SPRINGVILLE ROAD CROSSING
PROJECT ID: CEEN_CPST_006

by

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A Capstone Project Final Report

Submitted to

Chris Wilson
Springville City

Department of Civil and Construction Engineering
Brigham Young University

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Executive Summary

PROJECT TITLE: SPRINGVILLE ROAD CROSSING
PROJECT ID: CEEn_CPST_006
PROJECT SPONSOR: Springville City
TEAM NAME: A.B.C. Engineering

A.B.C. Engineering contracted with the City of Springville to develop a bridge crossing over Hobble Creek for a proposed roadway. The project included collecting data from public sources regarding hydrologic data, stream channel data, environmental data, and materials information for better design. In addition, with files from engineers at the Springville Public Works Department, the previously developed HEC-RAS model was run, and hydraulic data pulled from the model results. With hydrologic data and hydraulic data, a model for the crossing was developed, with alternatives, and has been proposed to Springville for review. Any specific City standards were followed during the design, and collaboration with professional engineers occurred throughout the process to ensure that the model was complete and professional. In addition, team members consulted the City engineer, Chris Wilson, to verify and clarify information regarding both the information in HEC-RAS and preliminary structural designs for the bridge.

The preferred alternative by A.B.C. Engineering is that a bridge crossing is built with two supplemental culverts, each sized 10 feet (ft) wide and 4 ft tall. The bottom elevation of each culvert is 4,511 ft. This alternative is preferred because it is the smallest size culvert that suits the project's needs. The supplemental culverts slightly increased the water velocity, but the effects should not be detrimental to the June Sucker, a protected species in the area. FEMA requires that any construction over Hobble Creek not raise the water level. The preferred alternative minimally decreases the water level. A.B.C. Engineering proposes further work in HEC-RAS with highly accurate creek cross sections to confirm the proposed culverts are adequate before detailed plans or construction commences. If further modeling does not reaffirm the proposed culvert design, investigation into levee construction is recommended.

This report presents the process of the bridge crossing design including an introduction, the project schedule, assumptions and limitations, design and results, related issues, lessons learned, conclusions, and recommendations.

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Introduction

A.B.C. Engineering's work for Springville regards the creation of a road in the north-south direction. This passage will contain a high concentration of passenger cars, semi-trucks, bicycles and pedestrians, which may often result in inefficient travel since parallel existing roads are congested during peak travel times. Springville is a growing area and will likely experience worsening traffic as more people begin to move to the area. In order to effectively re-route some of this future traffic and alleviate the current traffic, the City is proposing that this new road cross over an area that currently consists of open terrain, industrial facilities, and a floodplain. This floodplain is susceptible to flooding due to seasonal high flows of Hobble Creek; Hobble Creek receives water from various sources in the Wasatch front and then drains into Utah Lake to the east.

The proposed roadway will include a bridge that crosses over Hobble Creek. Since the area is susceptible to flooding, the water levels of Hobble Creek must remain unaffected during and post construction. In addition, the roadway, and thus bridge, will include 2 travel lanes in each direction, room for pedestrians and bikers along one side, and a median, meaning that the bridge will need be a suspension bridge so as not to affect the water levels. The specifications of the roadway cannot be changed since they will be essential to the functionality of this bridge in the long term as the city expands.

There are antique levees currently constructed along the banks of Hobble Creek, however, the Federal Emergency Management Agency (FEMA) cannot reasonably certify these levees as effective due to the lack of knowledge concerning what they are made of, their current condition, and the potential they have for failure. Due to these concerns, the City of Springville faces the challenge of designing a roadway that functions as if the levees are providing no reliable flood protection. Through the examination of elevation data in the area, it is clear that omitting the levees would greatly increase the span necessary for a bridge to cross the creek. This is a particularly difficult challenge because the design must simultaneously consider both FEMA's requirements that the levees cannot be used to hold water, and the undeniable fact that the levees are present and therefore affect the water flow.

In addition, as aforementioned, it is critical per FEMA regulation that the water level cannot be affected (i.e. raised) by any structure that is placed in or over it. This means that any positive change in the water level observed through trials with software denotes an insufficient bridge design that must be revised. The programs used to determine the crossing's effect were HY-8 and HEC-RAS. The city provided elevation data and flow data concerning this area. The flow values are based upon 100-year flood data preprogramed into the HEC-RAS file provided by the city engineers. By using these variables and design parameters, the longevity and effectiveness of the design can be ensured.

An additional consideration is the protected wildlife in the area. The primary species the City of Springville is concerned with protecting is the June Sucker. It is a relatively small fish that resides and spawns in the creek. Disrupting the ecosystem in this area with the addition of the bridge would not only be detrimental to the community who sees benefit from the June Sucker but would also be detrimental to the flora and fauna of the area. This species is also endangered, and therefore its continued existence is both morally and legally imperative.

The width and depth of the creek varies, so it is advantageous economically, aesthetically, and practically that the bridge be built over the smallest section to avoid the span being longer than necessary. These criteria are what led to the choice in location and the elevation data used to run the tests. This location choice is also supported by the natural progression of the new road and allows for the one of the most straightforward and time-efficient pathways through this part of the city. By minimizing the span of the bridge and finding a straightforward path for the road to follow, it is made more feasible, safe, and efficient for the residents.

By considering all these limitations and assumptions, this project will fulfill its purpose in providing the City of Springville with a baseline bridge design for this complex area. This hydraulic design and proof of functionality can then be combined with structural engineering and the necessary steps to get this bridge built can be put in motion. The design abides by FEMA standards, preserves the flora and fauna of the surrounding region, provides an efficient route to travel North and South, and most importantly, will help to divert some floodwaters. By consulting the engineers and city officials from the area, it is also apparent that this project would be well-received by the residents of the city and preserve the lifestyle needs of the City of Springville.

Schedule

The following schedule illustrates when important milestones for the project were completed compared to the dates proposed at the project's beginning. This comparison demonstrates the project’s progress over the last several months. If any milestones were completed after the proposed completion date, the reasoning for variance is given.

Hydraulic Analysis and Design – Proposed: March 25, Actual: March 25

Project Update – Proposed: March 25, Actual: March 25

Informational Poster – Proposed: April 3, Actual: April 3

Draft Final Report – Proposed: April 8, Actual: April 8

Team Evaluations – Proposed: April 15, Actual: April 15

Final Report – Proposed: April 17, Actual: April 17

Final PowerPoint Presentation – Proposed: April 17, Actual: April 22
April 22nd was the soonest the City of Springville and A.B.C. Engineering were available for the presentation.

Weekly meetings occurred each Saturday at 9 a.m. in the Engineering Building or another agreed location with Wi-Fi and lasted an average of 90 minutes. Meetings times were adjusted as needed to accommodate illness or other unforeseen situations. The agenda for meetings each week included a recap of weekly tasks, collaborative work, and assignments for upcoming tasks. To complete work assigned during these weekly meetings, each team member individually scheduled the time he or she would complete the work. Additionally, several weeks team members scheduled additional blocks of time to collaborate on hydraulic analysis or other work.

For approximately a month and a half in the middle of the semester, the team met with Dr. Hotchkiss at 9 am on Monday mornings to ask any pressing questions about HEC-RAS or HY-8 and receive extra project guidance.

Assumptions & Limitations

As with any project, there were several identified assumptions and limitations. Assumptions and limitations are important to understand because they impact the effectiveness of the project during construction and later public use. For example, if the assumed size and specifications of the bridge were much different than how it came to be constructed, the bridge design would not be effective and likely result in many issues for both users and the City. Therefore, this section is presented to diminish the impact of any assumptions and limitations on design effectiveness.

During the preliminary stages of hydrologic and hydraulic analysis, several assumptions were made; however, further communication with the City of Springville eliminated many of these initial assumptions. Both the assumptions and if they were corrected by the City are presented. The assumptions in the project included the following 1) the bridge will be designed so that it does not raise the water level of Hobble Creek, 2) a bridge design is being developed by another engineering consultant, and that design will not include any piers or supports within the channel, 3) the levees at the bridge crossing are ineffective, and 4) it is possible and preferable that the bridge is supplemented by two box culverts, one on either side of the bridge, to convey excess water during periods of high channel flow. Assumptions 1 and 4 were given by the City during the project's preliminary meeting on January 16, 2024, and thus were applied to the project. Assumptions 2 and 3 were checked with the City during communications throughout the project. Both were somewhat discussed during the project's preliminary meeting; however, they were verified later as needed by project work. Assumption 2 was important to verify with the City because the team spent notable time exploring bridge design and bridge options before asking the City for clarification, which promptly terminated any further investigation into bridge design options; this clarification allowed for further focus on supplementary culvert design. Assumption 3 needed further clarification since the levees were included in the HEC-RAS model even though the team was told that the levees are not recognized by FEMA.

In addition to assumptions, the project has various limitations that need be acknowledged. First, as the assumptions mentioned, the scope of the project did not include bridge design, and the team did not have explicit access to any bridge designs;

therefore, the designs presented are general and account for the design requirements presented by the City but not much more. Additionally, the hydraulic analysis was limited to that of the 100-year flood levels, 800 cubic feet per second (cfs), and larger storms or seasons were not included in analysis. Another limitation is that only concrete culverts were considered in the model, so if another material of culvert is desired by the City of Springville, further analysis is required. The last limitation that needs to be addressed is that, due to limited time, the bridge cross sections input into the model are copies of the closest cross sections up- and downstream, meaning that they don't exactly reflect the channel shape that exists in the field. As a result, the hydraulic analysis is an estimate of what might happen.

Design, Analysis & Results

The majority of design work for this project took place in HEC-RAS, a computer software which analyzes water flow through rivers and channels. The City of Springville provided a completed HEC-RAS file for Hobble Creek, so design work included choosing an appropriate cross section from the existing file, modeling a bridge with auxiliary culverts, and running analyses to compare outputs to the untouched channel. Figure 1 below illustrates the opening menu from HEC-RAS where many of the output tables and other functions can be found. As a note, all the following figures in this section are screenshots taken on the computer of a team member with HEC-RAS running unless otherwise noted.

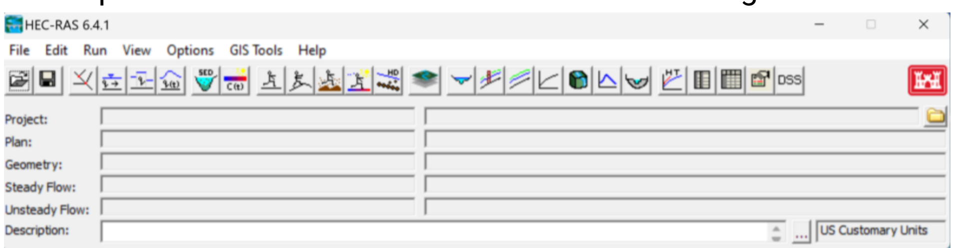


Figure 1: HEC-RAS opening menu (screenshot on computer)

Clicking on the icon third from the open file button, as shown in Figure 1, opens the geometric data (in Figure 2), or in other words, a two-dimensional depiction of all the cross sections, bridges, and culverts currently modeled for the stream reach. A.B.C Engineering chose the appropriate base cross section, 7510.3, by comparing this geometric data to a satellite view of the surrounding area in Springville City.

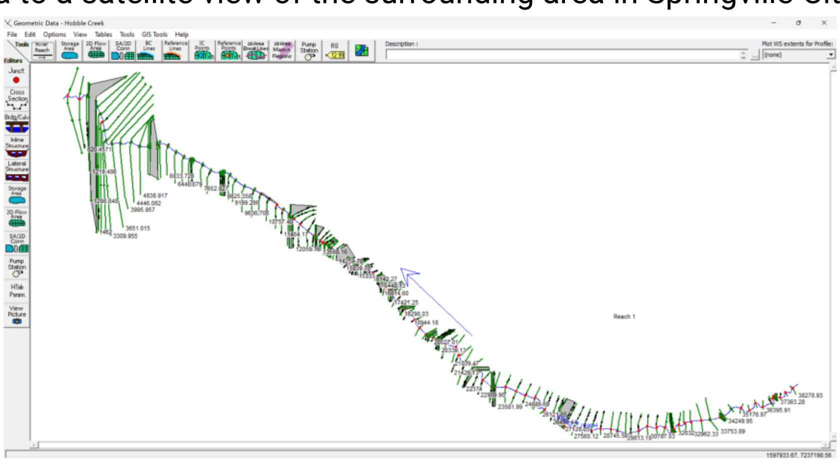


Figure 2: HEC-RAS geometric data plot for Hobble Creek

The next task required finding an average slope of the stream bed to help with the placement of cross sections for the bridge model. From the geometric data screen, a profile plot of the entire creek can be opened (see Figure 3 below). By zooming into the chosen cross section (Figure 4) and clicking on the streambed points above and below the cross section, A.B.C. Engineering calculated an average slope of the streambed using the slope formula $\frac{y2-y1}{x2-x1}$. Due to the nature of the streambed rising in elevation immediately downstream of our section, points for the slope needed to be chosen well upstream and well downstream of the section.

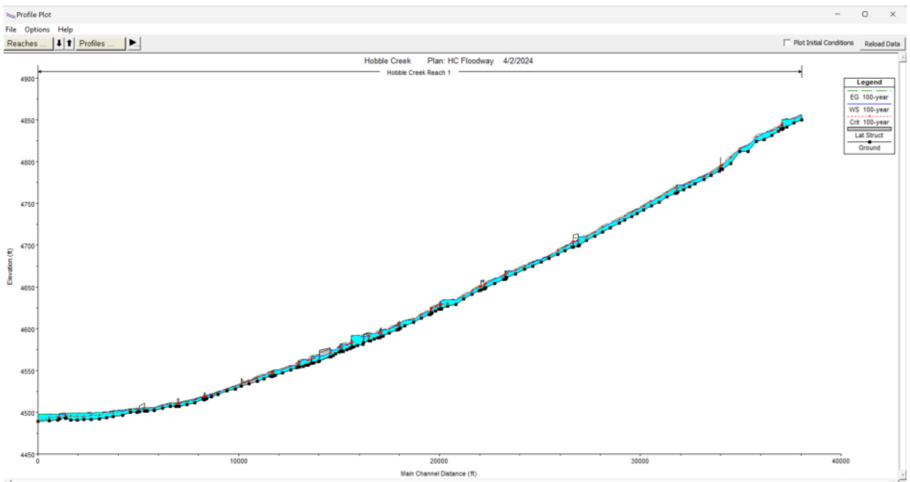


Figure 3: HEC-RAS full profile plot for Hobble Creek

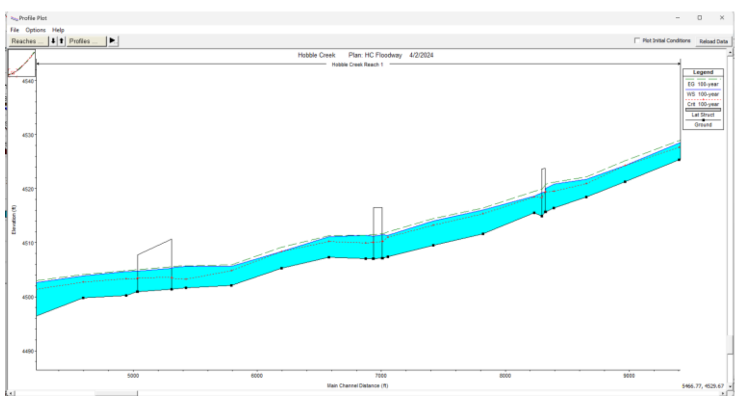


Figure 4: HEC-RAS profile plot zoomed in view

Per the HEC-RAS User's Manual, four cross sections are needed for a successful bridge analysis. Figure 5, from the manual, illustrates the locations of each of the four cross sections. Once the slope was determined, the cross sections around the bridge were created in the model. Cross section four is about one bridge width upstream from the bridge, while cross section one is about one-and-a-half bridge widths downstream from the bridge. Cross sections two and three are five feet out from each side of the bridge.

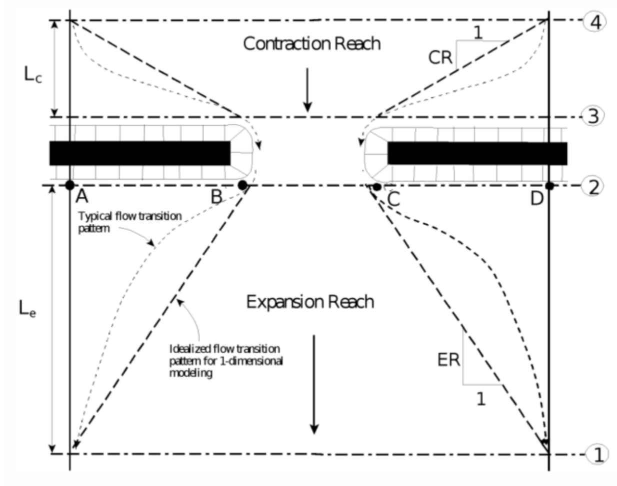


Figure 5: Four required cross sections for bridge modeling in HEC-RAS (PC HEC-RAS User's Manual)

Cross sections two and three needed to be adjusted to account for the culverts that would be modeled on the north and south banks. These adjustments were accomplished in the Graphical XS Editor. Figure 6 is the general view once the editor is opened and Figure 7 on the following page illustrates some of the options available. The points in the cross section (bold black dots) can be moved, added, or deleted. Areas on each side of the were flattened by deleting several points and moving the others in order to make space for the box culverts which were modeled later in the process.

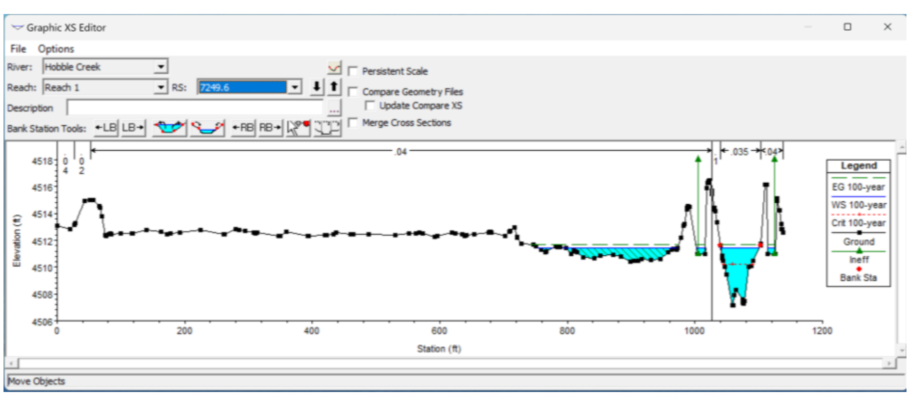


Figure 6: Graphical cross section editor

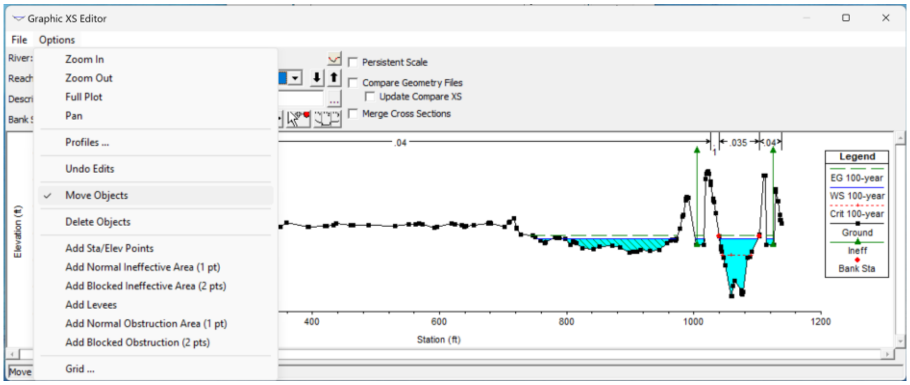


Figure 7: Graphical cross section editor with options visible

After the space is cleared for the culverts, the ineffective flow areas need to be adjusted so that the model can accurately account for water flow through the new culverts. The ineffective flow areas can be changed in the Cross Section Data screen.

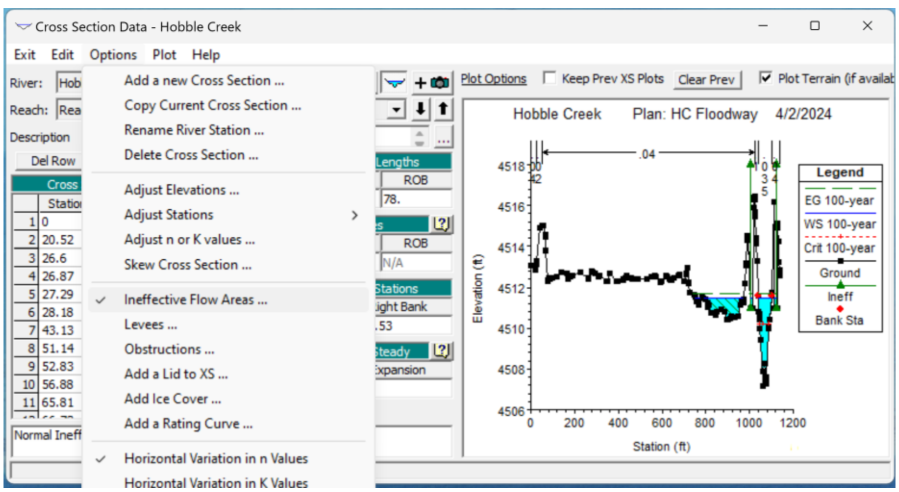


Figure 8: Graphical cross section editor tools

Once the cross sections are all prepared, the bridge deck and culverts can be specified in the bridge deck editor. The City of Springville gave A.B.C. Engineering specifications for the width of the bridge, but the rest of the details were open to interpretation. The low chord of the bridge was specified to touch the ground level in all places except the culverts and the actual bridge span to simulate the earth work needed to raise the road surface to the level of the bridge deck. The first culverts tried were ten feet wide by four feet tall at an elevation of 4,511 feet.

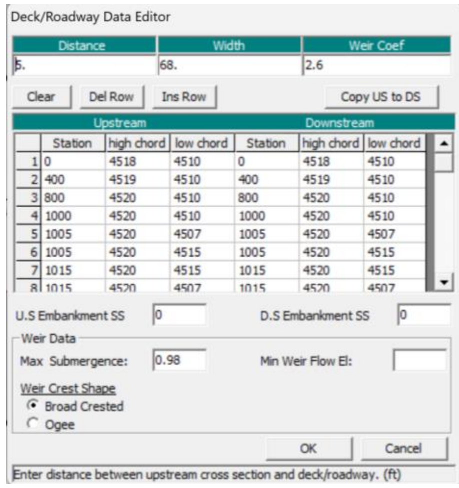


Figure 9: Bridge deck editor in HEC-RAS for modeling bridge structure

Figure 10 below illustrates the completed bridge cross section with the modified cross section and culverts.

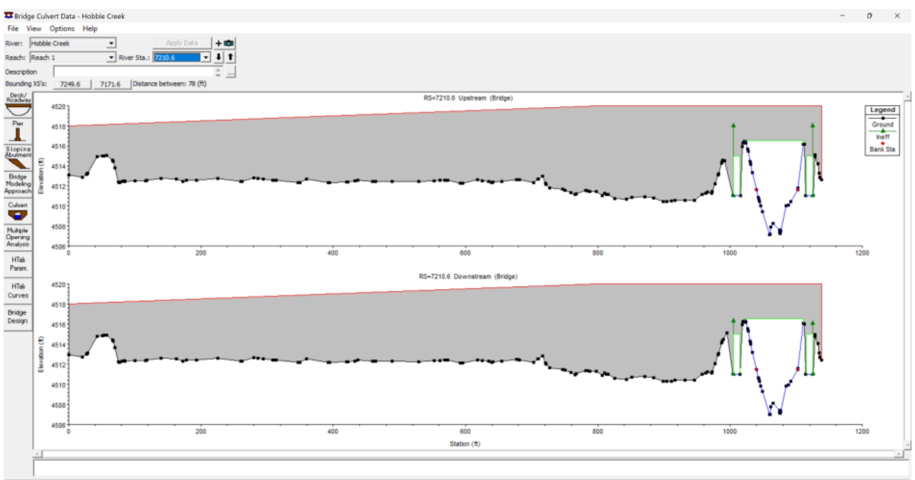


Figure 10: Cross section of the bridge after entering deck stations and elevations

Back on the main menu of HEC-RAS, steady and unsteady flow analyses can be run so that the model can account for the changes incurred by the newly modeled bridge and culverts.

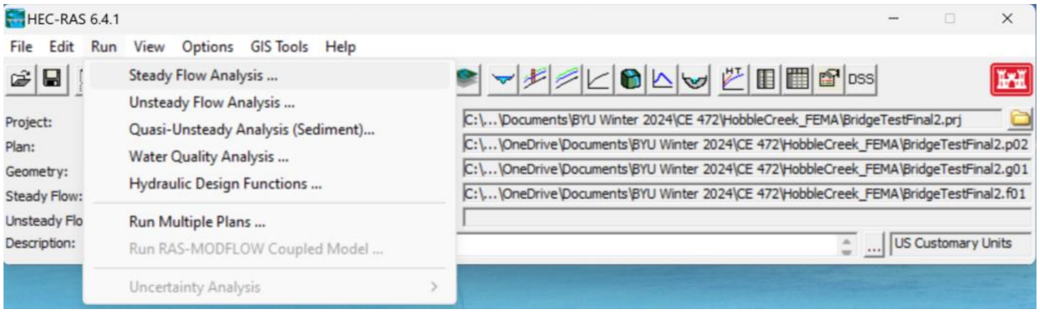
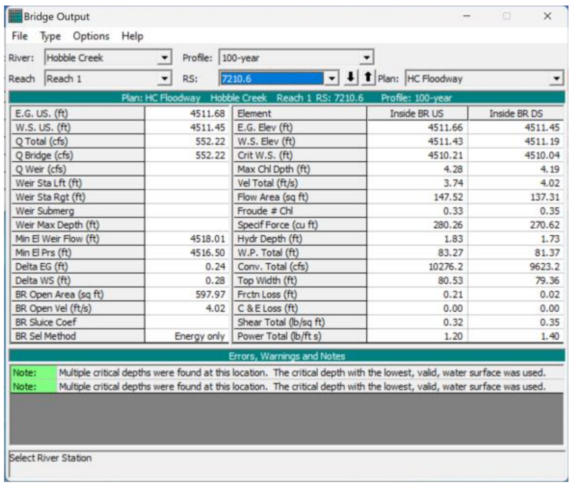


Figure 11: Run analysis button on the main menu after bridge creation

Finally, the bridge output table was generated. This table can be changed to illustrate 10-, 50-, 100-, and 500-year flood scenarios. The design for this bridge is affected by the 100-year flooding scenario. The outputs for the bridge were compared against the results for the same cross section, only from the original file before any adjustments were made.



E.G. US. (ft)	4511.68	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	4511.45	E.G. Elev (ft)	4511.66	4511.45
Q Total (cfs)	552.22	W.S. Elev (ft)	4511.43	4511.19
Q Bridge (cfs)	552.22	Crit W.S. (ft)	4510.21	4510.04
Q Weir (cfs)		Max Chl Dpth (ft)	4.28	4.19
Weir Sta Lft (ft)		Vel Total (ft/s)	3.74	4.02
Weir Sta Rgt (ft)		Flow Area (sq ft)	147.52	137.31
Weir Submerg		Froude # Chl	0.33	0.35
Weir Max Depth (ft)		Specif Force (cu ft)	280.26	270.62
Min El Weir Flow (ft)	4518.01	Hydr Depth (ft)	1.83	1.73
Min El Prs (ft)	4516.50	W.P. Total (ft)	83.27	81.37
Delta EG (ft)	0.24	Conv. Total (cfs)	10276.2	9623.2
Delta WS (ft)	0.28	Top Width (ft)	80.53	79.36
BR Open Area (sq ft)	597.97	Frctn Loss (ft)	0.21	0.02
BR Open Vel (ft/s)	4.02	C & E Loss (ft)	0.00	0.00
BR Sluice Coef		Shear Total (lb/sq ft)	0.32	0.35
BR Sel Method	Energy only	Power Total (lb/ft s)	1.20	1.40

Figure 12: Bridge output table from HEC-RAS

The process of adjusting the cross sections and bridge deck and then running the analysis occurred for each new culvert size in an attempt to find an optimal scenario for the bridge and culverts. A.B.C. Engineering created tables to neatly organize and compare the data from each analysis to the original flow data for Hobble Creek. Tables 1 and 2 illustrate key criteria for the channel before the bridge was placed and after it was placed, respectively. Each trial in HEC-RAS with varying culvert sizes was compared to the original flow data to determine viable culvert options for crossing.

Table 1: Flow data for the original channel before bridge adjustments

Pre-Bridge Channel Flow Data	
Energy Gradeline Elevation (ft)	4512.24
Water Surface Elevation (ft)	4512.08
Critical Water Surface Elevation (ft)	4510.16
Total Velocity (ft/s)	3.16
Maximum Water Depth (ft)	5.12

Table 2: Flow data for the channel after bridge placement

Bridge with 4x10 feet Box Culverts Flow Data	
Energy Gradeline Elevation (ft)	4511.68
Water Surface Elevation (ft)	4511.45
Critical Water Surface Elevation (ft)	NA
Total Velocity (ft/s)	3.75
Maximum Water Depth (ft)	4.28

After seventeen different trials with culverts of varying sizes from ten feet wide to sixty feet wide, no option kept the water level from rising. At that point, it was discovered the outputs were compared to the wrong flow data for the channel without the bridge crossing. By comparing the outputs from the trials to the correct flow data, the results from a 10ft x 4ft culvert placed at 4,511 ft provided adequate flow conveyance to prevent flooding and prevent the water surface level from rising. These results can be seen in Table 2 above. Finally, below is a three-dimensional model from HEC-Ras illustrating the completed and proposed bridge design.

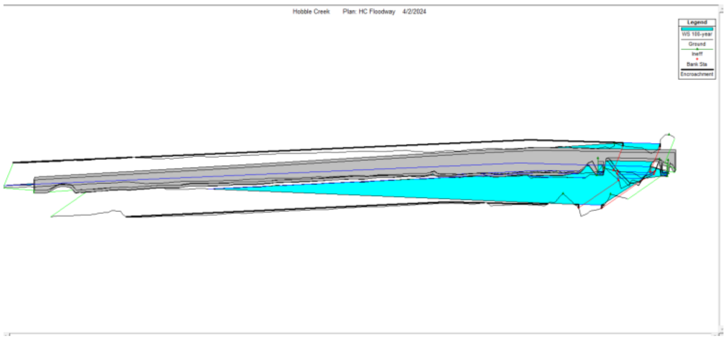


Figure 13: Side profile of complete bridge and culvert design

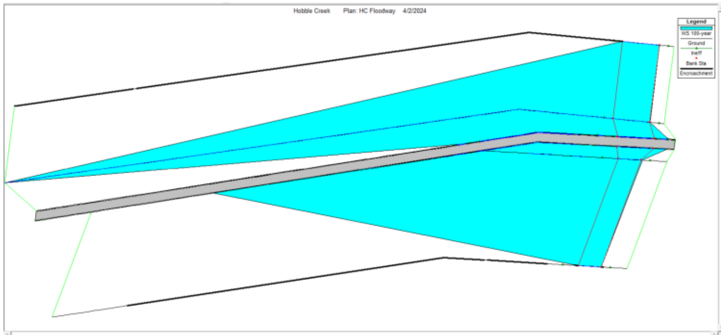


Figure 14: Aerial view of complete bridge and culvert design

Related Issues

In any infrastructure project, related issues must be considered to ensure the best engineering solutions are provided. If the best solution for any related issue cannot be achieved in the project, awareness of the issue allows for better recognition of the project's impact on its environment in the broad sense. This section addresses the impact of this project on related issues including public health, safety, welfare, global factors, cultural factors, social factors, environmental factors, and economic factors.

Public Health, Safety, Welfare

This project will likely have a positive impact on public health, safety, and welfare because, if the culverts work as designed, flooding is less likely to occur at and around the bridge site. A diversion of the flood waters will prevent fields from flooding, prevent cows from being stranded, and prevent crops from being ruined. Additionally, this flood prevention will help keep the water free from contaminants that may exist outside the channel in these nearby fields. The project will also benefit public health by diverting traffic from other busy roads, and hopefully decreasing the occurrence of car crashes during high volume traffic hours. However, at the same time, this bridge's construction might increase traffic hazards for those that live in nearby neighborhoods. To combat this increased risk, protected trails should be provided for pedestrians. Also, conversations should be held with the citizens of the City of Springville to consider their perspectives, especially when choosing alternatives for the project, and especially with those living in the neighborhoods nearest the proposed bridge crossing and road. Sound studies and other studies of the impact of the road construction on residents in nearby communities should be conducted and any negative impacts mitigated.

Global Factors

This project is a municipal project aiming to ease traffic on another road in Springville, Utah. As such, there are limited global factors that need to be considered as related issues. Some that should be included are the availability of materials that may need to be produced in other countries, and the global environmental impact of the use of these materials.

Cultural & Social Factors

Cultural factors are those that relate to a population's beliefs, values, and norms. This proposed project will likely not experience many issues related to cultural factors. However, farmers whose fields are nearby should be consulted and their opinions considered. Other social factors may include the bridge's construction impact on recreational activities at Hobble Creek at the point of the crossing.

Environmental Factors

Environmental factors are those related to the project's impact on local natural resources. Three environmental factors are important to consider in this project, 1) the impact of bridge construction on the June Sucker, 2) the bridge's impact on flooding, and 3) FEMA's designation of Hobble Creek as a protected waterway. First, after hydraulic analysis, it was determined the bridge construction will have no impact on water velocity and therefore no impact on the June Sucker's ability to swim upstream to spawn. Second, the bridge is designed to reduce flooding in the area and therefore decrease any negative impacts related to flooding. Third, with FEMA's designation of Hobble Creek as a protected waterway, the water surface level cannot be raised during bridge construction, and supports cannot be placed in the channel, meaning that a truss bridge will be constructed with limited impact on the creek's ecosystem.

Economic Factors

Economic factors that are connected to this project include the cost of bridge design and construction, the impact of the new road and bridge on transportation, and the positive impact of the bridge on flooding risks. Since the roadway, and bridge, are proposed to be four lanes wide, and the bridge will be a truss bridge, the cost of the project will be immense. The involvement of A.B.C. Engineering with culvert design will lower some of the project costs, but the cost of the project should be financed through federal funds, local government funds, and likely the City's taxpayers. As for transportation, the new road will have a positive impact on the economy because it will allow goods to be more easily transported through the City. Also, the bridge will lower flood risk and likely lower economic costs related to flooding.

Lessons Learned

The lessons learned are broken down into two sections: challenges encountered and solutions. The bullets from each list correspond to each other one for one.

Challenges Encountered

- Creating all the data for the analysis from scratch is beyond the scope of this project, however there is a FEMA report and HEC-RAS file with most of the baseline work done that will aid in the designs
- At the beginning of the semester, the scope of work needed to be completed urgently since the nature of the project changed last minute
- The City of Springville sent multiple files including to help the capstone project but only some of them seemed to open
- Planning out work to do without knowledge of how to use the HEC RAS program
- Both HY-8 and HEC-RAS are new and foreign programs that team members had no experience using
- Finding accurate elevations for the creek and floodplain
- One team member had to leave the state for PCI conference and was unavailable for the entire week
- The channel profile from the HEC-RAS file cannot be exported for use in HY-8 so the values need to be copied over one by one
- Becca cannot download the programs since she has a Mac, and the programs cannot run on MacOS
- Scheduling for regular meetings with Dr. Hotchkiss was a challenge due to everyone's varying schedules throughout the week
- Determining bridge size and location to model accurately in HEC RAS, not linked up with google or GPS
- Unsure how wide and large to make the bridge for accurate modeling in HEC RAS
- After running HECRAS team members couldn't see the results of running the program
- Already modeled a bridge, but needed to check flows with only the cross sections, so we had to spend extra time adding the cross sections to compare results
- HY-8 is taking a long time to add the culverts

- HEC RAS shows a raised water level for all options A.B.C. Engineering has tried and FEMA map and model show levees at different places
- The water level is lowered when compared to the original rile. When compared to the altered cross section files, the water level is 0.5 inches higher which is prohibited
- Midterms limit time to meet and work on the project

Solutions

- Dr. Hotchkiss filled out a GRAMA request and team members discussed receiving the file with the representatives from Springville to jumpstart the design process
- The work for the scope was divided equally among team members so that it could be completed in a timely manner
- Learned that the .prj files were the appropriate file type to open in order to use the HEC-RAS data
- Becca will meet to work with either Caroline or Andrew to assist in program modeling and flow analysis
- Team members met with Dr. Hotchkiss to learn about the programs. He lent some of his materials to learn both programs. He also showed where to find the user's manuals for the programs. Individually team members watched tutorials on the internet for supplementary information
- After learning about the profile plot in HEC-RAS, elevation data could be pulled directly from the model
- The other two team members met extra times during the week in order to stay on top of the work without the other member
- One team member would read the values from HEC-RAS while the other wrote them down and then that team member would read the values off to be input into HY-8
- Becca and Andrew met during the week to troubleshoot using the computer programs and setting up the test runs for initial culverts. Becca often met with the other team members to help with the programs.
- Team members had to sacrifice a small part of their week whether by coming sooner to campus or using study time in order to make the meetings happen
- Research on short span bridges, try to see what would work and whatnot. Use elevations to figure out what cross section to use

- Sent an email to Chris over in Springville to ask if there are already any designs for the bridge, and if not, what the criteria are for the bridge so that we can model it accurately in HEC RAs
- Reading the users' manual to find out how to view the results of HEC-RAS
- Becca and Andrew met to figure out the cross sections and compare results to the correct flow data to draw correct conclusions from the results
- Met as a team to work on HY-8 and focused on other aspects of the project while the program loaded in order to use time efficiently
- Email Chris about our challenges regarding FEMA map and water levels
- Try larger and larger culverts until the water level doesn't raise and continue to optimize the HEC-RAS file
- Met for longer during weekly meeting to talk about next steps and get started on documents

Conclusions

From the results of this project, A.B.C. Engineering has concluded that two box culverts should supplement the bridge by conveying extra water through the bridge cross section during peak flow times.

Seventeen trials were conducted in the model of Hobble Creek available in HEC-RAS to determine the best size for the box culverts. After analysis of the results, it was determined that although the water level increased with the addition of any size of box culverts, 10ft x 4ft (width by height) box culverts should be constructed. This conclusion was reached by comparing the results from all the trials, especially the stream velocities, and considering errors that may have occurred during modeling. In this instance, it is also important to note that hydrology is a general science and therefore changes in water surface level in hundredths of an inch are mere estimation.

Other conclusions include the fact that the June Sucker won't be impacted negatively by the bridge or culverts, and that the proposed bridge, and roadway, should have a positive impact on the City of Springville.

The negligible impact of the bridge on the June Sucker was determined by learning about the June Sucker's habits, specifically swimming upstream to spawn. The bridge would have negatively impacted the June Sucker if its construction increased the velocity of Hobble Creek significantly, making it harder for the June Sucker to swim upstream.

Also, a detailed consideration of related issues in the context of this project revealed that the bridge, and roadway, will have a positive impact on the City of Springville by mitigating flood hazards, likely providing more recreational facilities, and decreasing congestion. However, it should be noted that all these benefits will only occur if the remaining bridge design continues to consider related factors and mitigate any negative consequences of the project.

Recommendations

A.B.C. Engineering recommends placing two 10ft x 4ft (width by height) concrete box culverts at an elevation of 4,511 ft on each bank of the Hobble Creek. The act of adding the new cross sections for the bridge adjusted the flow values of the analysis, therefore more accurate cross sections may need to be created in order to more accurately model the flow through the bridge and provide a second check that the water level indeed does not rise. Another important consideration as the designs progress is the consideration between precast and cast in place culverts. The bridge's width is long enough that multiple precast culverts would need to be connected but may be more cost-effective than the form work needed for cast in place culverts. Finally, the results of a more in-depth analysis for confirmation of the culverts may necessitate looking into constructing approved levees to hold more water.

Appendix A

Related Figures and Tables

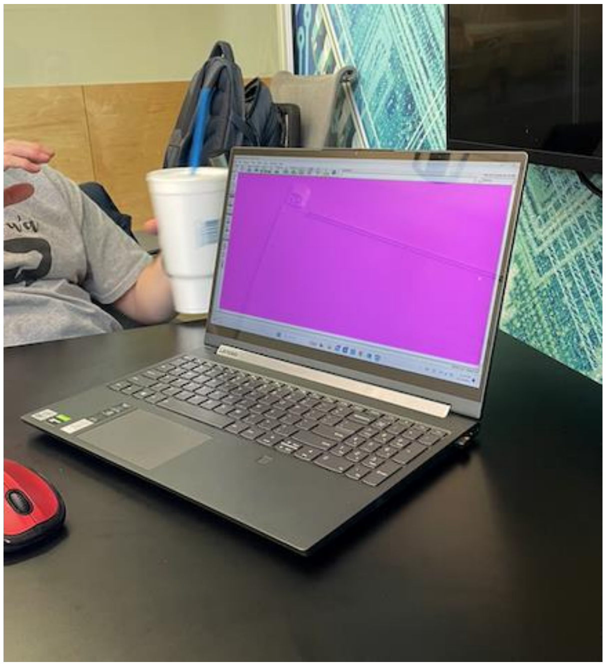


Figure 15: Issues with HEC-RAS (PC: Becca Apgar)

Figure 16: Site photo (PC: Andrew Olsen)

Original File				**With New Cross Sections**			
EG Elev	4512.24			**EG Elev**	4511.55		
WS Elev	4512.08			**WS Elev**	4511.32		
Crit WS	4510.16			**Crit WS**	4510.01		
Vel Total	3.16			**Vel Total**	3.85		
Max Depth	5.12			**Max Depth**	4.36		
10x4 ft at 4511 ft			Difference	**10x4 ft at 4511 ft**			Difference
EG Elev	4511.68		-0.56	**EG Elev**	4511.68		0.13
WS Elev	4511.45		-0.63	**WS Elev**	4511.45		0.13
Crit WS				**Crit WS**			
Vel Total	3.75	4.01		**Vel Total**	3.75	4.01	
Max Depth	4.28	4.19		**Max Depth**	4.28	4.19	
10x8 ft at 4507 ft				**10x8 ft at 4507 ft**			
EG Elev	4511.47		-0.77	**EG Elev**	4511.47		-0.08
WS Elev	4511.38		-0.7	**WS Elev**	4511.38		0.06
Crit WS	4509.15	4509.06		**Crit WS**	4509.15	4509.06	
Vel Total	2.48	2.45		**Vel Total**	2.48	2.45	
Max Depth	4.38	4.3		**Max Depth**	4.38	4.3	
11x8 ft at 4507 ft				**11x8 ft at 4507 ft**			
EG Elev	4511.46		-0.78	**EG Elev**	4511.46		-0.09
WS Elev	4511.38		-0.7	**WS Elev**	4511.38		0.06
Crit WS	4509.09	4509.01		**Crit WS**	4509.09	4509.01	
Vel Total	2.39	2.36		**Vel Total**	2.39	2.36	
Max Depth	4.38	4.3		**Max Depth**	4.38	4.3	
15x8 ft at 4507 ft				**15x8 ft at 4507 ft**			
EG Elev	4511.44		-0.8	**EG Elev**	4511.44		-0.11
WS Elev	4511.37		-0.71	**WS Elev**	4511.37		0.05

Figure 17: Results from HEC-RAS iterations, sent to the City

Table 3: List of files used and created during the project

BridgeTest1.prj	BridgeTest12.prj
BridgeTest2.prj	BridgeTest13.prj
BridgeTest3.prj	BridgeTest14.prj
BridgeTest4.prj	BridgeTest15.prj
BridgeTest4_2.prj	BridgeTest16.prj
BridgeTest5.prj	BridgeTest17.prj
BridgeTest6.prj	BridgeTestFinal.prj
BridgeTest7.prj	BridgeTestFinal2.prj
BridgeTest8.prj	HobbleCreek.prj
BridgeTest9.prj	HobbleSplitCalc.prj
BridgeTest10.prj	HobbleSplits.prj
BridgeTest11.prj	JustCrossSections1.prj
Capstone Calcs.xslx	Notes for Capstone.docx