
7. Paint			
8. Collision Damage			

ıeral Comments

ITEM 60 SUBSTRUCTURE CONDITION RATING: 3

931

IOWADOT

FIELD DATA COLLECTION FORM

Bridge ID: North Cedar Prairie Trail Bridge over Black Hawk Creek 8 FHWA No.: NA 90 Inspection Date: 7/12/2019

CHANNEL AND CHANNEL PROTECTION		REMARKS
1. Channel Scour	6	Minor scour and erosion
2. Embankment Erosion	7	
3. Drift	5	Extensive trees and other debris collecting under Spans 7, 8, & 9
4. Vegetation	8	Well vegetated channel slopes.
5. Channel Change	8	
6. Fender System		
7. Spur Dikes and Jetties		
8. Riprap		
9. Adequacy of Opening	8	

General Comments

ITEM 61 CHANNEL / CHANNEL PROTECTION CONDITION RATING: 6

Item 113 Scour Critical Bridges ______

Scour Critical Bridge

Scour Plan of Action (POA) Implemented for Bridges with Item 113 coded 0, 1, 2, or 3 (Upload POA):

Scour Analysis (Upload Analysis PDF): ☐ Level A ☐ Level B ☐ Level C

Bridge with Unknown Foundation

Unknown Foundation Analysis (Upload Analysis PDF): ☐ Level A ☐ Level B

Unknown Foundation Risk Level:

Plan of Action (POA) Implemented for Unknown Foundation determined to be Moderate or High Risk (Upload POA):

932

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 1 Date: 7/12/2019

West side of bridge looking north.

Photo Number: 2 Date: 7/12/2019

West side of bridge looking south.

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 3 Date: 7/12/2019

Top of pedestrian path deck looking north

Photo Number: 4 Date: 7/12/2019

Top of pedestrian path deck looking south

934

Pictures

NBI Number: Bridge ID: CITY BRIDGE 64

Facility Carried: CEDAR PRAIRIE TRAIL (N) Feature(s) Intersected: BLACK HAWK CREEK

Photo Number: 5 Date: 7/12/2019

Pedestrian trail looking south from bridge

Photo Number: 6 Date: 7/12/2019

Pedestrian trail looking north from bridge

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 7 Date: 7/12/2019

Damaged fence member along east side, looking northeastn nnn

Photo Number: 8 Date: 7/12/2019

Damaged fence along east side, looking northeast

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 9 Date: 7/12/2019

Upstream view looking southwest

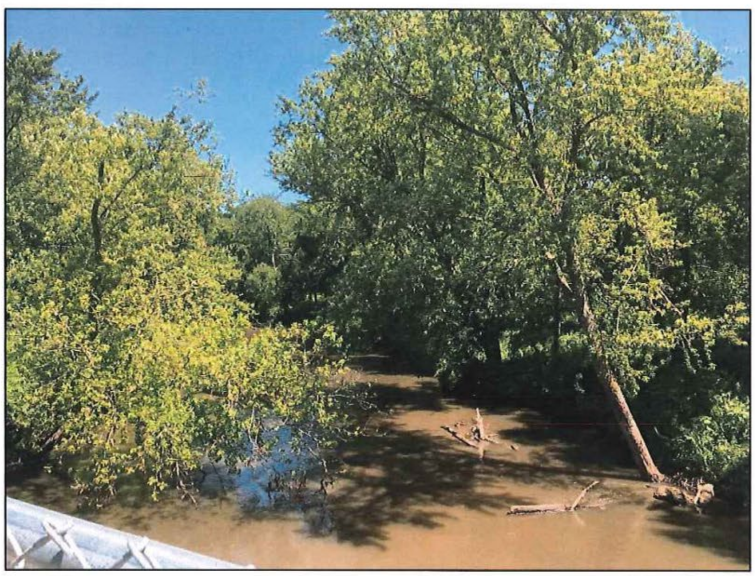


Photo Number: 10 Date: 7/12/2019

Downstream view looking northeast

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 11 Date: 7/12/2019

South Abutment timber bent looking east

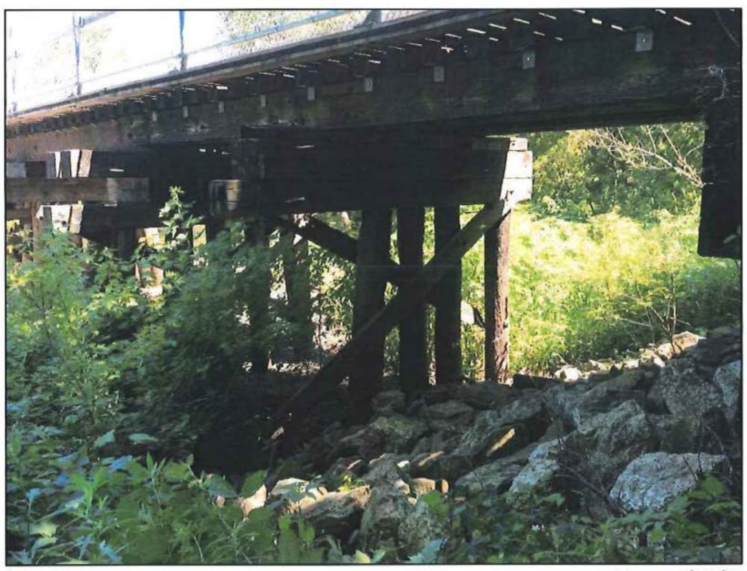


Photo Number: 12 Date: 7/12/2019

Pier 1 looking NE with missing timber piles at left side

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 13 Date: 7/12/2019

Pier 1 looking north with decayed timber cap and missing pile

Photo Number: 14 Date: 7/12/2019

Pier 2 looking south

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 15 Date: 7/12/2019

Pier 2 looking SE with failed pile on south bent at right

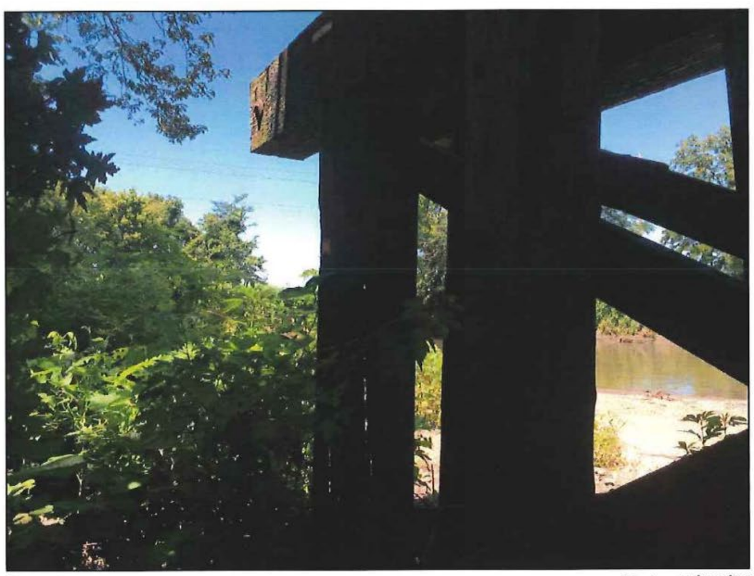


Photo Number: 16 Date: 7/12/2019

Pier 2 looking west, with daylight seen in pile splits

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 17 Date: 7/12/2019

Pier 3 looking NE, with two piles missing from north and south bents

Photo Number: 18 Date: 7/12/2019

Pier 3 looking SE, with two piles missing from west ends of north and south bents

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 19 Date: 7/12/2019

Pier 4 looking NE, with two piles missing from the west end of both bents, and fire char on remining piles and cap

Photo Number: 20 Date: 7/12/2019

Pier 4 looking SE with missing piles at right and severe char on upper piles and cap

942

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 21 Date: 7/12/2019

Pier 4 looking north showing missing piles at left and fire char at cap

Photo Number: 22 Date: 7/12/2019

Pier 5 looking NW, with pile at far left exhibiting a large split

943

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

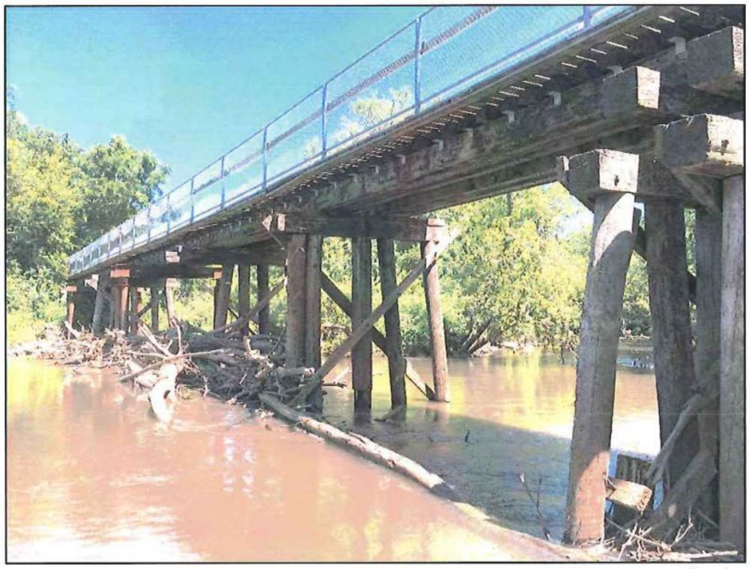


Photo Number: 23 Date: 7/12/2019

Timber pile bent Piers 6, 7, & 8 at center of channel, looking NE, with severe drift collection

Photo Number: 24 Date: 7/12/2019

Close-up of base of Pier 6, with severe timber decay and partial timber splice visible at waterline

944

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

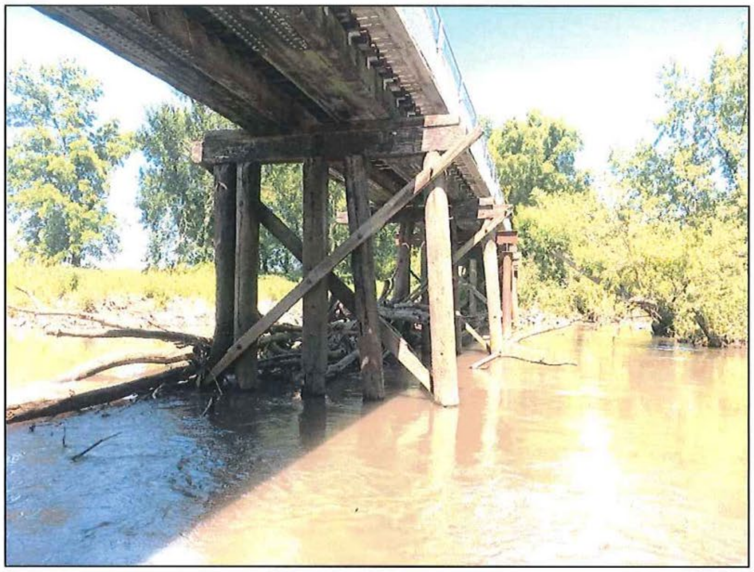


Photo Number: 25 Date: 7/12/2019

Pier 6 looking north, with large pile of fallen trees and other drift collecting under Span 7

Photo Number: 26 Date: 7/12/2019

Timber pile bent Pier 9 at left, and steel pile bent Pier 8 in channel, looking south

945

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

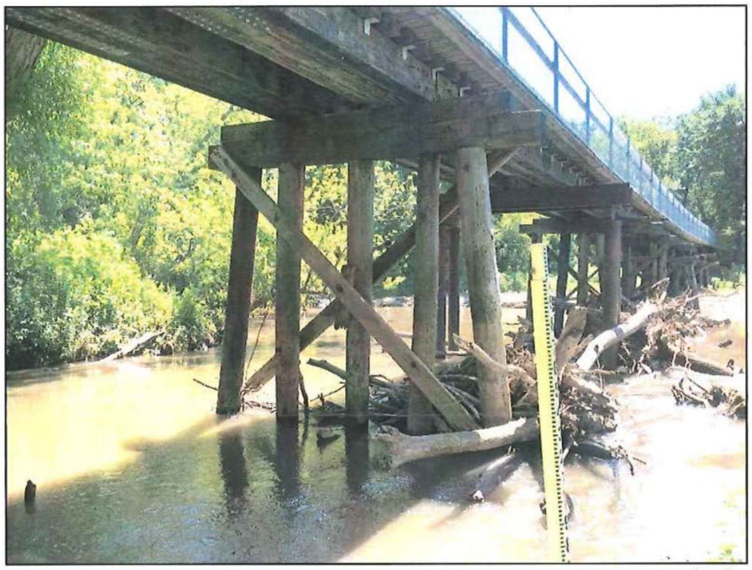


Photo Number: 27 Date: 7/12/2019

Pier 9 looking SE, with large timber debris pile collecting underneath span

Photo Number: 28 Date: 7/12/2019

Steel pile bent Pier 10, looking NE

946

Pictures

NBI Number:		Bridge ID:	CITY BRIDGE 64
Facility Carried:	CEDAR PRAIRIE TRAIL (N)	Feature(s) Intersected:	BLACK HAWK CREEK

Photo Number: 29 Date: 7/12/2019

Timber pile bent Pier 11, looking NE

Photo Number: 30 Date: 7/12/2019

Severe decay on timber cap of Pier 11, looking NE

Office of Bridges and Structures
Bridge Maintenance and Inspection Unit

Bridge Condition Report

Bridge ID: SOUTH TRAIL BRIDGE NBI Number:
District: Inspection Group: AECOM
Inspection Type: Routine
Inspection Date: 7/12/2019
Carrying: CEDAR PRAIRIE TRAIL
Location: OVER BLACK HAWK CREEK
Approved By: James Tippett

948

SIIMS

Appendix D: Western Bridge Calculations

For wood decking selecting Douglas Fir-Larch Select Structural

$F_b := 1500\ psi$ $\qquad C_d := 2.0$ $\qquad$ Impact

$C_t := 1$ $\qquad$ Exposure to elevated temperature in nature can be left as 1

$C_F := 1.3$

$C_{Fu} := 1.05$ $\qquad C_L := 1$

$M := 3.98\ kip \cdot ft$

$C_i := 1$ $\qquad C_m := 0.85$

$C_r := 1$

$$S \geq \frac{M}{F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_L \cdot C_F \cdot C_{Fu} \cdot C_i \cdot C_r} \xrightarrow{float,4} S \geq \frac{0.001143 \cdot ft \cdot kip}{psi}$$

$$\frac{0.001143 \cdot ft \cdot kip}{psi} = 13.716\ in^3$$

Select 4X8 for decking 14.80

Dead Load Calculations

W8X10 Stringers $\qquad w_s := 10\ plf$ $\qquad N_{st} := 5$ $\qquad N_T := 2$

$$w_{DS} := \frac{w_s \cdot N_{st}}{N_T} = 25\ plf$$

W8X10 Floorbeams

$s_{fb} := 12\ ft$

$$P_{DFB} := \frac{s_{fb} \cdot w_s}{N_T} = 60\ lbf$$

Decking

$N_{DB} := 211$ $\qquad w_{DB} := 6.65\ lbf$ $\qquad L_B := 130\ ft$

$$w_{DB} := \frac{N_{DB} \cdot w_{DB}}{N_T \cdot L_B} = 5.397\ plf$$

Truss self weight calculated in robot

Panel Point Dead Loads

$P_{wI} := 13\ ft$ $\qquad P_{wE} := \frac{P_{wI}}{2} = 6.5\ ft$

$P_{DI} := (w_{DS} + w_{DB}) \cdot P_{wI} + P_{DFB} = 0.455\ kip$ $\qquad P_{DE} := (w_{DS} + w_{DB}) \cdot P_{wE} + P_{DFB} = 0.258\ kip$

Live Load Calculation

$L_l := 90\ psf$ $\qquad s := 12\ ft$

$w_{LL} := \frac{L_l \cdot s}{N_T} = 540\ plf$

Panel Point Live Loads

$P_{LI} := w_{LL} \cdot P_{wI} = 7.02\ kip$

$P_{LE} := w_{LL} \cdot P_{wE} = 3.51\ kip$

Vertical wind loading

$P_V := 0.02\ ksf$ $\qquad WS_V := P_V \cdot 12\ ft = 240\ plf$

$VL_{lee} := WS_V \cdot \frac{\left(\frac{3}{4} \cdot 13\ ft\right)}{13\ ft} = 180\ plf$ $\qquad 180\ plf \cdot 1.4 = 252\ plf$

Live load is greater and therefore strength I is controlling load case

$VL_{wind} := WS_V \cdot \frac{\left(\frac{1}{4} \cdot 13\ ft\right)}{13\ ft} = 60\ plf$ uplift

Horizontal wind load calculations

Top and bot chord 12in each for length of bridge
Diagonal 6 in 15ft by per panel
End posts 10 in by 10ft
Int posts 8 in by 10ft
Decking 10 in for length of bridge

$$A_{wE} := 2 \cdot \frac{12\ in \cdot 13\ ft}{2} + 10\ in \cdot 10\ ft + \frac{6\ in \cdot 15\ ft}{2} + \frac{10\ in \cdot 13\ ft}{2} = 30.5\ ft^2$$

$$A_{wI} := 2 \cdot 12\ in \cdot 13\ ft + 8\ in \cdot 10\ ft + 6\ in \cdot 15\ ft + 10\ in \cdot 13\ ft = 51\ ft^2$$

$$P_z = 0.00256\ K_z \cdot G \cdot V^2 \cdot I_r \cdot C_d$$

$K_z := 1.0$ conservative

$G := 1.14$ minimum

$V := 100$

$I_r := 1.0$

$C_d := 2.0$

$$P_z := 0.00256\ K_z \cdot G \cdot V^2 \cdot I_r \cdot C_d \cdot psf = 58.368\ psf$$

$P_E := P_z \cdot A_{wE} = 1.78\ kip$ $P_I := P_z \cdot A_{wI} = 2.977\ kip$

$$\frac{P_I}{11\ ft} = 0.271\ klf$$

Total lateral load for strength III on entire bridge

$$2 \cdot (P_E \cdot 2 + P_I \cdot 8) \cdot 1.4 = 76.649\ kip$$

Loads and forces on members were calculated using Autodesk Robot

A := READEXCEL (“.\Load Calcs.xlsx”, “UNFACTORED AXIAL FORCE!B2:G45”)

A =

“HSS Size”	“Position”	“Bar”	“Dead Load Truss”	“Dead Load Deck”	“Live Load”
NaN	NaN	NaN	“(kip)”	“(kip)”	“(kip)”
“12X6X0.375”	“Bot Chord ”	1	0	0	0
“↓”	“Bot Chord ”	2	−9.34	−2.66	−41.07
“↓”	“Bot Chord ”	3	−16.6	−4.73	−73.01
“↓”	“Bot Chord ”	4	−21.78	−6.21	−95.82
“↓”	“Bot Chord ”	5	−24.89	−7.1	−109.51
“↓”	“Bot Chord ”	6	−24.89	−7.1	−109.51
“↓”	“Bot Chord ”	7	−21.78	−6.21	−95.82
“↓”	“Bot Chord ”	8	−16.6	−4.73	−73.01
“↓”	“Bot Chord ”	9	−9.34	−2.66	−41.07
“↓”	“Bot Chord ”	10	0	0	0
“↓”	“Top Chord”	11	9.34	2.66	41.07
“↓”	“Top Chord”	12	16.6	4.73	73.01
“↓”	“Top Chord”	13	21.78	6.21	95.82
“↓”	“Top Chord”	14	24.89	7.1	109.51
“↓”	“Top Chord”	15	25.93	7.39	114.07
“↓”	“Top Chord”	16	25.93	7.39	114.07
“↓”	“Top Chord”	17	24.89	7.1	109.51
“↓”	“Top Chord”	18	21.78	6.21	95.82
“↓”	“Top Chord”	19	16.6	4.73	73.01
“↓”	“Top Chord”	20	9.34	2.66	41.07
“10X6X0.375”	“L End Post”	21	7.74	2.05	31.59
“8X6X0.3125”	“Int Vertical”	22	6.38	1.59	24.57
“↓”	“Int Vertical”	23	4.79	1.14	17.55
“↓”	“Int Vertical”	24	3.19	0.68	10.53
“↓”	“Int Vertical”	25	1.6	0.23	3.51
“↓”	“Int Vertical”	26	0.65	0	0
“↓”	“Int Vertical”	27	1.6	0.23	3.51
“↓”	“Int Vertical”	28	3.19	0.68	10.53
“↓”	“Int Vertical”	29	4.79	1.14	17.55
“↓”	“Int Vertical”	30	6.38	1.59	24.57
“10X6X0.375”	“R End Post”	31	7.74	2.05	31.59
“6X4X0.3125”	“Diagonal”	32	−11.78	−3.36	−51.81
“↓”	“Diagonal”	33	−9.16	−2.61	−40.3
“↓”	“Diagonal”	34	−6.54	−1.87	−28.78
“↓”	“Diagonal”	35	−3.93	−1.12	−17.27
“↓”	“Diagonal”	36	−1.31	−0.37	−5.76
“↓”	“Diagonal”	37	−1.31	−0.37	−5.76
“↓”	“Diagonal”	38	−3.93	−1.12	−17.27
“↓”	“Diagonal”	39	−6.54	−1.87	−28.78
“↓”	“Diagonal”	40	−9.16	−2.61	−40.3
“↓”	“Diagonal”	41	−11.78	−3.36	−51.81
NaN	NaN	NaN	NaN	NaN	NaN

A := READEXCEL (".\Load Calcs.xlsx", "UNFACTORED AXIAL FORCE!J2:M5")

A =

"Reactions"	"Dead Load Truss"	"Dead Load Deck"	"Live Load"
NaN	"(kip)"	"(kip)"	"(kip)"
"Left"	8.2	2.31	35.1
"Right"	8.2	2.31	35.1

A := READEXCEL (".\Load Calcs.xlsx", "UNFACTORED AXIAL FORCE!O2:R5")

A =

"Loading"	"Dead"	"Live"	"Total"
NaN	"(kip)"	"(kip)"	"(kip)"
"Load per Truss"	21.02	70.2	91.22
"Load on Bridge"	42.04	140.4	182.44

A := READEXCEL (".\Load Calcs.xlsx", "UNFACTORED AXIAL FORCE!U2:z9")

A =

NaN	"Max Loads"	"Dead Truss"	"Dead Decking"	"Live"	"Tension or Compression"
NaN	*NaN*	"(kip)"	"(kip)"	"(kip)"	*NaN*
"12X6X0.375"	"Bot Chord "	−24.89	−7.1	−109.51	"T"
"12X6X0.375"	"Top Chord"	25.93	7.39	114.07	"C"
"10X6X0.375"	"L End Post"	7.74	2.05	31.59	"C"
"10X6X0.375"	"R End Post"	7.74	2.05	31.59	"C"
"8X6X0.3125"	"Int Vertical"	6.38	1.59	24.57	"C"
"6X4X0.3125"	"Diagonal"	−11.78	−3.36	−51.81	"T"

A := READEXCEL (".\Load Calcs.xlsx", "UNFACTORED AXIAL FORCE!AB2:AE10")

A =

"Factored Loads"	"Dead Truss"	"Dead Decking"	"Live"
NaN	"(kip)"	"(kip)"	"(kip)"
"Factors"	1.25	1.25	1.75
"Bot Chord "	−31.113	−8.875	−191.643
"Top Chord"	32.413	9.238	199.623
"L End Post"	9.675	2.563	55.283
"R End Post"	9.675	2.563	55.283
"Int Vertical"	7.975	1.988	42.998
"Diagonal"	−14.725	−4.2	−90.668

Resistance Calculations

Tension

$\sigma = \frac{P}{A_g}$ yield occurs at $P_y = F_y \cdot A_g$ $\phi_t := 0.9$

As this is preliminary design connections are not being designed which means there is no fracture consideration

From steel construction manual available tensile strength

HSS 12X6X3/8 $\phi_t P_n := 531\ kip$ due to yield $\phi_t P_{nR} := 412\ kip$ Due to Rupture

Required strength $P := 191.6\ kip$ Acceptable

HSS 6X4X5/16 $\phi_t P_n := 237\ kip$ due to yield $\phi_t P_{nR} := 184\ kip$ Due to Rupture

Required strength $P := 90.7\ kip$ Acceptable

Compressive Strengths

Assuming K = 1 for all members based on all connections being pins

$L_c = K \cdot L_B$ L_B = unbraced length Strengths from AISC steel manual

HSS 12X6X3/8 and $L_c = 13\ ft$ $\phi_c P_n := 399\ kip$ Top chord in compression alone is adequate

HSS 10X6X3/8 and $L_c = 10\ ft$ $\phi_c P_n := 392\ kip$ End post in compression alone is adequate

HSS 8X6X5/16 and $L_c = 10\ ft$ $\phi_c P_n := 284\ kip$ Interior post in compression alone is adequate

Slenderness ration for top chord

$L := 13\ ft$ $K := 1$ $r_x := 4.28\ in$ $r_y := 2.49\ in$

$\frac{K \cdot L}{r_x} = 36.449$ $\frac{K \cdot L}{r_y} = 62.651$ acceptable is under 120

Lateral force in vertical members

$$H_f := \frac{0.01}{K} \cdot 240\ kip = 2.4\ kip$$

$$E := 29000\ ksi \qquad F_y := 50\ ksi$$

$$F_e := \frac{\pi^2 \cdot E}{62.651^2} = 72.919\ ksi$$

$$\frac{K \cdot L}{r_x} = 36.449$$

$$\frac{K \cdot L}{r_y} = 62.651 \quad <= \quad 4.71 \cdot \sqrt{\frac{E}{F_y}} = 113.432$$

$$F_{cr} := \left(0.658^{\frac{F_y}{F_e}}\right) F_y = 37.526\ ksi$$

$$\phi_c := 0.9 \qquad A_g := 7.59\ in^2$$

$$\phi P_n := \phi_c \cdot F_{cr} \cdot A_g = 256.338\ kip$$

$$P_c := \phi P_n = 256.338\ kip$$

$$M_{rx} := 1.75 \cdot 4.84\ kip \cdot ft$$

$$P_r := 52.961\ kip$$

$$M_{cx} := 77.3\ kip \cdot ft$$

$$\frac{P_r}{P_c} = 0.207$$

$$\frac{P_r}{P_c} + \frac{8}{9} \cdot \left(\frac{M_{rx}}{M_{cx}}\right) = 0.304$$

adequate

Bracing Calculations

$\phi := 0.75$ $\quad P_r := 58.29$ $\quad L_{BR} := 10 \cdot 12$

$\beta_{BR} := \frac{1}{\phi}\left(\frac{8 \cdot P_r}{L_{BR}}\right) = 5.181\ \frac{kip}{in}$ $\qquad k = \frac{3\ E \cdot I}{L^3}$ Required bracing stiffness

$E_s := 29000\ ksi$ $\qquad I_{br} := 0.747\ in^4$ $\qquad L_{br} := 13\ ft$

Guess Values

$I_{br} := 0.747\ in^4$

Constraints

$k_{br}\left(I_{br}\right) := \frac{48\ E_s \cdot I_{br}}{{L_{br}}^3} - 5.181\ \frac{kip}{in}$

Solver

$\text{root}\left(k_{br}\left(I_{br}\right), I_{br}\right) = 14.13\ in^4$

Guess Values

$I_{br} := 0.747\ in^4$

Constraints

$k_{br}\left(I_{br}\right) := \frac{192\ E_s \cdot I_{br}}{{L_{br}}^3} - 5.181\ \frac{kip}{in}$

Solver

$\text{root}\left(k_{br}\left(I_{br}\right), I_{br}\right) = 3.533\ in^4$

$I_{br1} = 14.13\ in^4$ pin pin point load in center

$I_{br2} = 3.533\ in^4$ Fixed Fixed point load in center

To error on the safe side in connection can not act as fixed select HSS4.5X4.5X5/16 - I =13.5in^4

Vibration check

$$f = 0.18 \cdot \sqrt{\frac{g}{\Delta_{DL}}} \qquad g := 32.2\ \frac{ft}{s^2} \qquad \Delta_{DL} := (.0978 + 0.3535)\ in$$

$$f := 0.18 \cdot \sqrt{\frac{g}{\Delta_{DL}}} = 5.267\ Hz$$

3 hz is minimum

Live load deflection

$$\Delta_{LL} \le \frac{L}{360} \qquad \Delta_{LL} := 1.5026\ in \qquad L := (130 \cdot 12)\ in$$

$$\Delta_{LL} \le \frac{L}{360} \xrightarrow{float,4} 1.503 \cdot in \le 4.333 \cdot in$$

Satisfies live load deflection requirements

Bearing connections can be selected with 30 kip lateral capacity each with 4 connections having a total capacity of 120 kips and a total vertical load capacity of 100 kip and the required vertical strength being 300 kip
Bearing connections selected from
https://www.rjwatson.com/bridge-highway/bridge-structural-bearings/disktron-bearings

Use fixed connection with 30% lateral capacity on one end and
Unidirectional with 30% lateral capacity both with 100 kip vertical capacity

Appendix E: Hydraulic Analysis Details

A: Scour

East Alternative

Event	Depth, US, ft	Depth, bridge, ft	Velocity US, ft/s	Velocity DS, ft/s	V_*, ft/s	w, ft/s	V_*/w	S_1	k_1	W1, ft	W2, ft	Q1, cfs	Q2, cfs	y2/y1	y2, ft	y_s, ft
2 year	11.1	10.8	0.65	0.49	0.93168	0.005	186.3352	0.0024286	0.69	80	38	324.675	94.08	0.57807	6.41657	-4.6834
10 year	12.2	12.1	2.23	1.99	1.00507	0.005	201.0134	0.0025714	0.69	80	38	1224.27	382.08	0.61603	7.51561	-4.6844
100 year	14.2	13.9	4.4	4.3	1.2906	0.005	258.1209	0.0036429	0.69	80	38	2811.6	825.6	0.58469	8.30256	-5.8974
500 year	14.4	14.11	3.96	3.88	1.27392	0.005	254.7846	0.0035	0.69	80	38	2566.08	744.96	0.579	8.33759	-6.0624

West Alternative

Event	Depth, US, ft	Depth, bridge, ft	Velocity US, ft/s	Velocity DS, ft/s	V_*, ft/s	w, ft/s	V_*/w	S_1	k_1	W1, ft	W2, ft	Q1, cfs	Q2, cfs	y2/y1	y2, ft	y_s, ft
2 year	11.68	11.52	3.64	3.86	0.35782	0.005	71.56331	0.0003404	0.69	165	135	3720.08	2798.5	0.89984	10.5102	-1.1698
10 year	13.31	13.22	4.04	4.33	0.53453	0.005	106.9058	0.0006667	0.69	165	135	4705.085	3139.25	0.81189	10.8063	-2.5037
100 year	15.58	15.47	4.4	4.3	0.54864	0.005	109.728	0.0006	0.69	165	135	5998.3	3117.5	0.65541	10.2113	-5.3687
500 year	15.69	15.58	4.78	5.3	0.58036	0.005	116.071	0.0006667	0.69	165	135	6562.343	3842.5	0.72593	11.3898	-4.3002

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1} \qquad (6.2)$$

$$y_s = y_2 - y_o = \text{(average contraction scour depth)} \qquad (6.3)$$

where:

y_1 = Average depth in the upstream main channel, ft (m)
y_2 = Average depth in the contracted section, ft (m)
y_o = Existing depth in the contracted section before scour, ft (m) (see Note 7)
Q_1 = Flow in the upstream channel transporting sediment, ft^3/s (m^3/s)
Q_2 = Flow in the contracted channel, ft^3/s (m^3/s)
W_1 = Bottom width of the upstream main channel that is transporting bed material, ft (m)
W_2 = Bottom width of main channel in contracted section less pier width(s), ft (m)
k_1 = Exponent determined below

V_*/T	k_1	Mode of Bed Material Transport
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

V_* = $(\vartheta_o/\Delta)^{1/2} = (g y_1 S_1)^{1/2}$, shear velocity in the upstream section, ft/s (m/s)
T = Fall velocity of bed material based on the D_{50}, m/s (Figure 6.8)
For fall velocity in English units (ft/s) multiply T in m/s by 3.28
g = Acceleration of gravity (32.2 ft/s^2) (9.81 m/s^2)
S_1 = Slope of energy grade line of main channel, ft/ft (m/m)
ϑ_o = Shear stress on the bed, (lb/ft^2) (Pa (N/m^2))
Δ = Density of water (1.94 $slugs/ft^3$) (1000 kg/m^3)

Calculations performed assuming temp. of 60°F.

B: Model and Parameters

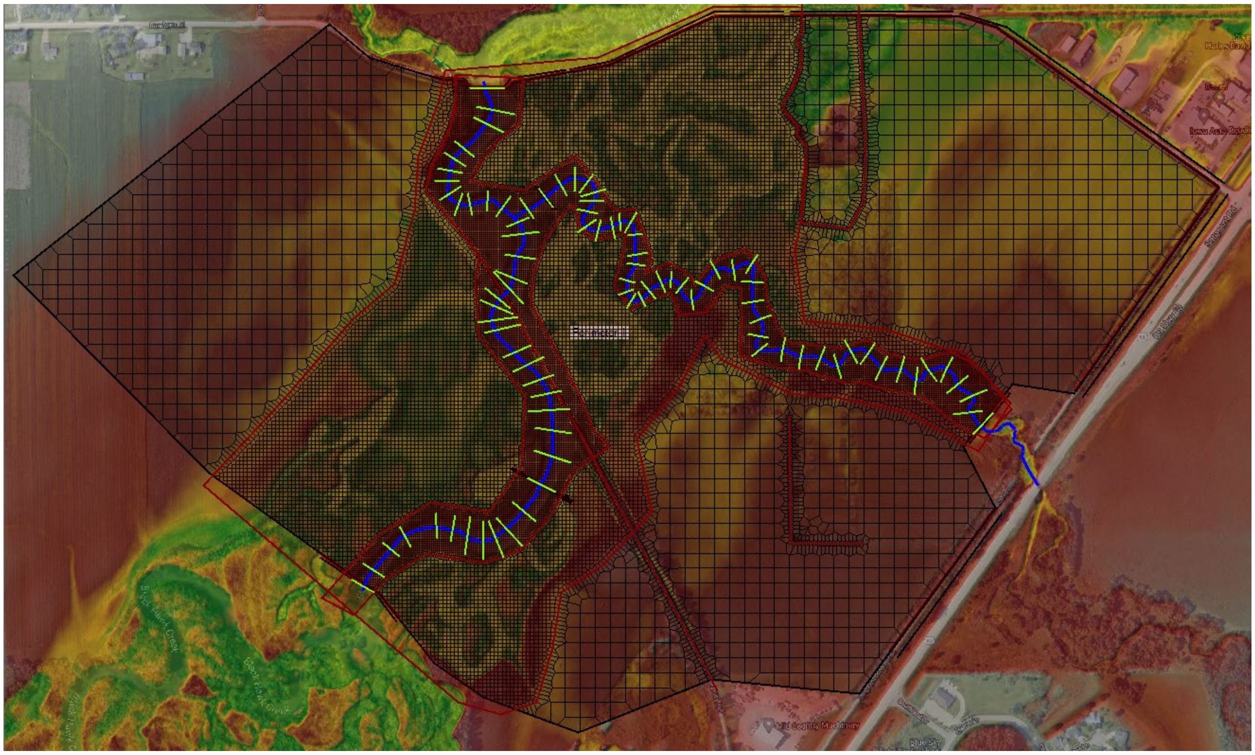


Figure 29: Model showing computational mesh with breaklines, refinement regions and boundary condition lines, as well as cross-sections used to create channel modifications

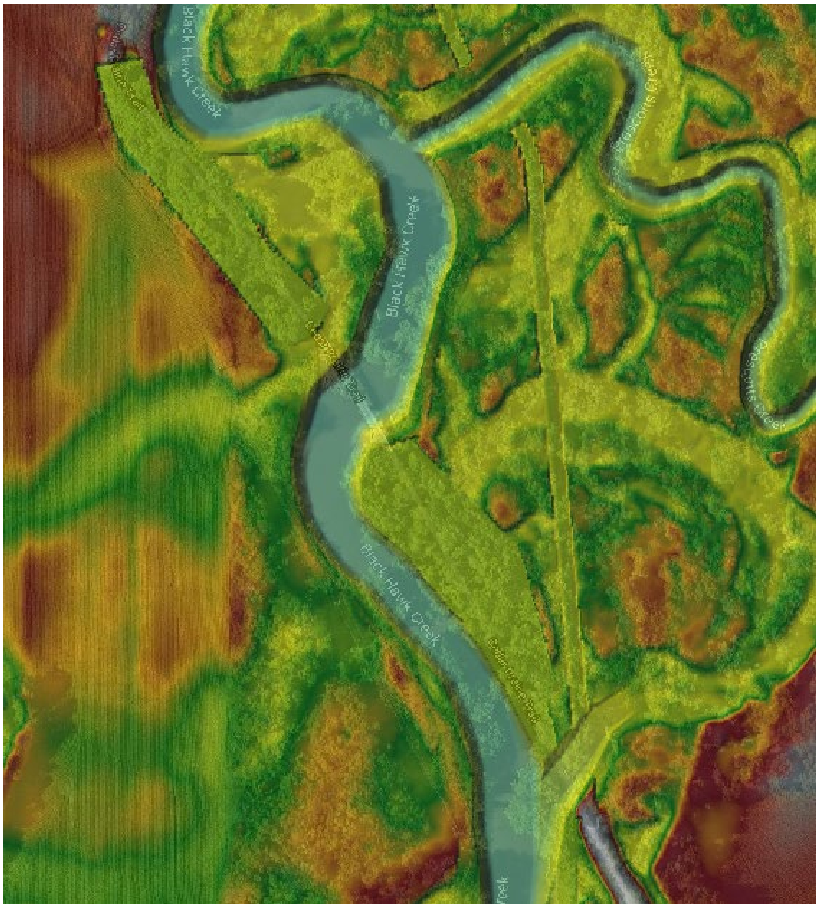


Figure 30: Terrain for eastern alignment with embankments removed

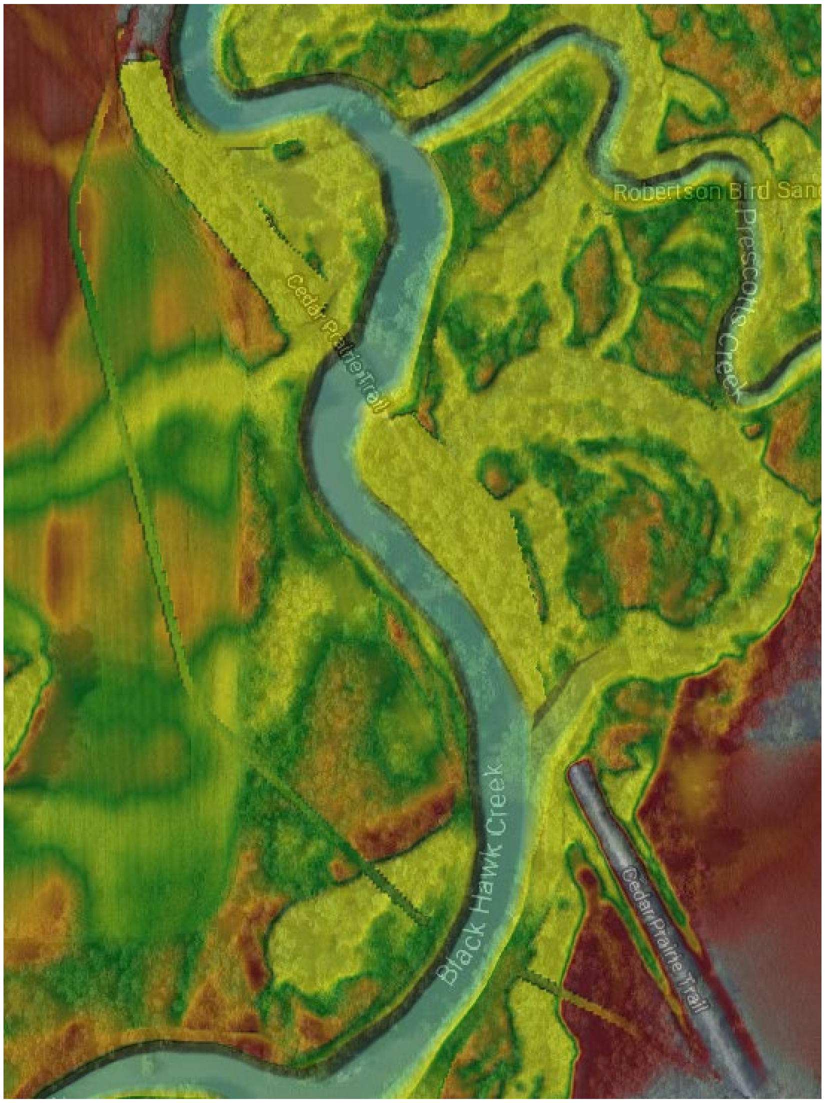
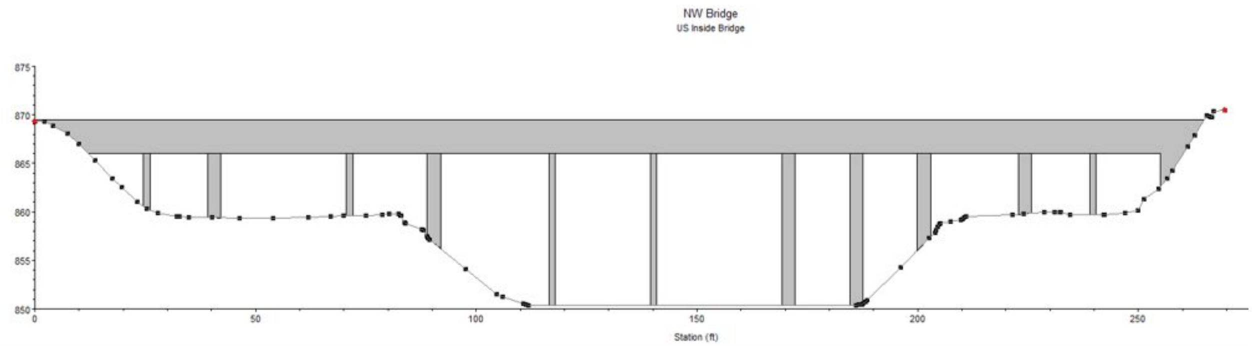
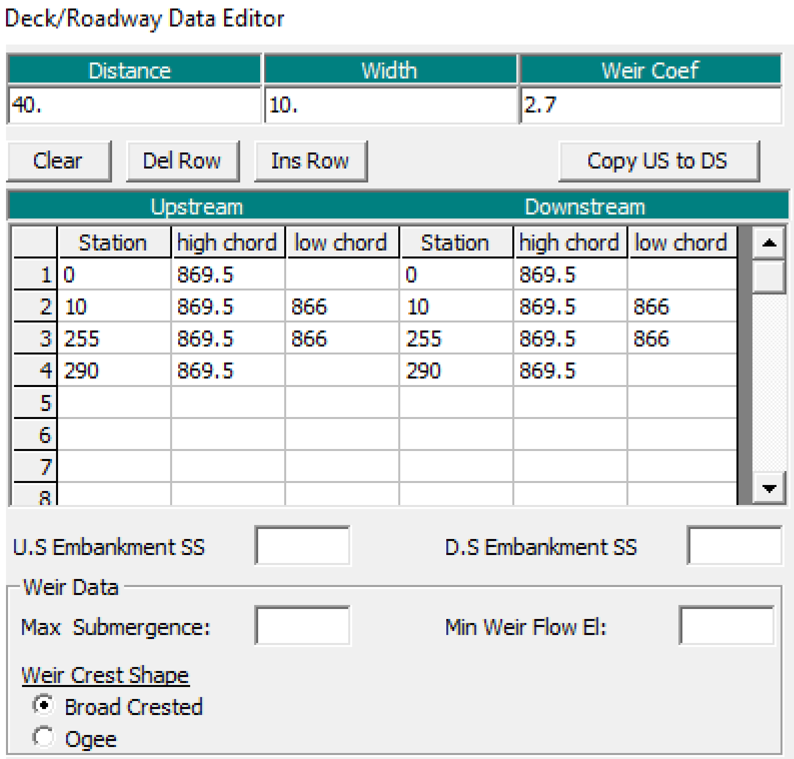


Figure 31: Terrain for western alignment with embankments removed

Bridge models used




Deck/Roadway Data Editor

Distance	Width	Weir Coef
40.	10.	2.7

Clear | Del Row | Ins Row | Copy US to DS

	Upstream			Downstream		
	Station	high chord	low chord	Station	high chord	low chord
1	0	869.5		0	869.5	
2	10	869.5	866	10	869.5	866
3	255	869.5	866	255	869.5	866
4	290	869.5		290	869.5	
5						
6						
7						
8						

U.S Embankment SS D.S Embankment SS

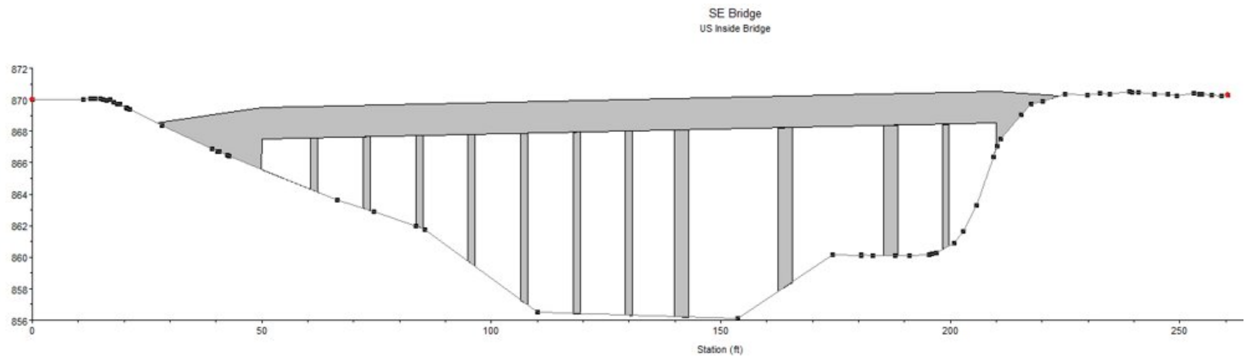
Weir Data

Max Submergence: Min Weir Flow El:

Weir Crest Shape

(•) Broad Crested

( ) Ogee



Deck/Roadway Data Editor

Distance	Width	Weir Coef
30.	10.	2.7

Clear | Del Row | Ins Row | Copy US to DS

	Upstream			Downstream		
	Station	high chord	low chord	Station	high chord	low chord
1	0	867.4		0	867.4	
2	50	869.5	867.5	50	869.5	867.5
3	210	870.5	868.5	210	870.5	868.5
4	261	869.5		261	869.5	
5						
6						
7						
8						

U.S Embankment SS   D.S Embankment SS

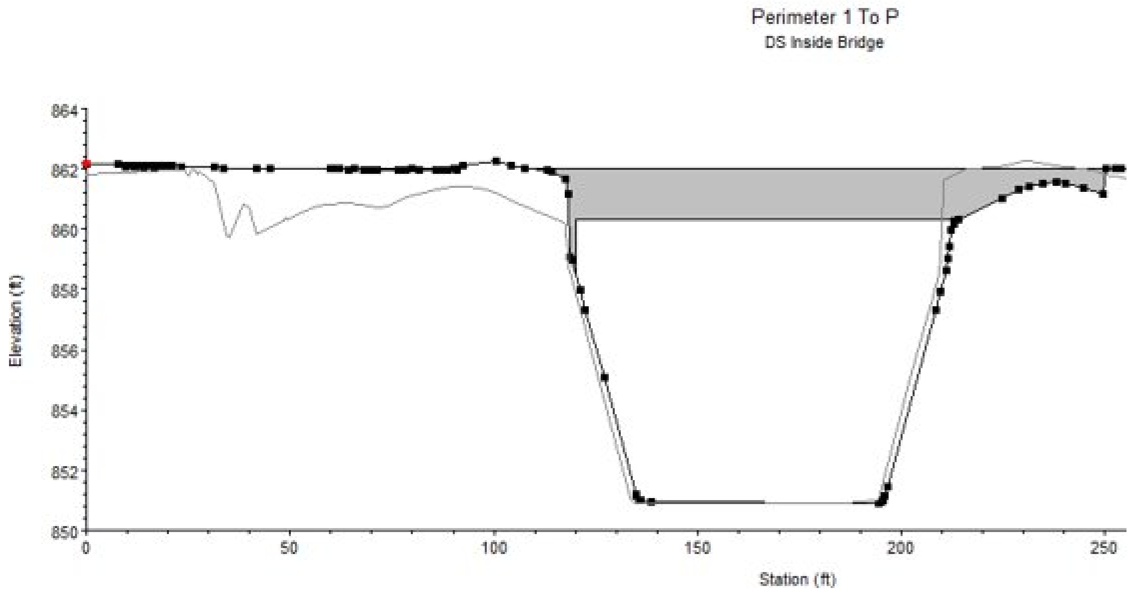
Weir Data

Max Submergence: Min Weir Flow El:

Weir Crest Shape

(•) Broad Crested

( ) Ogee



Deck/Roadway Data Editor

Distance	Width	Weir Coef
20.	12.	2.7

Clear | Del Row | Ins Row | Copy US to DS

	Upstream			Downstream		
	Station	high chord	low chord	Station	high chord	low chord
1	60	862		60	862	
2	120	862	860.3	120	862	860.3
3	255	862	860.3	255	862	860.3
4	270	862		270	862	
5						
6						
7						
8						

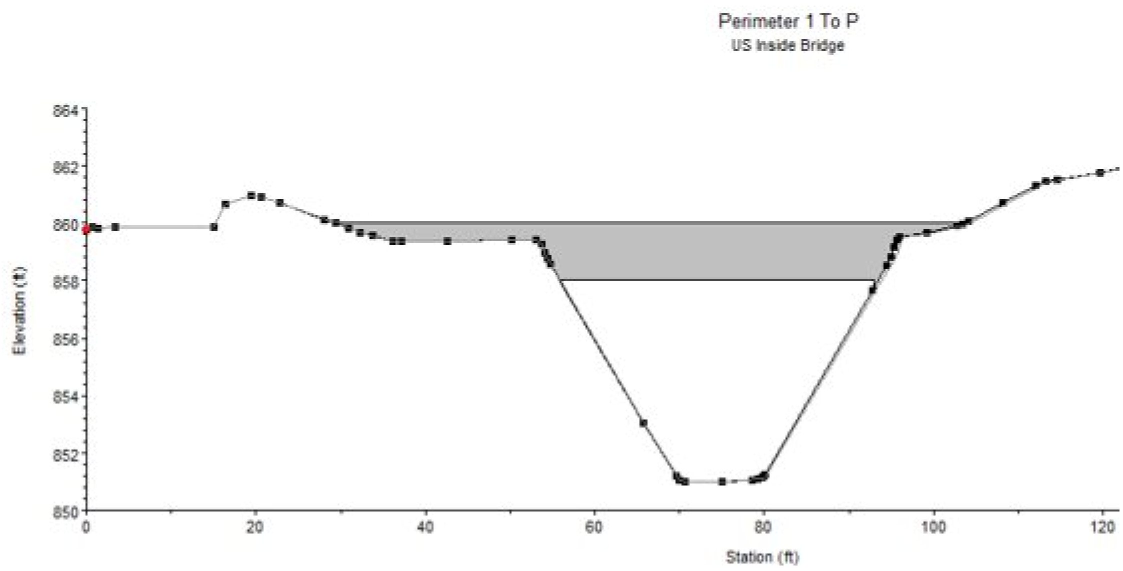
U.S Embankment SS: 3.   D.S Embankment SS: 3.

Weir Data

Max Submergence: Min Weir Flow El:

Weir Crest Shape

- (•) Broad Crested
- ( ) Ogee



Deck/Roadway Data Editor

Distance	Width	Weir Coef
15.	12.	2.7

Clear · Del Row · Ins Row · Copy US to DS

	Upstream			Downstream		
	Station	high chord	low chord	Station	high chord	low chord
1	25	860		25	860	
2	55	860	858	55	860	858
3	93	860	858	93	860	858
4	110	860		110	860	
5						
6						
7						
8						

U.S Embankment SS: 3. D.S Embankment SS: 3.

Weir Data

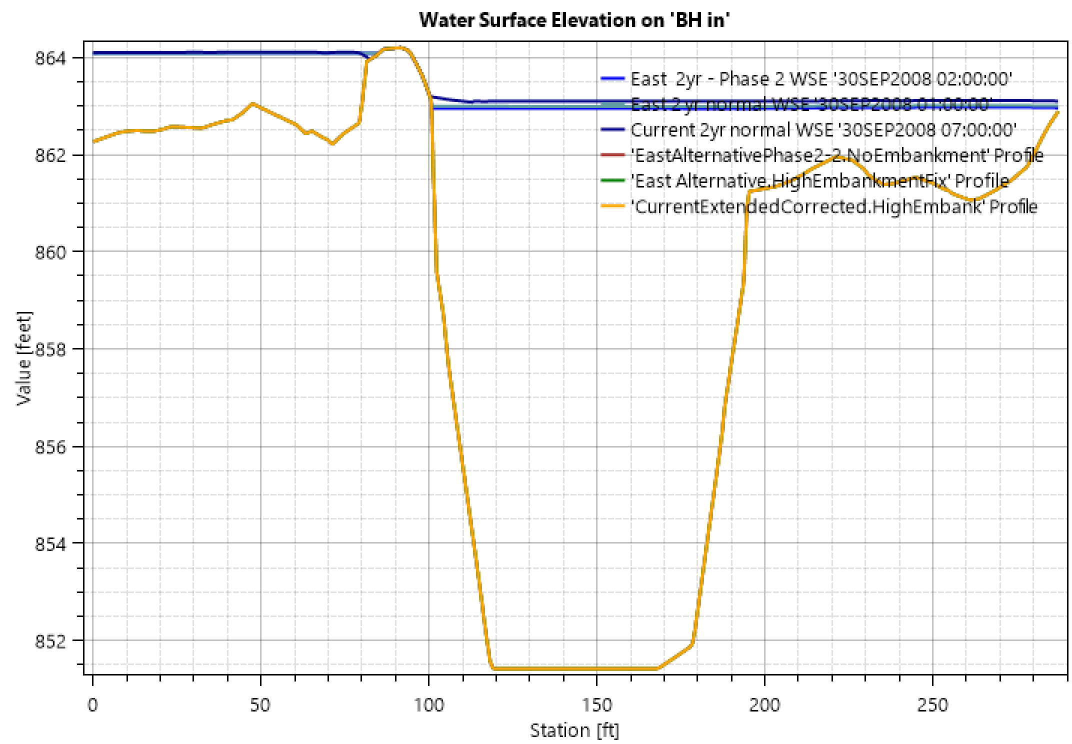
Max Submergence: Min Weir Flow El:

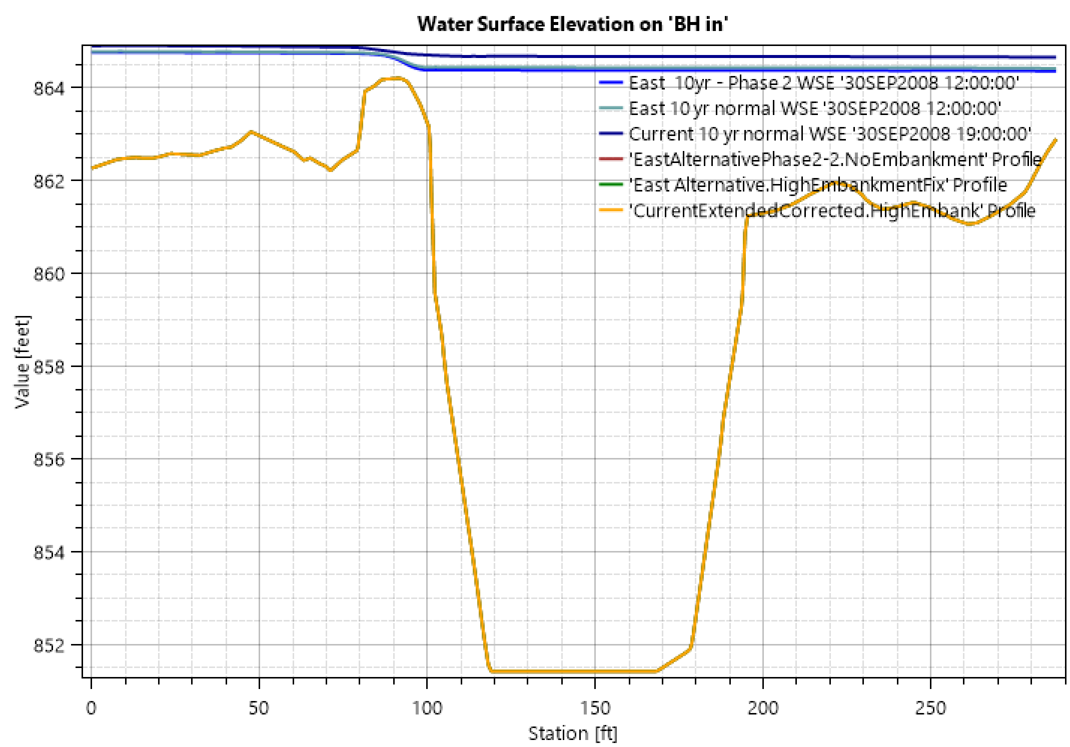
Weir Crest Shape

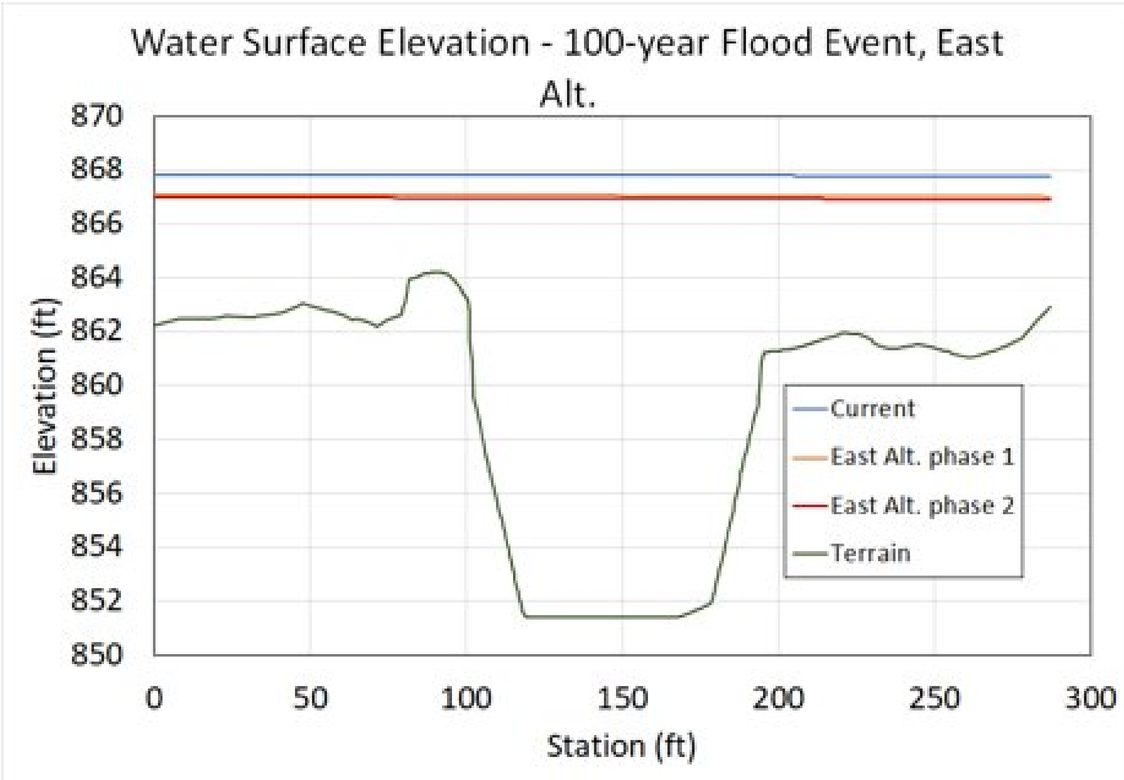
(•) Broad Crested

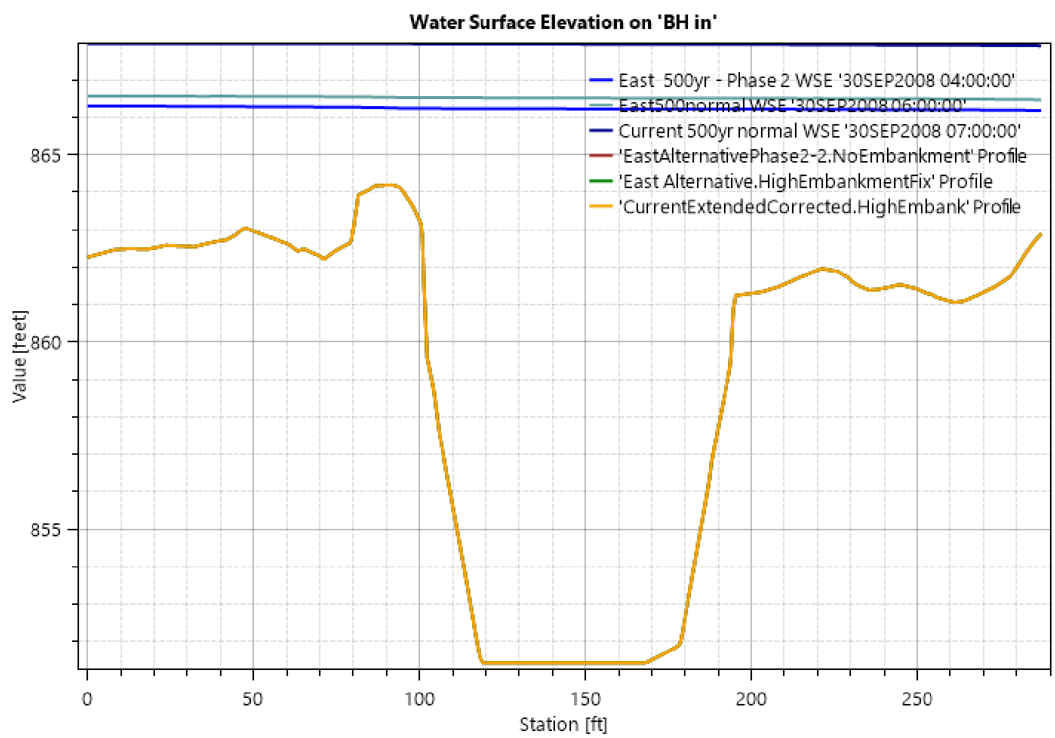
( ) Ogee

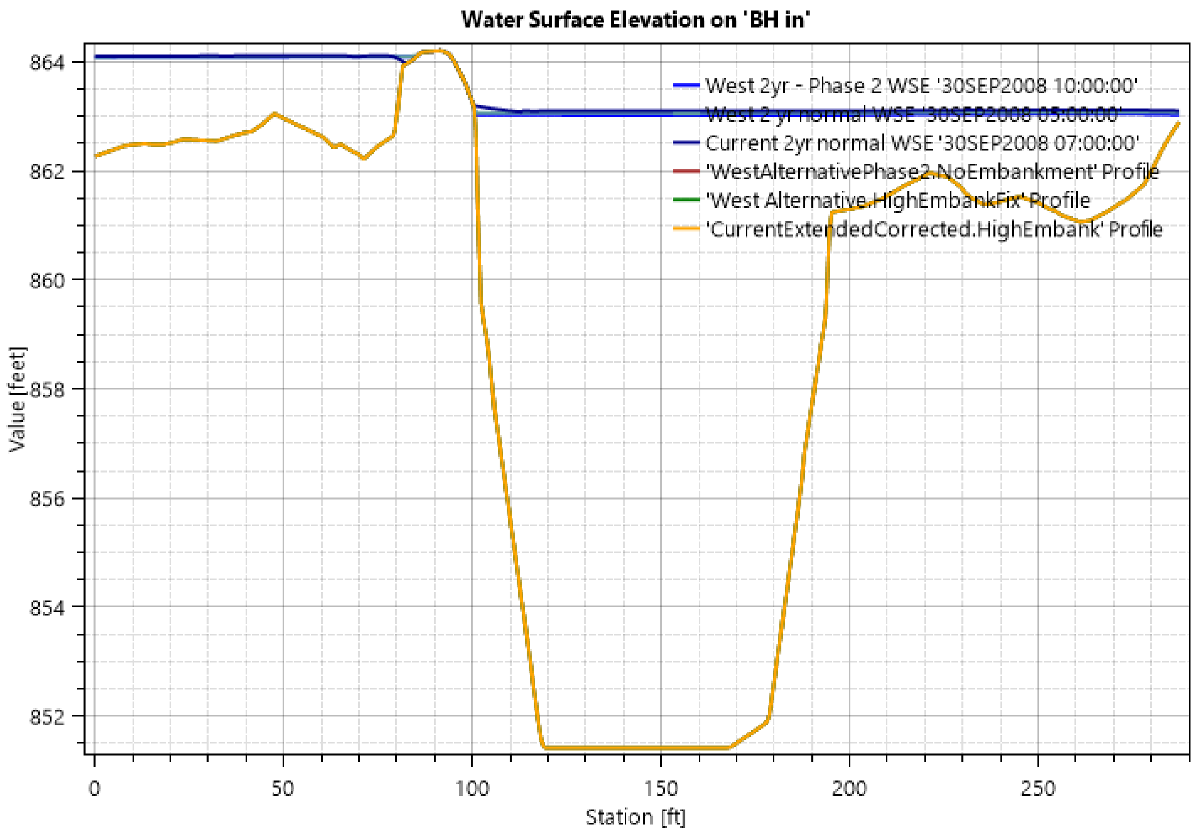
C. Hydraulic Results

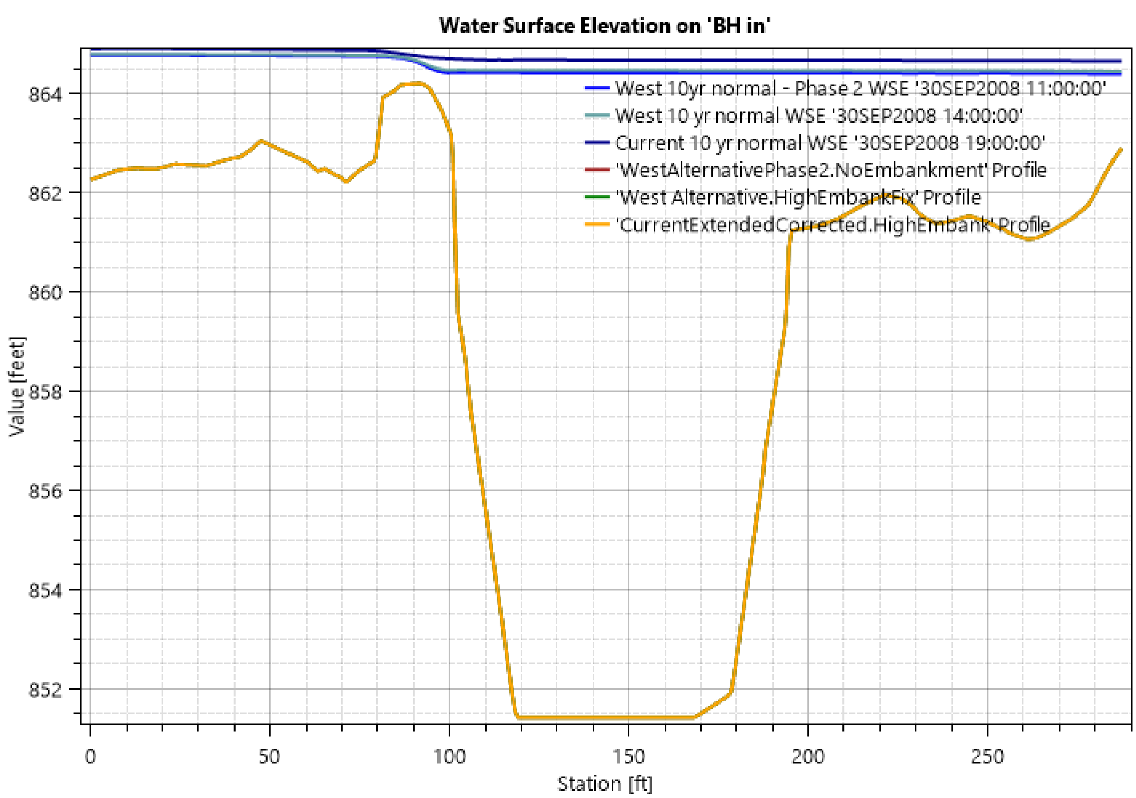


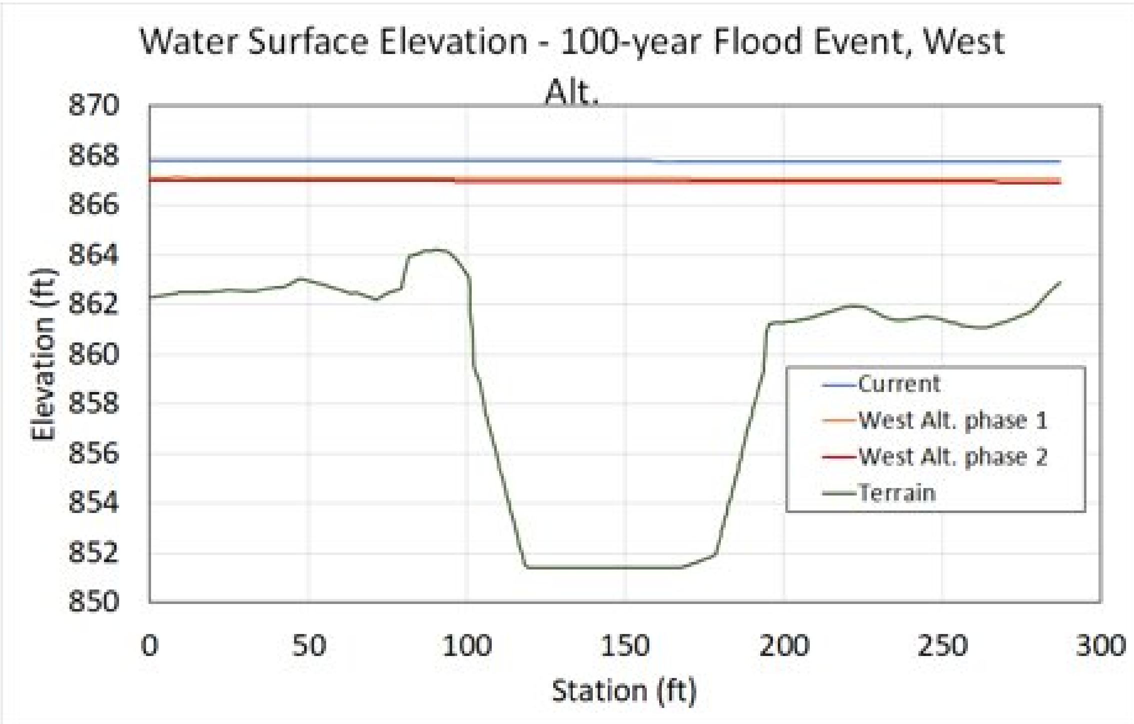


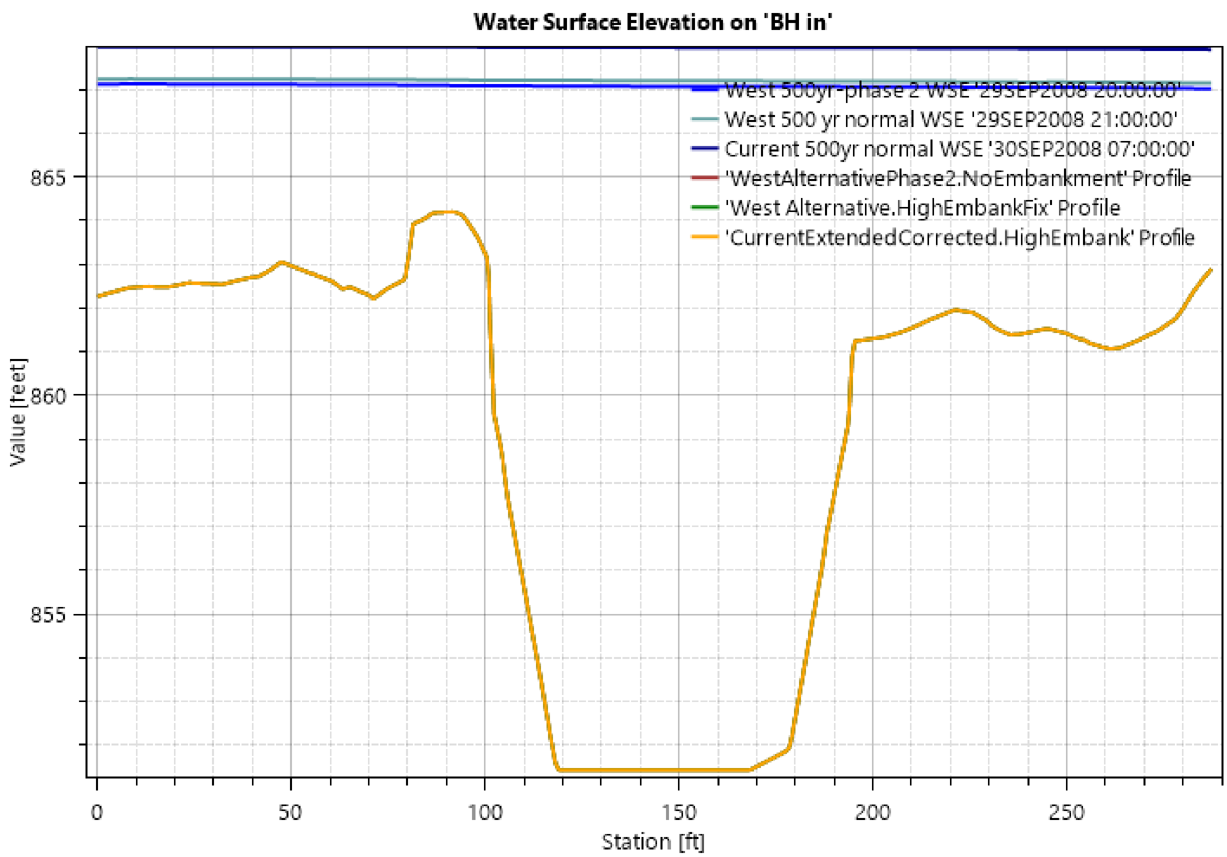

Water Surface Elevation - 100-year Flood Event, East Alt.
Elevation (ft)
870
868
866
864
862
860
858
856
854
852
850
0
50
100
150
200
250
300
Station (ft)
Current
East Alt. phase 1
East Alt. phase 2
Terrain


Water Surface Elevation on 'BH in'
East 500yr - Phase 2 WSE '30SEP2008 04:00:00'
East500normal WSE '30SEP2008 06:00:00'
Current 500yr normal WSE '30SEP2008 07:00:00'
'EastAlternativePhase2-2.NoEmbankment' Profile
'East Alternative.HighEmbankmentFix' Profile
'CurrentExtendedCorrected.HighEmbank' Profile
Value [feet]
865
860
855
0
50
100
150
200
250
Station [ft]


Water Surface Elevation on 'BH in'
West 2yr - Phase 2 WSE '30SEP2008 10:00:00'
West 2 yr normal WSE '30SEP2008 05:00:00'
Current 2yr normal WSE '30SEP2008 07:00:00'
'WestAlternativePhase2.NoEmbankment' Profile
'West Alternative.HighEmbankFix' Profile
'CurrentExtendedCorrected.HighEmbank' Profile
Value [feet]
864
862
860
858
856
854
852
0
50
100
150
200
250
Station [ft]


Water Surface Elevation on 'BH in'
West 10yr normal - Phase 2 WSE '30SEP2008 11:00:00'
West 10 yr normal WSE '30SEP2008 14:00:00'
Current 10 yr normal WSE '30SEP2008 19:00:00'
'WestAlternativePhase2.NoEmbankment' Profile
'West Alternative.HighEmbankFix' Profile
'CurrentExtendedCorrected.HighEmbank' Profile
Value [feet]
864
862
860
858
856
854
852
0
50
100
150
200
250
Station [ft]


Water Surface Elevation - 100-year Flood Event, West Alt.
Elevation (ft)
870
868
866
864
862
860
858
856
854
852
850
0
50
100
150
200
250
300
Station (ft)
Current
West Alt. phase 1
West Alt. phase 2
Terrain


Water Surface Elevation on 'BH in'
Value [feet]
865
860
855
0
50
100
150
200
250
Station [ft]
West 500yr-phase 2 WSE '29SEP2008 20:00:00'
West 500 yr normal WSE '29SEP2008 21:00:00'
Current 500yr normal WSE '30SEP2008 07:00:00'
'WestAlternativePhase2.NoEmbankment' Profile
'West Alternative.HighEmbankFix' Profile
'CurrentExtendedCorrected.HighEmbank' Profile

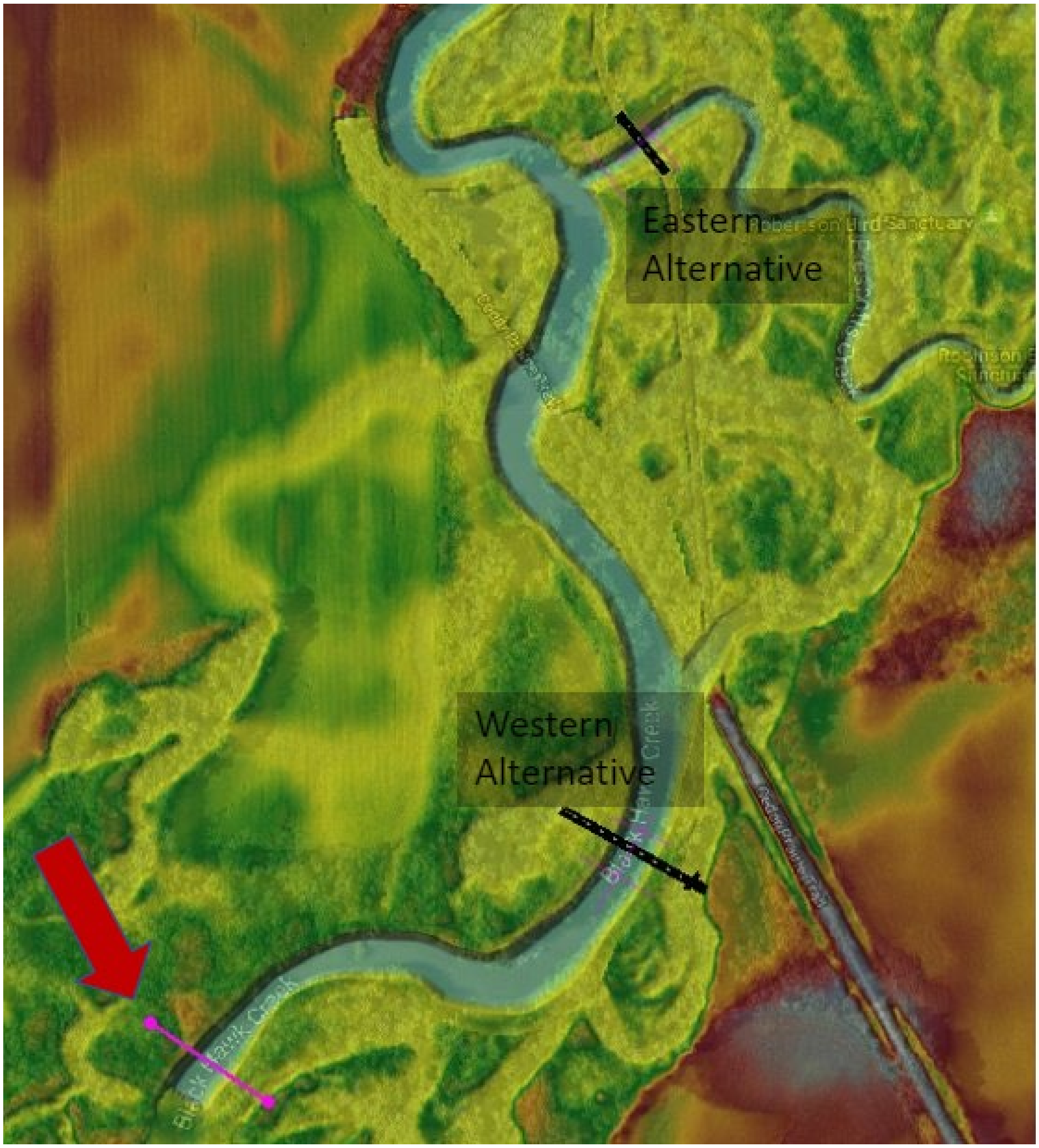
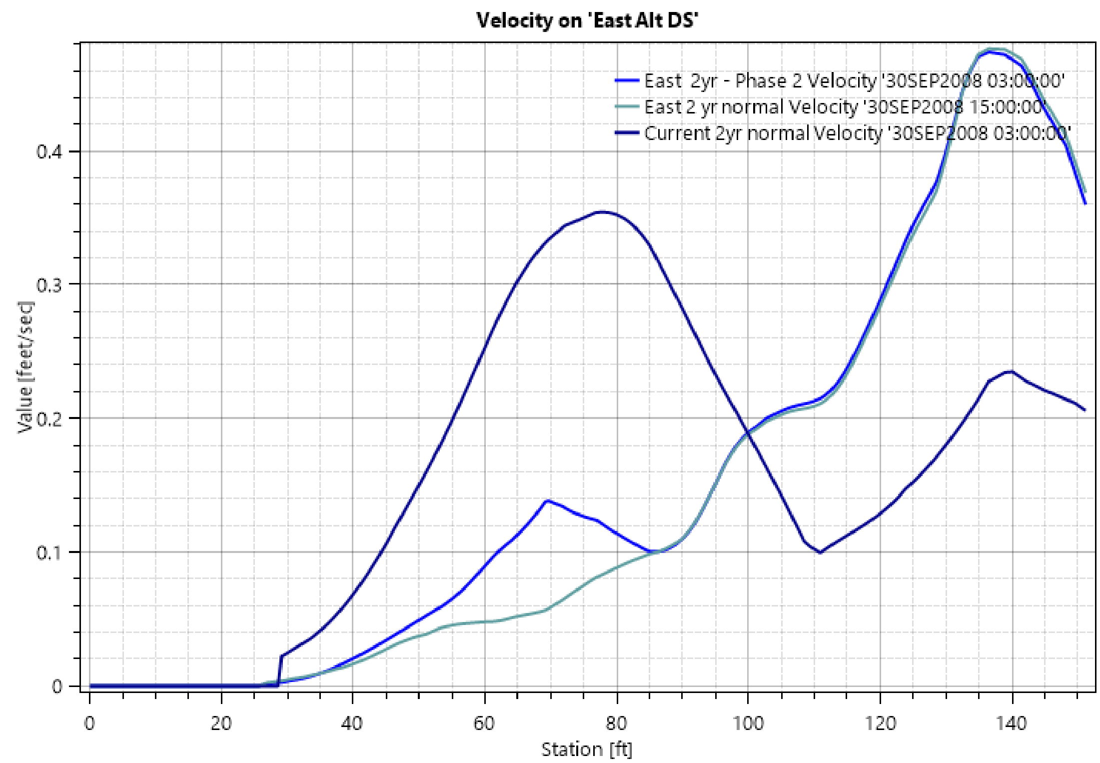
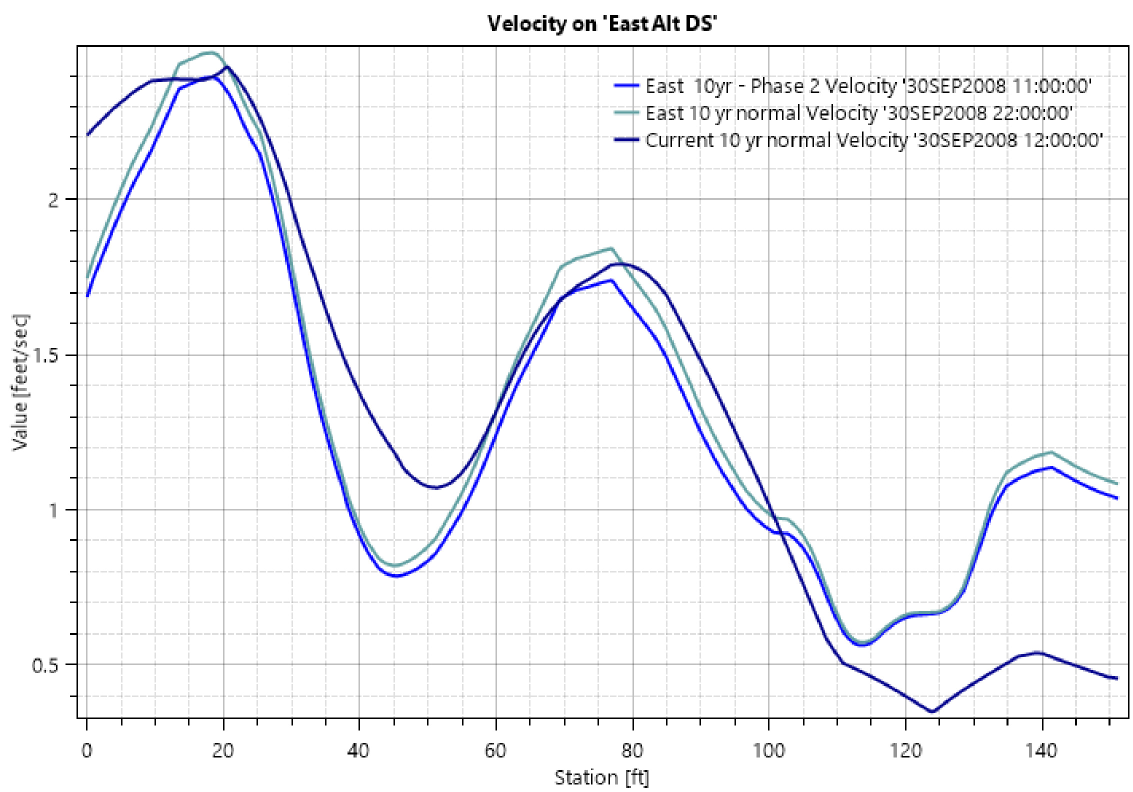
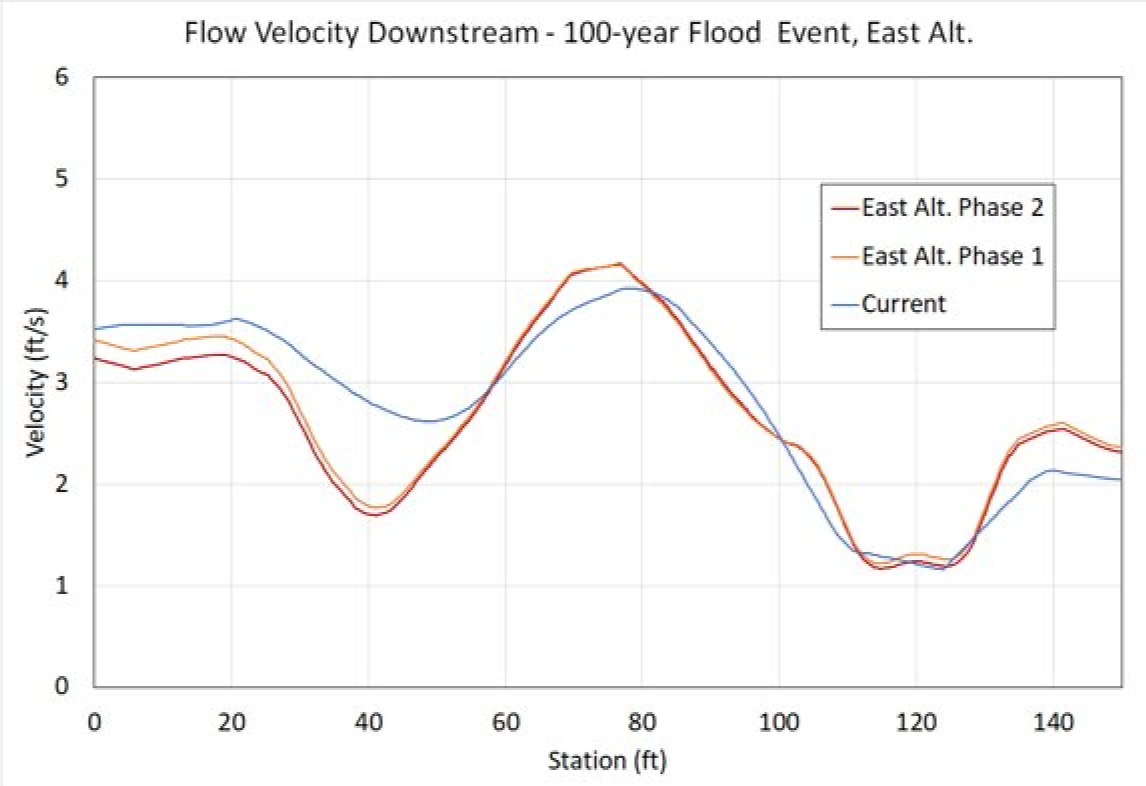
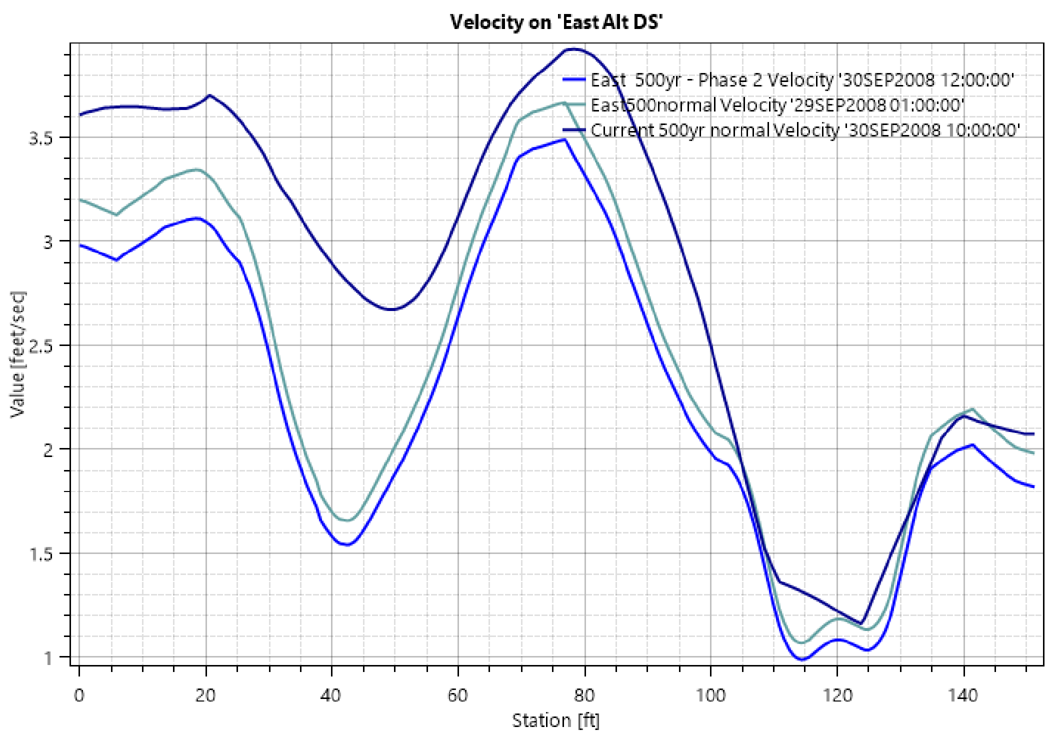


Figure 32: Location of cross-section used for water surface elevation measurements


Velocity on 'East Alt DS'
East 2yr - Phase 2 Velocity '30SEP2008 03:00:00'
East 2 yr normal Velocity '30SEP2008 15:00:00'
Current 2yr normal Velocity '30SEP2008 03:00:00'
Value [feet/sec]
Station [ft]
0
0.1
0.2
0.3
0.4
0
20
40
60
80
100
120
140


Velocity on 'East Alt DS'
East 10yr - Phase 2 Velocity '30SEP2008 11:00:00'
East 10 yr normal Velocity '30SEP2008 22:00:00'
Current 10 yr normal Velocity '30SEP2008 12:00:00'
Value [feet/sec]
Station [ft]
0.5
1
1.5
2
0
20
40
60
80
100
120
140


Flow Velocity Downstream - 100-year Flood Event, East Alt.
East Alt. Phase 2
East Alt. Phase 1
Current
Velocity (ft/s)
Station (ft)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
140


Velocity on 'East Alt DS'
East 500yr - Phase 2 Velocity '30SEP2008 12:00:00'
East500normal Velocity '29SEP2008 01:00:00'
Current 500yr normal Velocity '30SEP2008 10:00:00'
Value [feet/sec]
Station [ft]
1
1.5
2
2.5
3
3.5
0
20
40
60
80
100
120
140

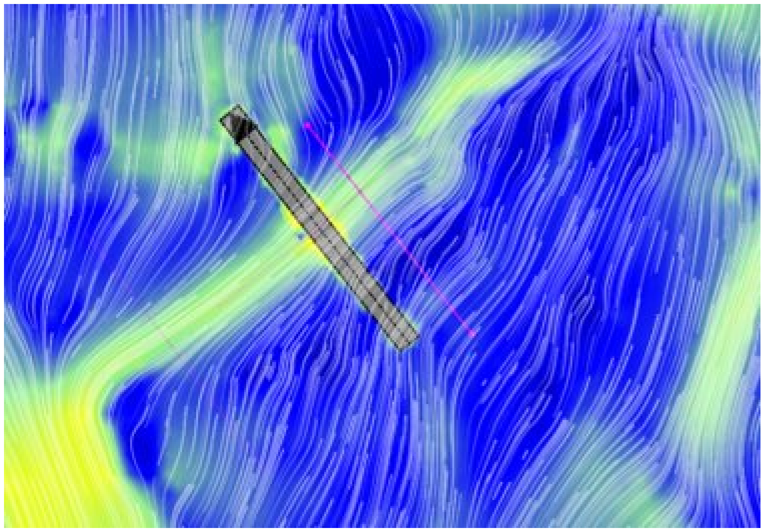
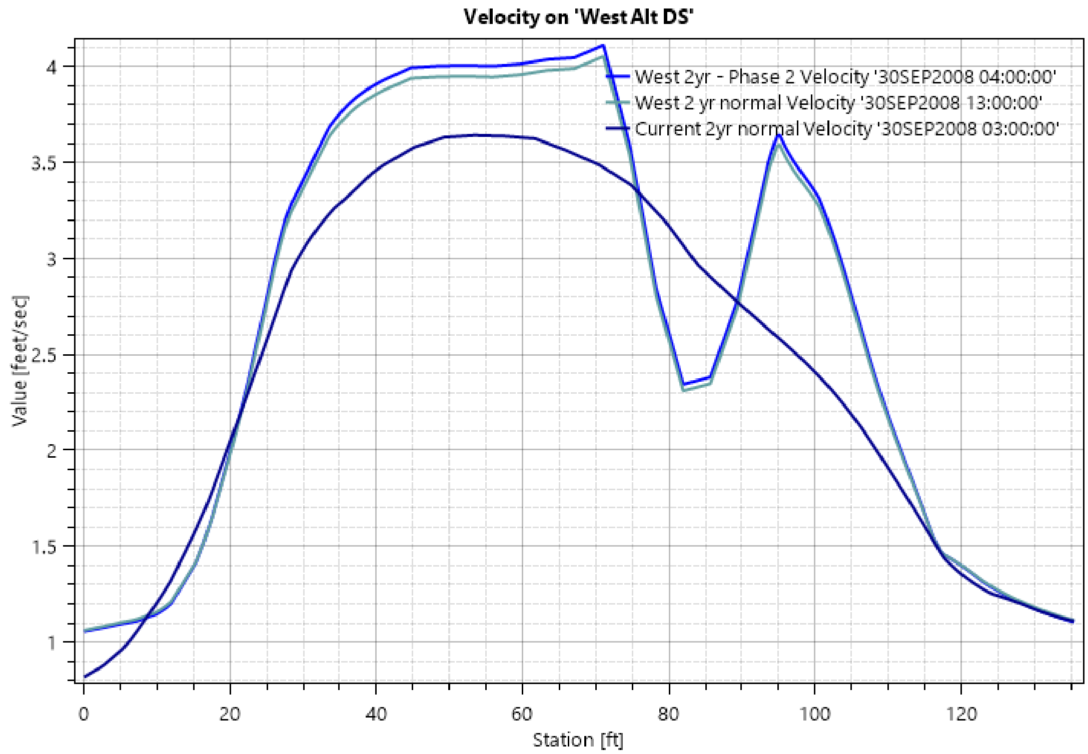
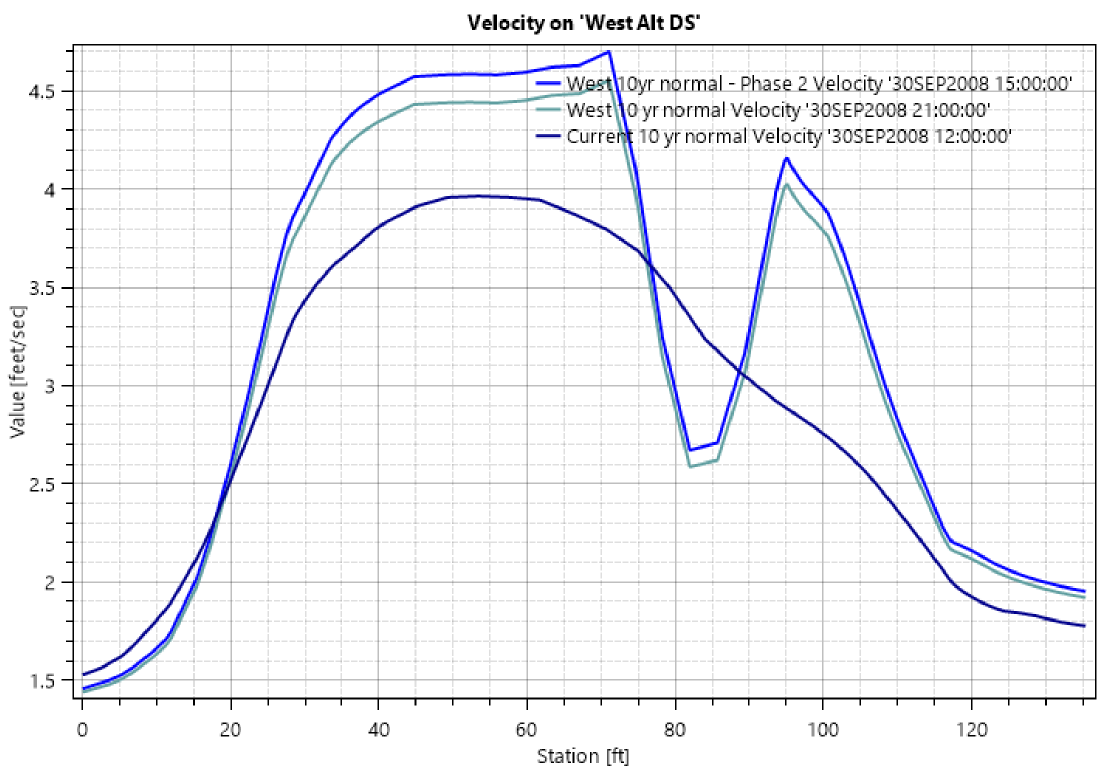
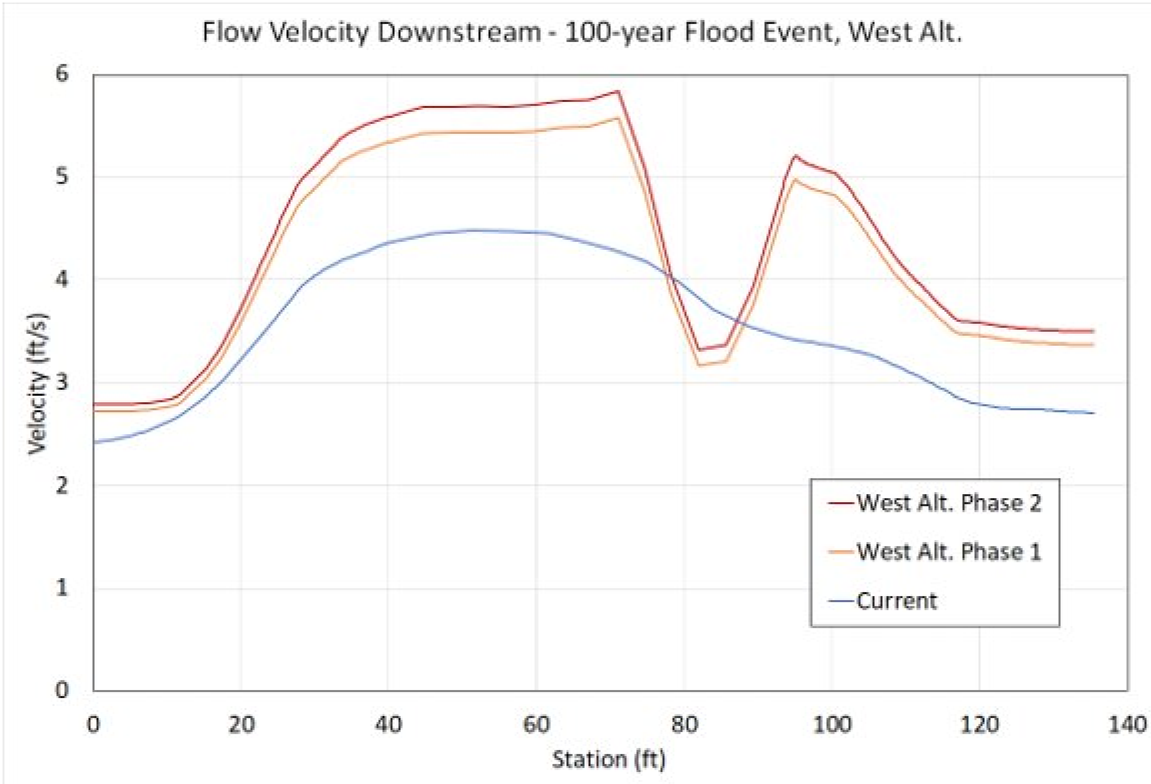
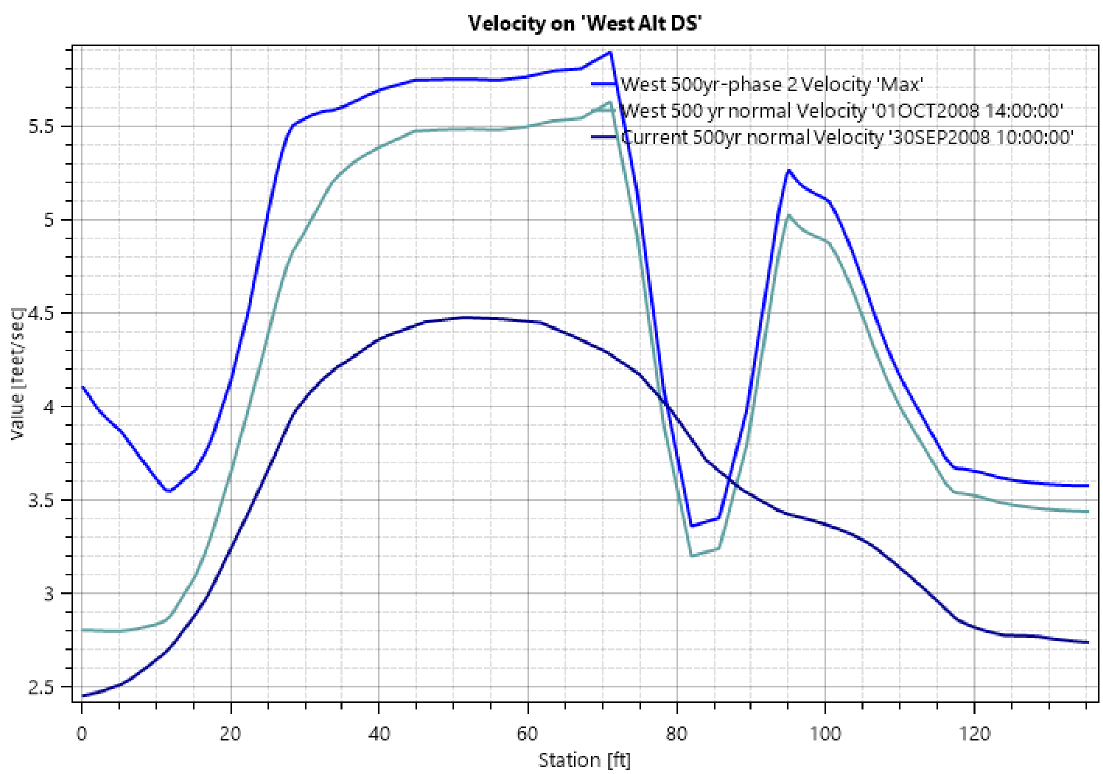


Figure 33: Velocity streamlines showing location of cross-section and direction of flow (Eastern Trail Alignment)


Velocity on 'West Alt DS'
West 2yr - Phase 2 Velocity '30SEP2008 04:00:00'
West 2 yr normal Velocity '30SEP2008 13:00:00'
Current 2yr normal Velocity '30SEP2008 03:00:00'
Value [feet/sec]
1
1.5
2
2.5
3
3.5
4
0
20
40
60
80
100
120
Station [ft]


Velocity on 'West Alt DS'
West 10yr normal - Phase 2 Velocity '30SEP2008 15:00:00'
West 10 yr normal Velocity '30SEP2008 21:00:00'
Current 10 yr normal Velocity '30SEP2008 12:00:00'
Value [feet/sec]
1.5
2
2.5
3
3.5
4
4.5
0
20
40
60
80
100
120
Station [ft]


Flow Velocity Downstream - 100-year Flood Event, West Alt.
Velocity (ft/s)
Station (ft)
West Alt. Phase 2
West Alt. Phase 1
Current
0
1
2
3
4
5
6
0
20
40
60
80
100
120
140


Velocity on 'West Alt DS'
West 500yr-phase 2 Velocity 'Max'
West 500 yr normal Velocity '01OCT2008 14:00:00'
Current 500yr normal Velocity '30SEP2008 10:00:00'
Value [feet/sec]
Station [ft]
2.5
3
3.5
4
4.5
5
5.5
0
20
40
60
80
100
120

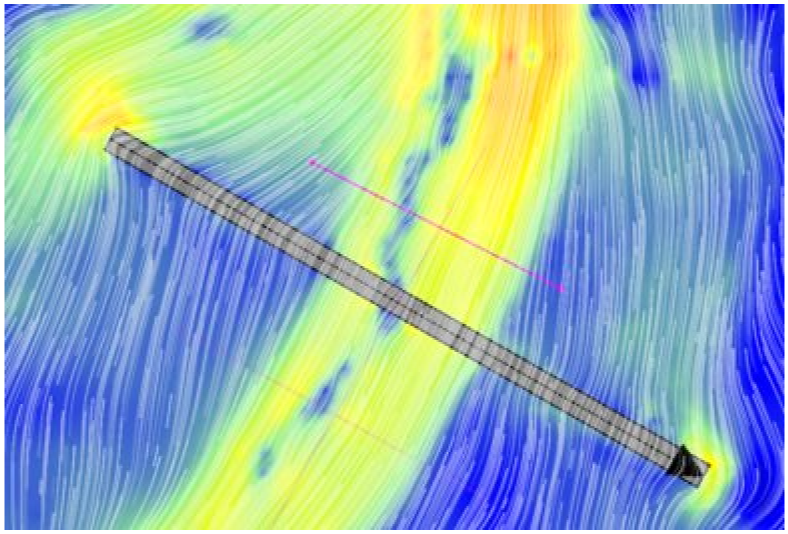
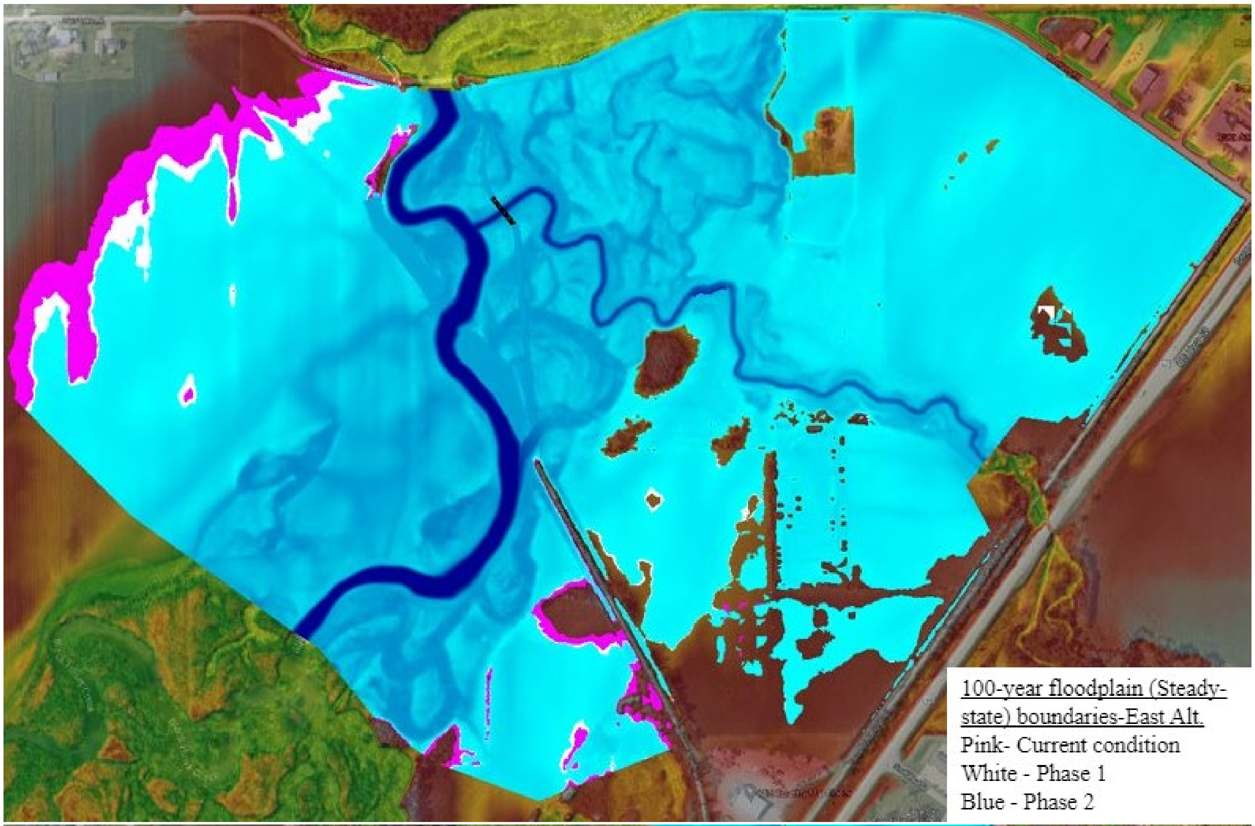
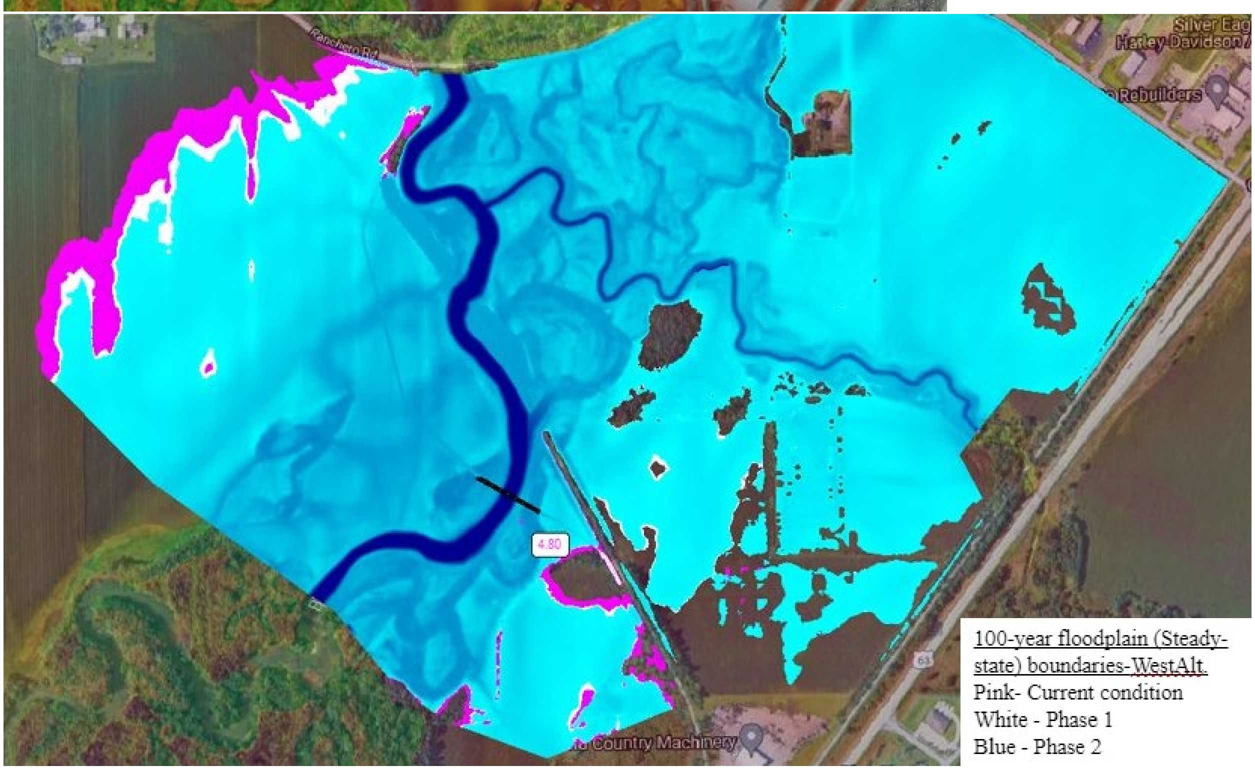


Figure 34: Velocity streamlines showing location of cross-section and direction of flow (Western Trail Alignment)

100-year flood event water surface elevation comparison

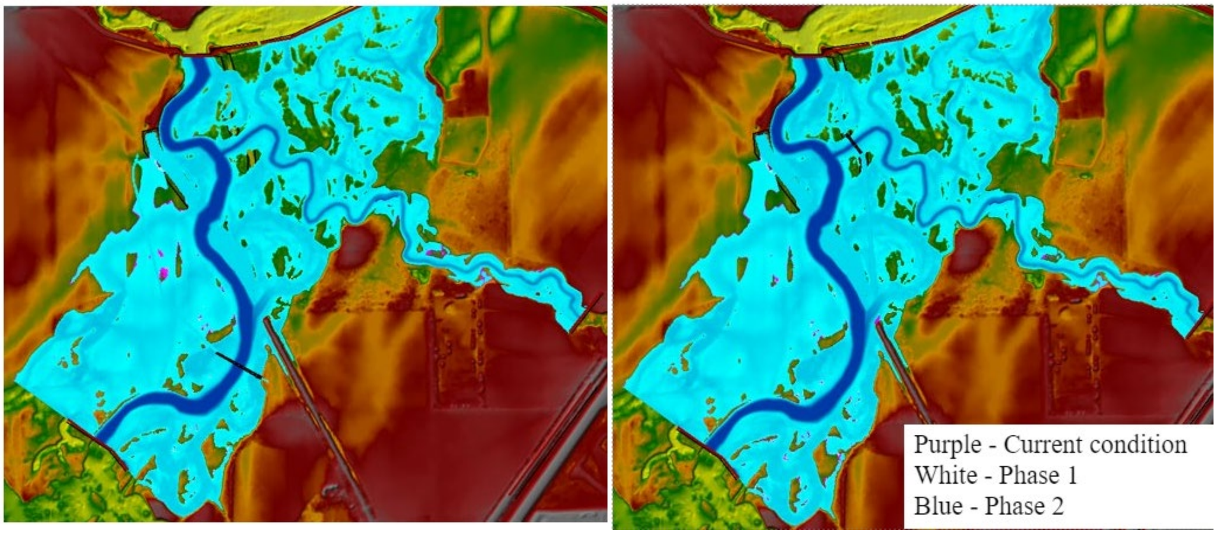




2-year flood event water surface elevation comparison

Western Alignment

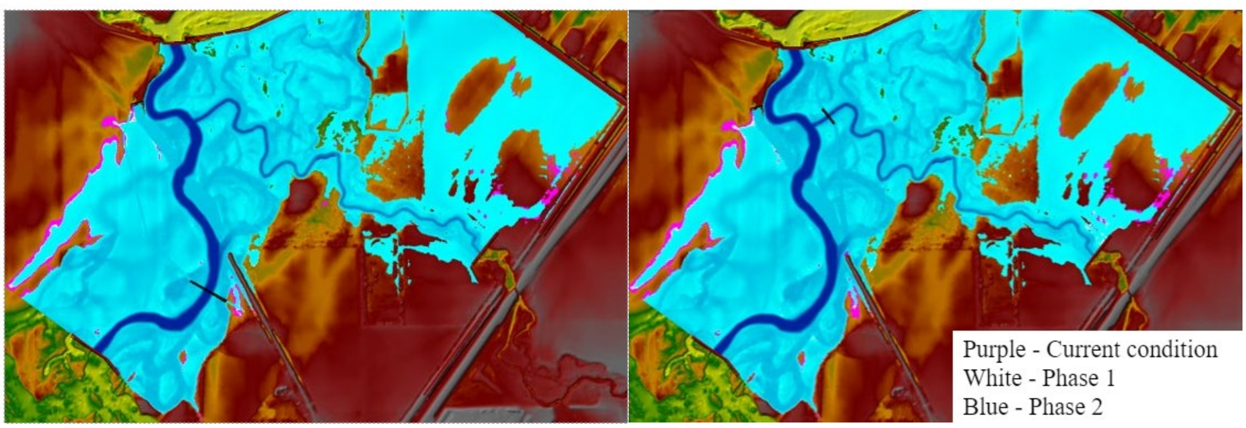
Eastern Alignment



10-year flood event water surface elevation comparison

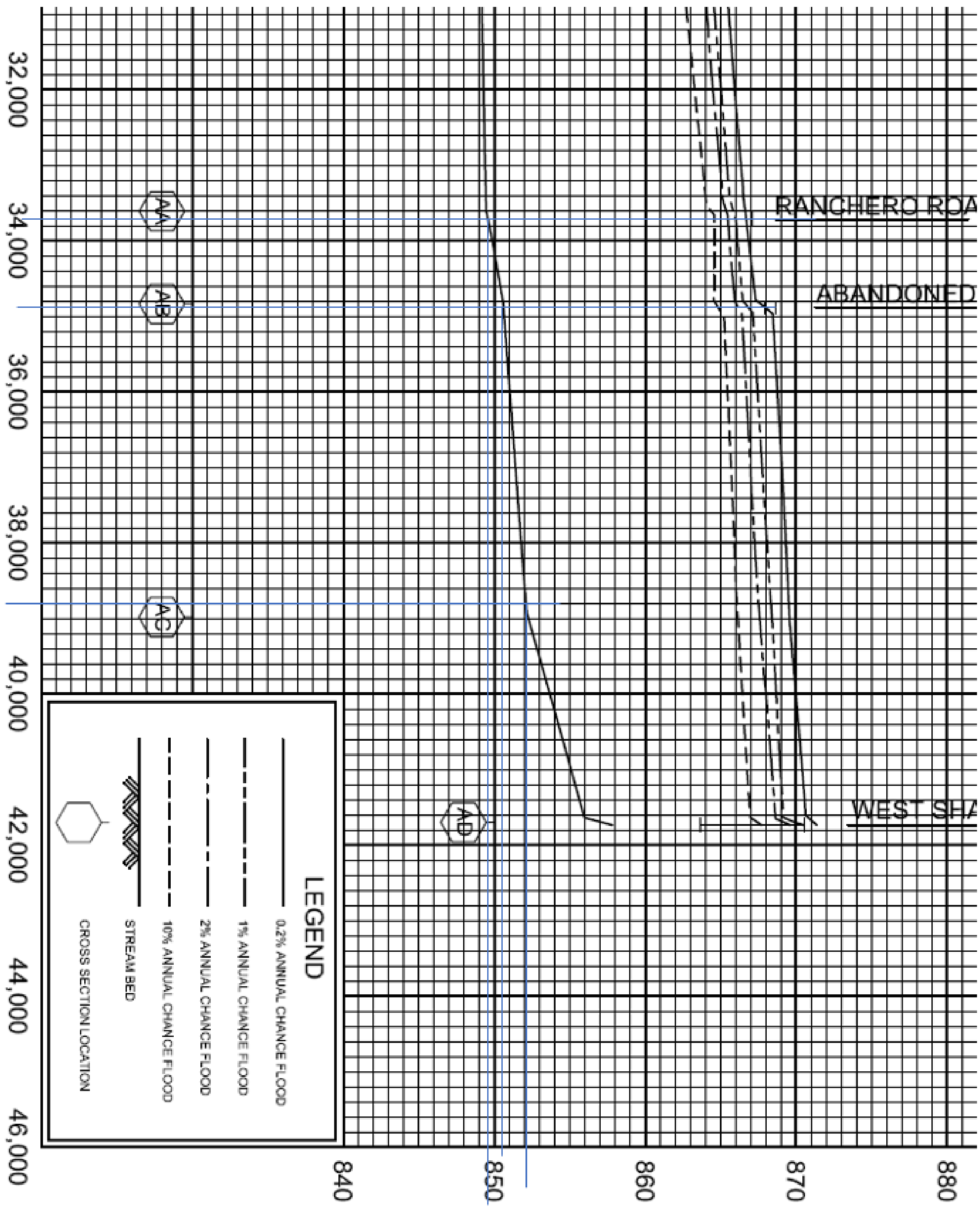
Western Alignment

Eastern Alignment

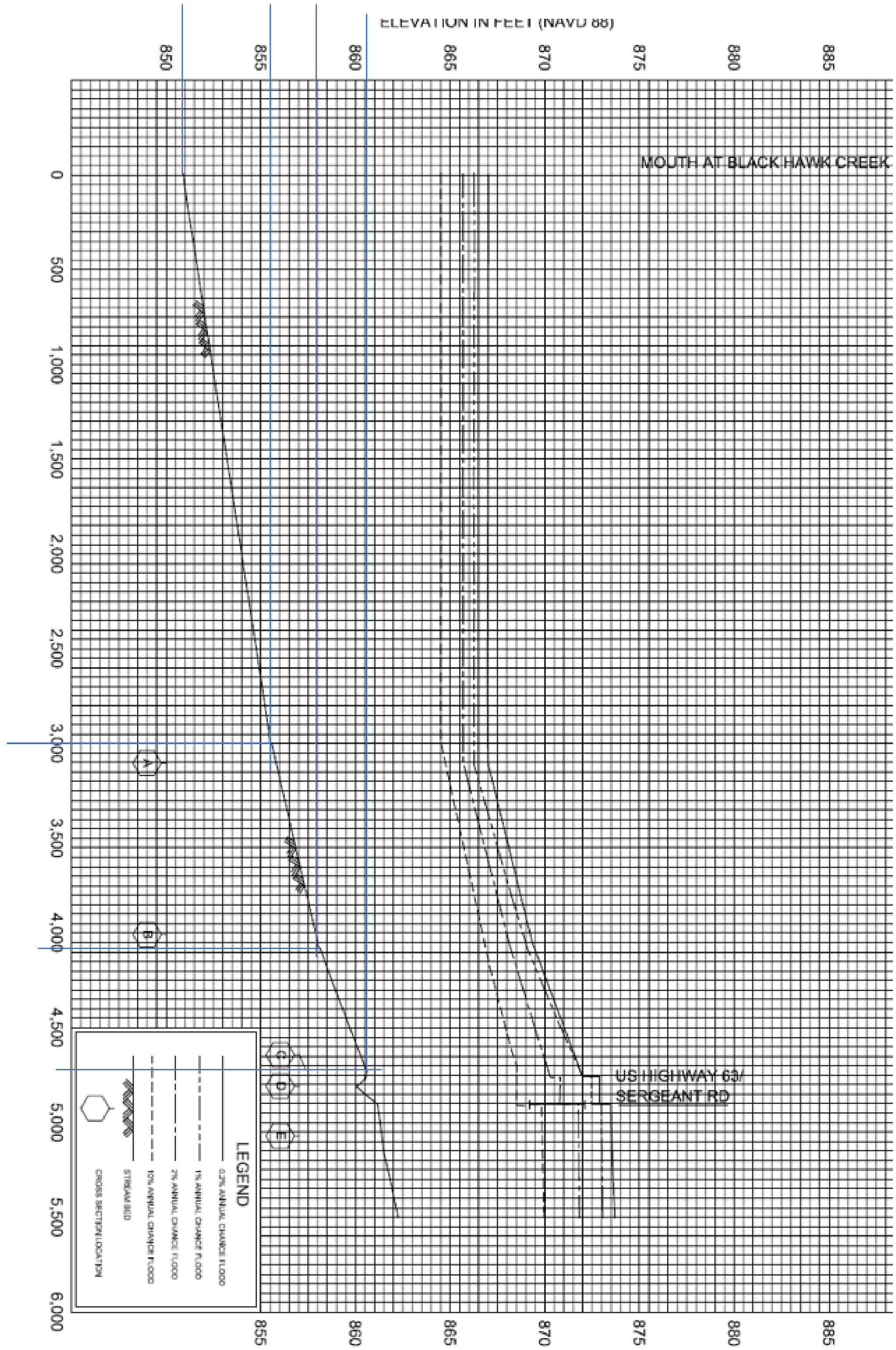


D. Streambed Elevations

Black Hawk Creek



Prescott's Creek



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