Manchester Riverwalk Pedestrian Bridge

Community Partner: Bill Laberge, Manchester Riverwalk Committee

UVM CE186 Capstone Design Project
Final Submission
Instructor: Professor John Lens

Submitted by: Andrea Ameden, August Arles, Kate Fuller, Shaun Roberts

Civil and Environmental Engineering
The University of Vermont
Burlington, VT 05405

April 20, 2018

UVM Project Team Manchester Riverwalk
213 Votey Hall
33 Colchester Avenue
Burlington, VT 05405

April 20, 2018

Mr. Bill Laberge
Manchester Riverwalk Committee
5046 Main St.
Manchester Center, VT 05255

Re: *Manchester Riverwalk* with UVM CEE Senior Capstone Design Final Design Report

Dear Mr. Laberge:

We are pleased to provide you this finalized design report. This report describes our recommended design based on your input and our analyses.

Please review this report and provide your comments and questions to us by early May 2018. We hope to have these designs handed off to you, for further approval from a Professionally Licensed Engineer, by the end of our academic year in mid-May.

Thank you for providing this opportunity for us to serve your community.

Sincerely,

UVM CEE Project Team Manchester Riverwalk.

Shaun Roberts
Team Project Manager
scrobert@uvm.edu
(410)660-5466

Andrea Ameden
August Arles
Kaitlyn Fuller

Attachment: Final Design Report dated April 20, 2018

ACKNOWLEDGMENTS

We would like to give special thanks to Cassidy Cote, with Vermont Transportation Agency Hydraulics Department, for his dedication to helping us with our data collection and analysis for this project.

Also, Josh Carvajal and team in Bennington County ANR department for providing us with feedback at different points of our design to ensure we would be able to get this design processed through the State.

Finally, thank you to the Manchester Riverwalk Committee for giving us the opportunity to work with them on this project to enhance the beauty of Manchester, Vermont. It has been a pleasure and we hope to see these plans carried out and implemented in the future.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Manchester Riverwalk (MRC) project consists of designing a pedestrian bridge to cross the Battenkill River to connect two portions of the existing riverwalk trail. This report provides a detailed evaluation of the current site conditions, data gathered, risks and uncertainties, our four alternatives, and our final design with details. Hydraulic and subsurface soil data was collected on site, with the help of a VTrans Hydraulic Engineer and ANR Representative.

It was initially proposed to utilize the VTrans Truss Re-Use Program for the stream crossing, but, after photo investigation of bridges in storage around the state, it was concluded that designing an arched bridge will be the most effective for the MRC's project. Other stream crossings were evaluated, such as implementing formal stepping stones. This is a lower cost option but limits trail accessibility and denies trail use during high-water events (i.e. spring snowmelt). A floating bridge was assessed, but by our judgement would not be ecologically or economically friendly for the MRC. A more conservative design of an arched bridge as a crossing was addressed and highly encouraged by the committee and our team, as it fulfilled all requirements of our client.

Although more expensive, an arched bridge is most reasonable to meet the client's needs at this time. This allows for water, sediment, debris, and wildlife to safely pass without damming. The current limitations of this alternative are its cost, at about $106,100, the concerns of getting equipment to the site, and possibly having to build from only one side of the river. This alternative provides for a safe crossing of the Battenkill River and meets the needs of the users, and will be the main focus of our design.

In Appendix IV - Cost Analysis, the billable hours pertaining to this project can be found. Note that the time seems to be enlarged quite a bit to what would normally come from a smaller-scaled project like this one. This is because this was a learning process as a team, where all members were tackling one task that possibly only one person would tackle alone in the real world. This billable time would be added to the cost of the bridge fabrication, leaving a total of the project of around $126,000.

1.0 BACKGROUND INFORMATION

1.1 The Site

Our site, being located in Manchester, VT, intends to have a pedestrian bridge implemented at approximately 43.176707, -73.055199. Figure 1 shows the site location with our proposed location for the bridge, as well as a bridge being implemented about 200 ft upstream, by a company out of Burlington, VT (VHB). The MRC Bridge Location's intends to connect the lower ends of the riverwalk already in place, and VHB Bridge's intends to connect higher banks, out of the riverwalk.

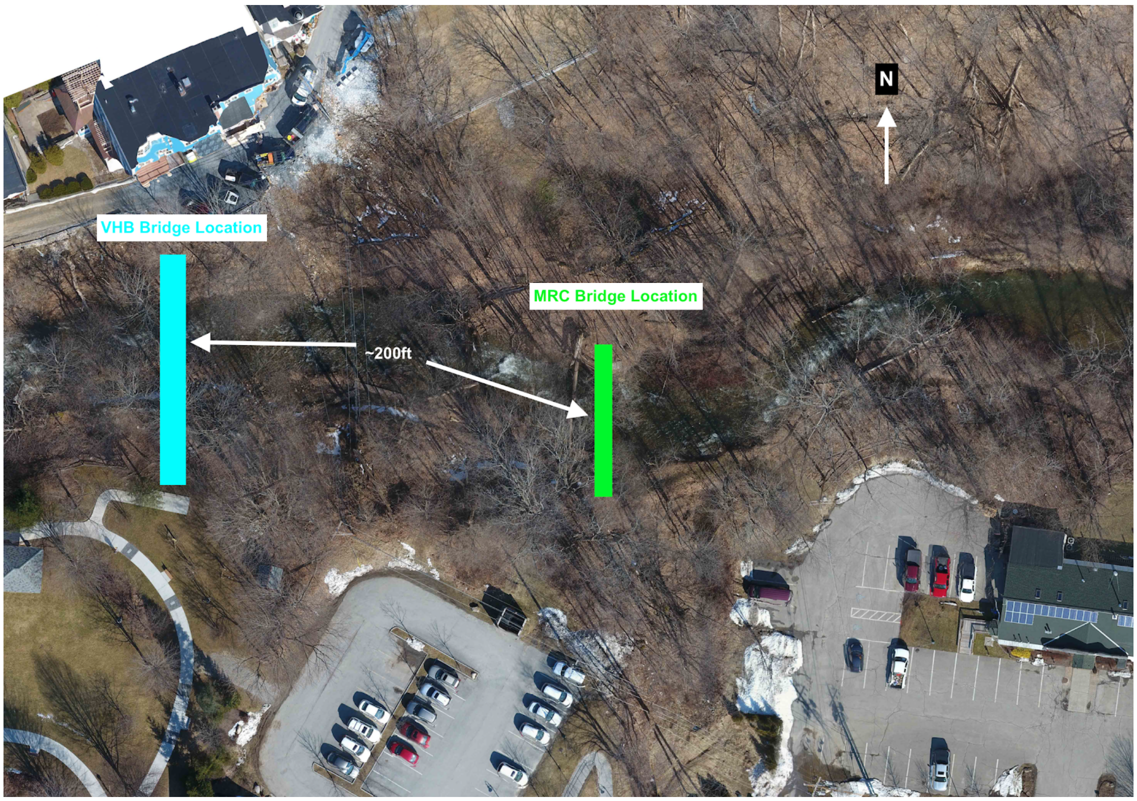

Figure 1: Aerial View of Site Location

Below, Figure 2 shows the upstream view of the site location looking downstream to our site, note the fallen tree currently being used as the river crossing. The site itself will require some maintenance before any construction can occur. Our recommendation is to thin out some of the fallen-in, smaller trees that are close to the site location. These cause potential hazards for the bridge in future years, as the trees grow and get larger, they could fall over (like the one seen in this picture) and destroy the bridge.

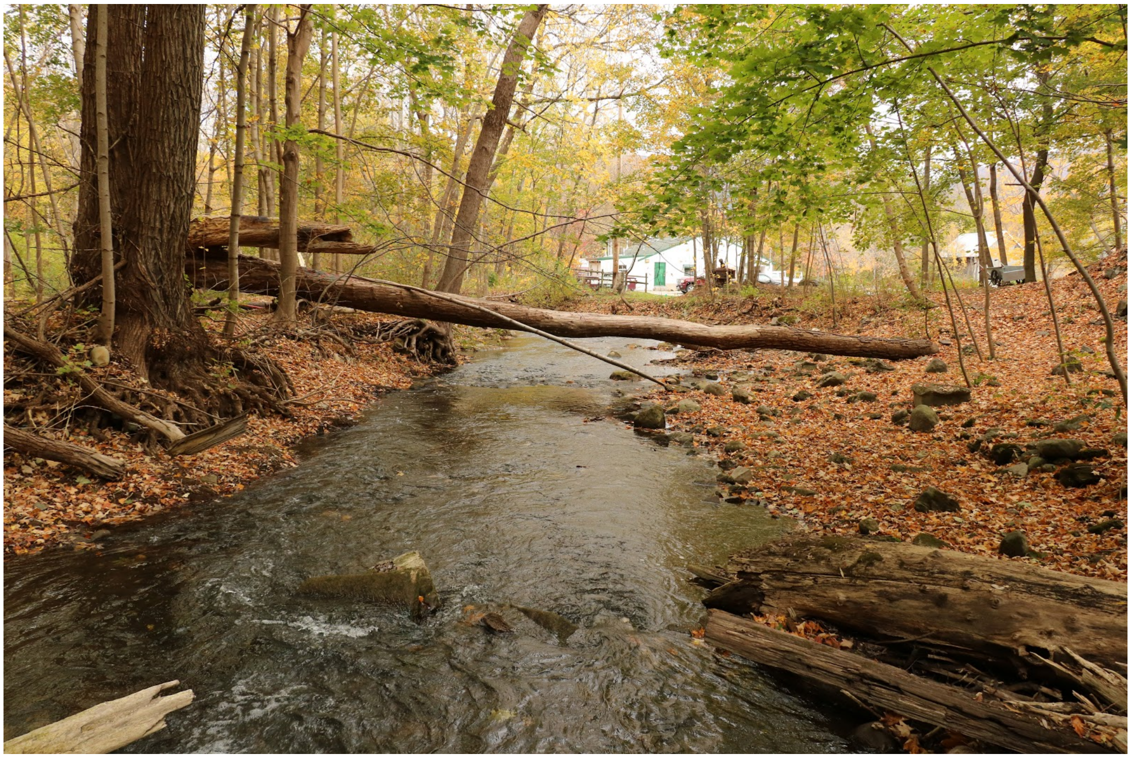

Figure 2: Upstream View of Site Location

1.2 Applicable Design Standards

Table 1 lists the applicable design standards for the implementation of a pedestrian bridge. The State of Vermont or Federal Government imposes each of these applicable standards, but, Vermont State standards are the most fitting to this project because this project is privately funded. Appendix V - Precedents and State of the Practice Report, has the conducted research for each of these standards and where they are most applicable to our design, as well as Appendix VIII - Project Sustainability, has the relatable clauses of Act 250 that will be followed.

Table 1. Applicable Design Standards

Ecology	Hydraulic	Structural	Geotechnical	Land Use
Vermont Statutes Title 10	Stream Alteration General Permit	VTrans Structures Design Manual	FHWA	Act 250
Chapter 111: Fish 4607 Obstructing Streams	Equilibrium Standard	LRFD Specifications	AASHTO LRFD	No Adverse Impact Standard (NAIS)
Environmental Protection Rules	Connectivity Standard	AASHTO Bridge Specifications	VTrans Structures Design Manual	Federal Regulations: Executive Order 11988
Chapter 27: Vermont Stream Alteration Rule	Vermont Flood Hazard Area and River Corridor Rule	ASCE Minimum Design Loads for Buildings	VTrans Hydraulics Manual	

1.3 Project Scope

The initial client agreement is attached as Appendix I for reference, it provides a brief overview of what the clients wants and objectives are for this project. The stakeholders for this project have been identified to be the Manchester Riverwalk Committee (MRC), financial supporters of the MRC, the community of Manchester (users of riverwalk), the environment and ecological community of the Battenkill River, and the University of Vermont.

This is a privately funded venture, so all funds are raised with specific costs in mind. The project has already received specific donations for certain aspects of the project (signage, ecological restoration, borings, design and engineering, etc.). Based on the most current meeting minutes (02/24/2018), the Manchester Riverwalk Association raised $35,752 in 2017 and has $55,640 available this year.

1.4 Uncertainties

The uncertainties that we have identified associated with the pedestrian bridge crossing are listed below in Table 2. A risk was determined by multiplying the probability (0-1, 1 being very likely) with a cost factor (0-1, 1 being higher pricing). From this table, we were able to focus on the higher risks, as these would be the ones we want to ensure are avoided at all costs. As seen in the Table, the highest risk is not getting community acceptance. This is because if the community does not approve the design, they will not help with donating the funds to cover the cost of the bridge.

Table 2. Risk Cost Analysis

ASSOCIATED RISKS	PROBABILITY	COST	RISK (PxC)
Technical Feasibility of Implementation	0.25	1	0.25
Not Meeting Permitting Needs	0.1	0.1	0.01
Lack of Funding	0.1	1	0.1
Not Getting Community Acceptance	0.5	1	0.5

1.5 Brief Overview of Project Motivation

The overall objective of this project is to help the community of Manchester, VT enhance the natural beauty of the town, while providing a safe, alternative path for pedestrians and bicyclists to travel without the rush of cars in the Manchester Center area. The design that we hope to carry out will not only provide a way to cross the river, but will hopefully be a unique, fun design that will attract more people to the riverwalk. The committee organizing this project hopes to expand the riverwalk from its current location and length, to connect to other existing trails throughout the town of Manchester.

The motivating factor of this project is being the technical voice behind the MRC's dream. The MRC is a diverse committee, made up of volunteers ranging from teachers and artists to solar power installers. Being able to provide the MRC with an affordable, unique design instills in us a high motivation. Furthermore, having two team members' residences located in the area increases this motivation to provide a useable and respected product.

2.0 EXISTING CONDITIONS, CONSTRAINTS, and IDENTIFIED NEEDS

2.1 Data

2.1.1 Provided Data

A light detection and ranging (LIDAR) survey was completed by Mance Engineering Partners, P.C. out of Manchester, VT and was provided to us by Carolyn Carlson. See Figure No. 1 Existing Site Conditions in the AutoCAD section of this report for this survey.

Figure 3, below, shows an overview of the floodplain for different storm severities, from a FEMA report. The blue and red colored diagonal covered area is the normal floodplain of this location, while the area covered in a light blue is the one percent annual flood area. The primary bridge location for the MRC is designated with the orange line. We have added a secondary location for the bridge, designated by the pink line in the Figure below; this location was not considered in the calculations and design presented in this report. It was a suggestion for an alternative early on, but was recommended by ANR to disregard. If the bridge was placed at this alternative location, backwater cause by the bridge could flood the parking lot.

The existing wood chip path is also highlighted in yellow in this picture. On the South (bottom) side of the river, the floodplain goes right up to the wood chip path. This is an issue that is seen for the Riverwalk during the spring snowmelt, which leaves the path unusable. Ideally, the path would be raised so it could still be used during these wet times, but due to floodplain and river corridor regulations, any addition or removal from this area must retain a netzero impact, meaning, what you take out, must be put in and vice versa.

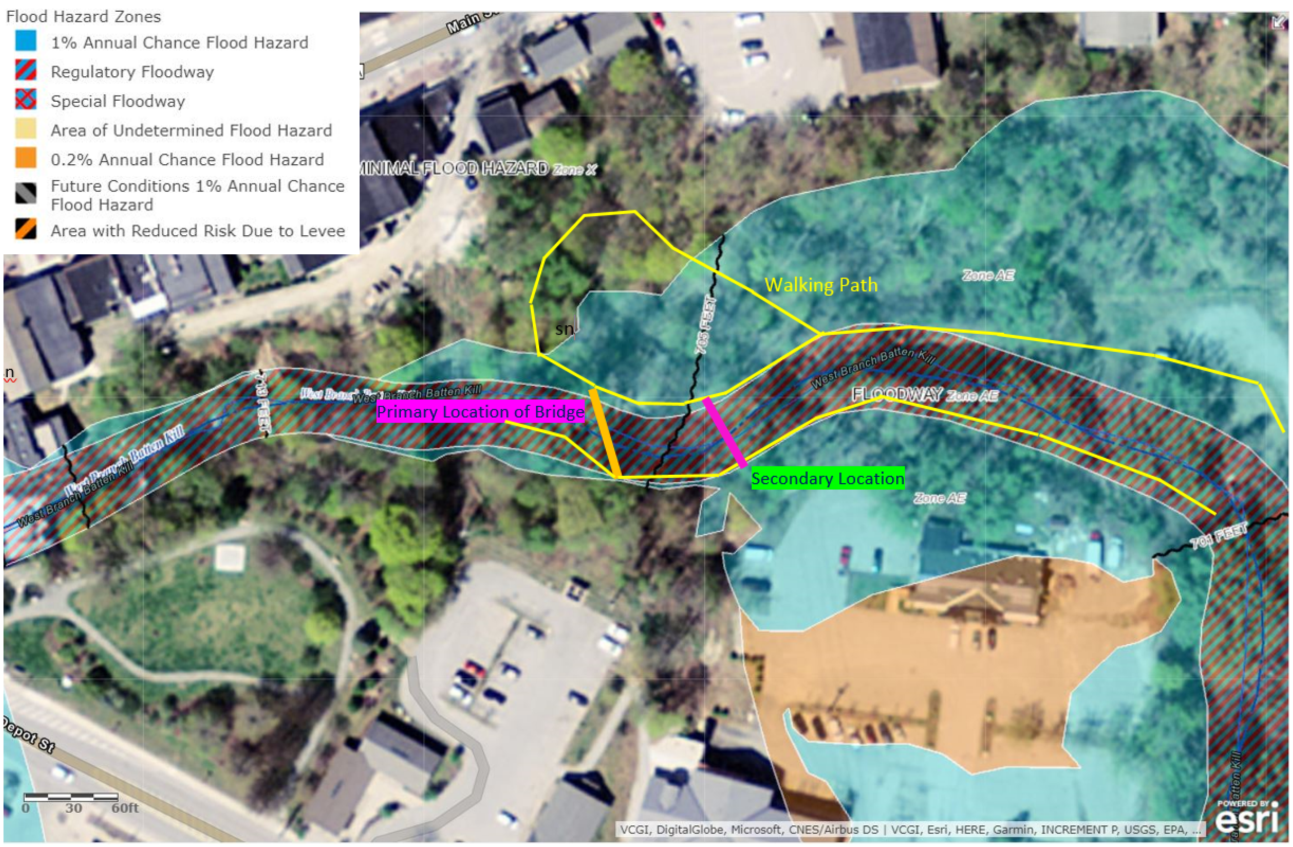

Figure 3: Plan View of Site with Highlighted Floodplains

2.1.2 Hydraulic Collected Data

A transit level and grade rod were used to get the depths and horizontal distances required to generate a stream cross-section. Referencing Appendix II provides a full hydraulic analysis based on the field collected data; i.e. the bankfull widths, bankfull depths, and the horizontal distance associated with each depth. See Figure No. 10 Channel Cross Section at Stream Crossing in the AutoCAD section of this report for this survey.

Collected hydraulic data was uploaded to the hydraulic modeling program, HEC-RAS, which calculates the elevation of water after a 10-year storm, per the Town of Manchester standards. The program also shows the water elevation in relation to the low-beam elevation of the bridge and will describe if the structure tops out or not. A structure tops out of the water becomes higher than the structure. In the Hydraulic calculations portion of this deliverable, the charts and figures created by HEC-RAS are shown. From the model, our bridge is required to have a low beam elevation of at least 6-ft. Due to this restrictive height, an arched bridge would be an ideal design for this location. The cross-sectional area under an arched bridge is larger than a simple-span which allows for higher flow during snowmelt season and more debris to flow under the bridge which decreases the risk of damming and flooding. Figure 4 below represents the depth of water after a 10-year storm in relation to the low-beam height of the bridge.

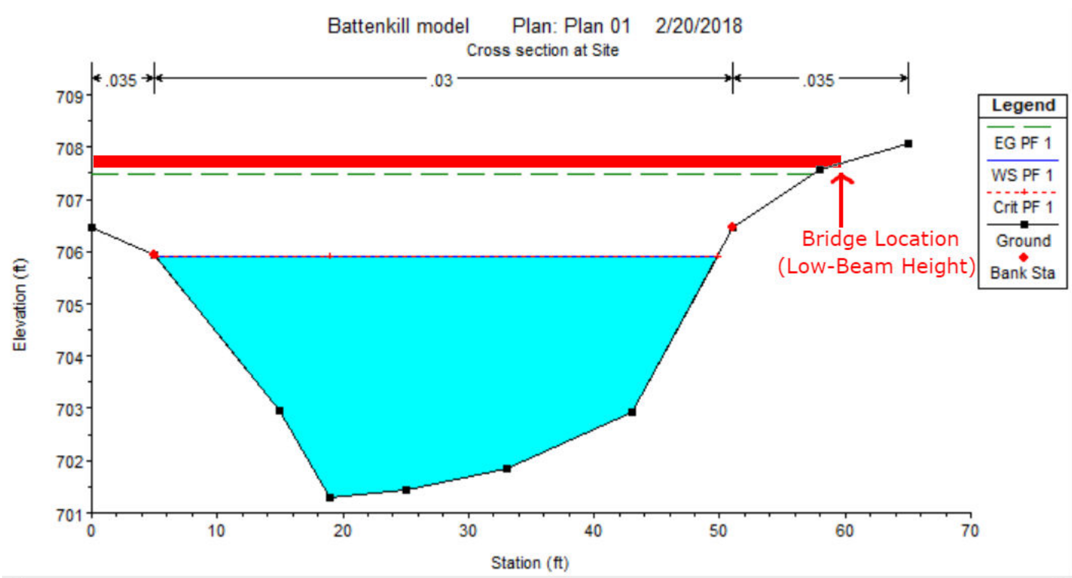

Figure 4: Cross-section at bridge site with water and low-beam elevations

There are also a series of wooden boardwalk-style pathways that lead to and from the future bridge location. The elevation of these paths relative to the water's surface is all but a few inches. The walkways are also very unstable in their current condition, and flex under the weight of a single pedestrian on it. There have been previous issues of these walkways flooding after storms and in the spring after the snow melt. Now, as a part of the river corridor, these walkways should only be removed when degradation of the boardwalks prevent usage.

2.1.2 Geotechnical Collected Data

Table 5 in Appendix II shows the data gathered from the hand auger exploration at the site. Boring 1 was dug on the top of the foundation where the existing abutments are, Boring 2 was dug to the left of the foundation, and Boring 3 was dug on the right side of the river at the top of the riverbank. The auger went further down than was recorded at the end, this is due to the soil being loose and collapsing in on the hole when the sampler was taken out of the whole to gather the soil data.

During site visits, approximately 4-inches of scour was measured on each existing abutment as seen in Figure 5 below. Our team also expressed concerns with the instability of the failing slope on the left side of our site, as well as the banks adjacent to buildings further upstream, but this was not in the scope of our project to be addressed. The remnants of the previously demolished bridge are currently in the floodplain, and to meet regulations of no net fill requirements.

Figure 5: Scour present on the current abutments

2.2 Project Constraints

Below in Table 3, the uncertainties associated with our project are listed and the mitigation tactics that we have taken in order to reduce this uncertainty from occuring. The final column is the probability this has to occur and the impact it would have on the success of our project. The ranking is high - likely to happen / very high impact of failure, to, low - low probability and low impact of failure.

Table 3. Risks and Mitigations

UNCERTAINTIES	MITIGATIONS	Probability/Impact
Technical Feasibility of Implementation	● Creating designs that can be built from one side of the river ● Designing for easily implemented bridge ● Avoiding deep foundation ● Contacting local contractors to get professional opinions	High / High
Meeting Permitting Needs	● Creating a design where abutments/other foreign objects remain out of the river corridor ● Communicating with property owners to remove hazardous trees/materials ● Ensuring our design meets bankfull elevation requirements.	Medium /High
Budget / Uncertainty of Funding Sources	● Keeping a constant communication of our plans and the committee's budget	Low / High
Community Acceptance	● Running all designs by the committee to ensure it is meeting aesthetic wants	Low / Medium

3.0 ALTERNATIVES EVALUATED

3.1 Alternative 1 - Design a New, Arched Bridge

Our site, being sensitive due to the large floodplain and lack of channel constraints, will benefit most from an arched pedestrian bridge, as seen in Figure 6. The biggest challenge for any structure implementation is minimizing impediment of river sediment or water. An arched bridge is the only feasible option for a footbridge at this location. Having the bottom chord of the bridge at a higher elevation satisfies VT ANR regulations and also provides less of a chance for debris and ice to be caught and cause a potential dam. See Figures No. 11-15 in the AutoCAD section of this report for further details of this design.

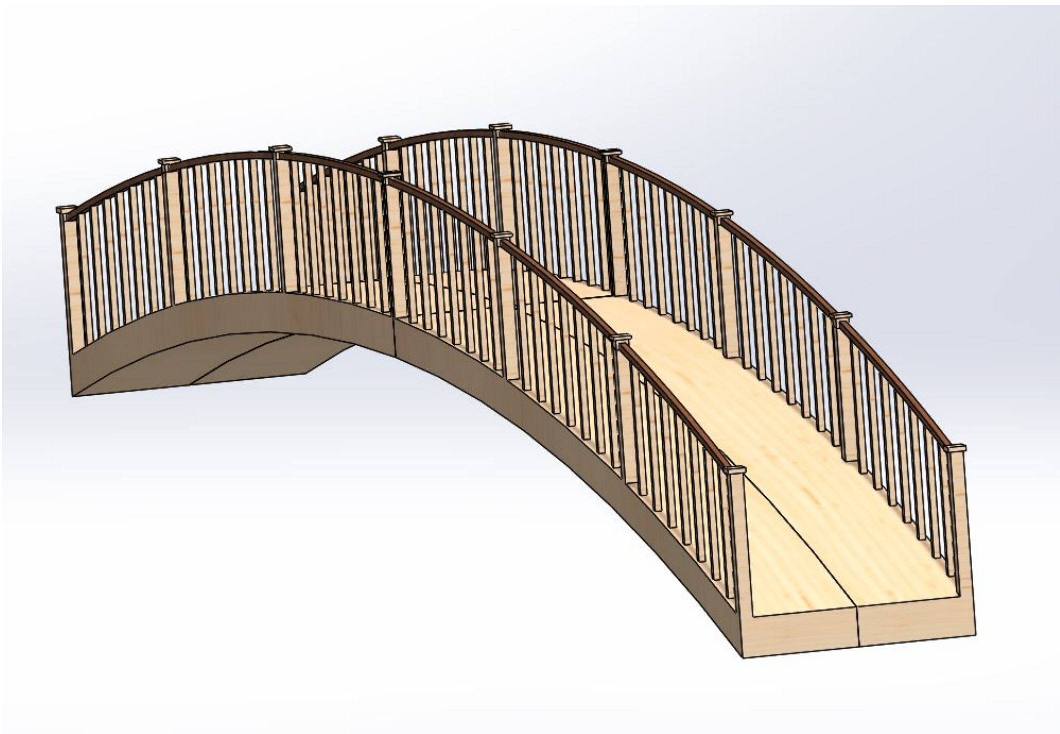

Figure 6: SolidWorks Preliminary Design for Arched Bridge; NTS

The challenges associated with the arched bridge design is the constructibility. Innovative ideas from the contractors will be necessary to transport materials, dig, and build the bridge. The use of smaller equipment such as an ATV, small truck, mini-excavator, skid steer, etc. will be of use in the construction phase. Table 4 below lists the advantages and disadvantages of pursuing an arched bridge design for the MRC.

Table 4. Advantages and Disadvantages of Arched Bridge

Advantages	Disadvantages
Fulfills clients expectations	Expensive
Low probability of damming with sediment or debris	Difficult Constructability
Would not necessarily have to perform trail maintenance	

3.2 Alternative 2 - Floating Bridge

This design alternative will be the most expensive for the MRC but meets their desire for a bridge. As said before, this site is very susceptible to flooding. A floatable bridge is a feasible option for a footbridge at this location because the pile sleeves allow for a sturdy support for the structure while allowing the bridge to translate vertically in the event of severe flooding. The piles (similar to Hapgood Pond, in Figure 7) are expected to be driven outside of the channel but within the floodplain.

Figure 7: Hapgood Pond "floating" bridge structure (left) and adjustable sleeve piles supporting the structure (right) (Photo property of Ken Allard)

Although a unique alternative, this will be difficult to implement. This option also requires the most cosmetic and foundational work before bridge construction. Lastly, there are unknown hydraulic concerns and other possible unforeseen consequences with the implementation of these piles within the floodplain. Table 5 below lists the advantages and disadvantages of pursuing the floating bridge and pile design for the MRC.

Table 5. Advantages and Disadvantages of Floating Bridge

Advantages	Disadvantages
Fulfills clients expectations	Expensive
Can alter with rising stream conditions during peak flood season	May take away from the natural aesthetic of the area
Would not necessarily have to perform trail maintenance	Possible damming/ debris buildup

3.3 Alternative 3 - Stream Crossing

The stream crossing involves creating a unique stepping stone design for trail-users to cross this section of the Battenkill. This alternative would only allow access to cross the stream in warm seasons where high-water and ice conditions will not pose a danger to visitors. In the event of flooding, the stone path would stay in place while the water would rise over it. This would also only allow for able pedestrians to cross the river, bicyclists would be detoured around to the upper level bridge.

The biggest design challenge posed with the stepping stone path is damming of sediment, flow, and any aquatic wildlife. The stepping stone crossing adds a dynamic feeling to the riverwalk and allows a greater capacity for this trail to become a park that feels alive. A full analysis of the stepping stone design implemented in the Manchester Riverwalk will be evaluated in hydraulic software to ensure any structure is capable of passing sediment and debris. The stream crossing structure would be similar to Figure 8 below located at Mad River Path River Crossing.

The rock stream crossing along the river bed is the least technically challenging option out of the possible designs we have come up with, besides the 'Do Nothing' approach. However, a stream crossing poses threats to the surrounding ecosystem that we will have to take into consideration. Large rocks that are being placed directly into the stream bed derive problems to change of flow to the river, and pose a threat to native species that may navigate this river. When looking further into the possibility of this design we need to take into consideration the adverse effects it will have on the surrounding environment.

Figure 8: Mad River Path River Crossing (Source: http://www.wvnh.com/mad-river-stepping-stones/)

Figure 9 below shows the plan view of the stepping stones in the proposed bridge location. It is unsure at this time how stepping stones would alter the hydraulics of the river. This is not what the MRC is looking for, we propose this as a fun alternative to keep in mind.

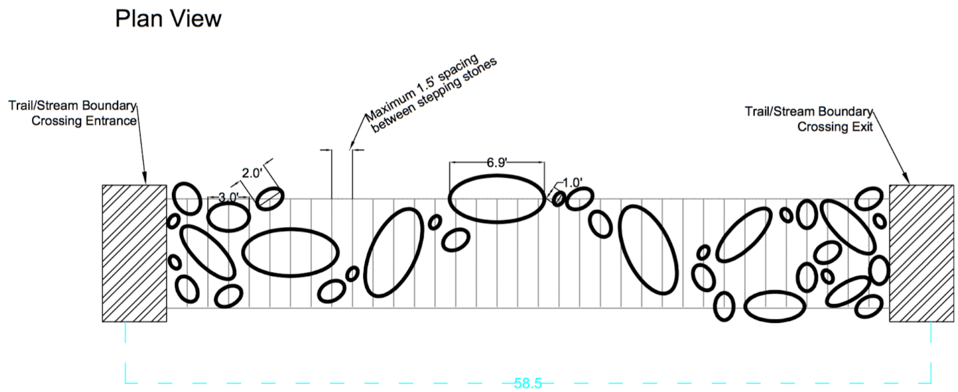

Figure 9: Plan View Stepping Stones Design; NTS

Table 6. Advantages and Disadvantages of Stepping Stones

Advantages	Disadvantages
Fun, unique, attractive alternative	Only abled bodied pedestrians can cross
Cost-effective	Only able to use when river is low
	Possible injuries from slipping on rocks
	Possible damming

3.4 Alternative 4 - "Do Nothing" Riverwalk Maintenance

The final alternative involves doing nothing. While low-cost, this alternative meets none of the MRC's needs. Shown in Figure 3 on page 9, the majority of the Riverwalk lays in a floodplain or river corridor. If the site remains untouched, the channel bank erosion and high risk of flooding to neighboring properties exists. If the trail remains unmaintained, the condition and therefore attraction of it to users ceases. The "do nothing" alternative gains nothing for anyone involved in this project.

Table 7. Advantages and Disadvantages of Riverwalk

Advantages	Disadvantages
Fixes trail from washing out	Expensive
Prevents future flood problems for future bridge design / VHB's bridge	Won't necessarily allow for future bridge

4.0 SUSTAINABILITY

4.1 Design Alternatives Ranking

Table 8 below shows the ranking of each alternative for our designs. The rankings are based on impacts to the social, environmental, and economical sustainability of our project and surrounding site. These ranking were based off of a 1-4 scale, where 4 was denoted to the alternative ranking best in each specific category mentioned. That ranking was then multiplied with a value of 0.25 (social), 0.5 (environmental), and 0.25 (economical) , by how important we believed that aspect to be in choosing which alternative to move forward with. An alternative would ideally be chosen at the end with the highest score.

Table 8. Alternatives Ranking

Alternative	Social	Environmental	Economical	Total Score
Do Nothing	3	4	4	1.25
Stepping Stones	2	3	2	2.5
Floating Bridge	1	1	1	1
Arched Bridge	4	2	3	2.75

The arched bridge alternative has the highest score, which is one of the reasons we have chosen this to move forward with for our design. Not only do we feel the arched bridge will be meeting all of our clients expectations and wishes, but it will be the most socially, environmentally, and economically sustainable alternative. Secondly ranked would be to implement stepping stones, then do nothing, and finally, a floating bridge.

4.2 Comparison of Sustainability

Table 9 below shows the comparison and weightings of the social, environmental, and economical sustainability aspects of this project. The weights were given as +1 for positive impacts, 0 for neutral, and -1 for negative impacts. The points for each aspect were tallied and divided by the number of aspects, giving a final score between 0 and 1, with 1 being the most sustainable aspect. As seen in Table 9, the economical sustainability ranks highest, then environmental, and then social. The social aspects rank lowest because there are more uncertainties (as seen in the table) associated with this aspect than the others.

Table 9. Comparison of Sustainability Aspects

Social			
Item	**Score**	**Justification**	**Total**
Increase in outdoor activities	1	less air pollution from driving around town where walking is applicable	0
Opportunity to build off of in future	1	more jobs (to build it), more outside friendly area, encourages healthy outdoor activities	
Provides a safe place during the day to hang out	1	encourages kids and teens to go outside instead of go home and sit inside after school	
Tourist attraction	0	can lead to more foot traffic and more pollution, but also could help local economy	
Unlit area at night	-1	potential for crimes	
Property still owned privately	-1	property owners being unhappy with foot traffic or littering with no one responsible to clean it up	
More people to pollute river	-1	more foot traffic and people hanging out usually leads to more trash which can pollute river and kill off species of fish and other aquatic animals there	

Environmental			
Item	**Score**	**Justification**	**Total**
Air	1	initial affect from construction equipment, but over time would ideally improve air quality by encouraging more people to walk / bike	0.4
Surface Water	1	no impact because of all ANR regulations we are following, construction could cause some preliminary pollution	
Soil	1	no impacts because of all ANR regulations	
Groundwater	-1	no impacts foreseen at this time, but there is an uncertainty involved once excavation begins	
Stream Alteration	0	ANR regulations to avoid this, but could be potential damming or flooding that is unforeseen and unavoidable	

Economic			
Item	**Score**	**Justification**	**Total**
Bridge	1	fundraise from locals to be able to buy and build	0.75
Future plans	1	encourages others to build similar structures around area, put money back into local economy	
Tourist attraction	1	more people coming into the center of town and walking, possibility to eat and shop locally	
Unknown use of bridge	0	could be a waste of money if not built correctly or used for the intended uses	

The total overall score for our projects sustainability is an average of about 60% sustainable. This number is sufficient for our project, because of how low-scaled it actually is, the sustainability will actually be much higher. We took into account risks that are very unlikely to occur, but scored them as a -1 just incase they were to occur. We are prepared to move forward with our project and emphasize the sustainability aspects it entails.

We believe that the above social, environmental, and economic sustainability attributes are addressing the goals of our community partner. The major goal for our community partner is to provide a safe way to cross the river while enhancing the natural beauty of the surrounding site. We, as soon to be Professional Engineers, have a responsibility that our structure and site are safe and serviceable. We do not want to set others up for failure on a structure that will not hold up, possibly causing injuries. We want to provide a structure that can be maintained and easily replaced if needed. Those are two key things we have learned in our undergrad career at UVM, all structures need to be safe and serviceable. We as a team did strive for these as we finalized the design of our bridge.

View Appendix VII - Cost Analysis for details on our life cycle cost analysis, created in rsmeans. Please also view Appendix VIII, as it states the applicable standards per Vermont Act 250 that we will be following for our project, to ensure the highest quality of sustainability is reached.

5.0 CONCLUSIONS and RECOMMENDATIONS

5.1 Project Objectives

The below Figure, Figure 10, shows the stakeholders that we have identified for our project and the objectives that we believe that fall under each. We have strived in each aspect of our design process to meet the overall objectives of the project, and individually for our community partners and stakeholders.

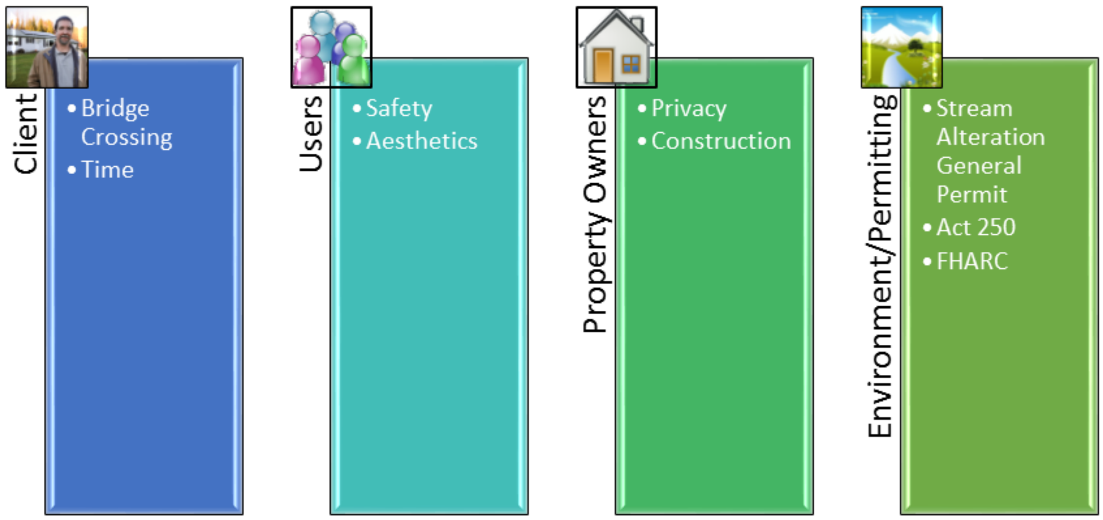

Figure 10: Stakeholders and Associated Objectives

5.2 Final Design

5.2.1 Alternative Chosen

Our team, after discussing our alternatives with professionals and the MRC, decided the alternative that was most fit for our site was the arched bridge. This alternative is ranked as number 1 because, as seen in Table 4, it has advantages that outweigh the disadvantages, and in the sustainability section of this report it was ranked the most sustainable in all categories. It also meets the clients expectations, which is important in our choosing of a design.

The arched bridge will meet the above objectives (Figure 8) for all four primary stakeholders. There is some uncertainty associated with this design, such as ground conditions and altering stream heights. River patterns present difficult to predict conditions during flash or severe flooding, even more so today with the changing climate. For the successful implementation of the bridge, the biggest constraint for the MRC is making sure all standards and permits are met.

Although a unique alternative that may be difficult to implement, we believe that the arched bridge is the best option as it meets both MRC’s and VT ANR’s regulations. This design does have considerable drawback. Because of the current site conditions this will be the option that needs the most cosmetic and foundational work done before we consider building.

This type of bridge will bring the natural aesthetic feel to the Manchester area that the committee is looking for. The current cost, outlined in Appendix 4, required for the implementation of the bridge is $126,000. It is important to note that our client has confirmed there is not yet a specific budget "constraint" on this project. The better aesthetic presentation of the bridge will generate a higher probability meeting the fundraising requirement.

5.2.2 Final Foundation Design

Due to the state of the current abutments, all new ones were designed in order to ensure maximum safety and serviceability. The abutments are to be designed with 4000 psi concrete, and will be shallow, spread footings approximately 3'x8'x2.5'. Details of this can be seen in the attached AutoCAD plans. Because of the project site being in the river corridor and floodplain, there is a no net fill requirement to be met, so for every cubic yard of fill we bring into the site, we have to remove the same. This was considered for the abutment design, we tried for similar sized abutments so that removing the old ones would meet the no requirement by replacing with the new ones. Detailed calculations for the abutment design can be seen in the attached calculations portion of this report.

Although, we believe from our subsurface exploration that bedrock is less than 5-ft below surface level, we have incorporated scour prevention methods to ensure the new abutments will not be as susceptible to scour as the old ones were. The scouring tactic will be to place about a 6-inch thick layer of ¾" crushed gravel at the bottom of the trench dug for each abutment. We believe our foundation design to be of the utmost quality in providing safety and serviceability to our bridge.

5.2.3 Final Structure Design

Eastern White Pine was the wood species chosen for the majority of this structure due to its wide availability, especially in the northeast. By the Northeastern Lumber Manufacturers Association research, this pale softwood is highly renewable due to its fast growth rate and has a low environmental footprint due to being locally grown and sustainably harvested. Naturally, it is resistant to common defects found among lumber, especially checks. It also experiences minimal shrinkage when properly treated compared to other species. The Wood Database says there are cases of reported allergies related to Eastern White Pine but when properly treated and glued, this can be prevented. For the structural stringer arches, 5x22 Glued Laminated (Glulam) Southern Pine beams were chosen. Glulam is necessary for this member due to its additional available bending and shear strength for the longer 66.5 foot span. Southern Pine was chosen for the species due the ease of calculations. For a more sustainable species choice, a professional, structural engineer should reevaluate this.

Eastern White Pine is easy to work with both by hand and on machine, per the Wood Database, which will make the fabrication of the 6x12 select structural beams easier and therefore more cost-effective. Load Factor Reduction Design (LRFD) was used for the design of both sized beams and idealized as straight, not curved members for the ease of calculations. The arch stringers were able to be idealized as straight since the length to depth ratio approximately 17 (greater than 10) which allows for curvature to be neglected by the Advanced Mechanics of Materials text (Boresi and Schmidt), Edition 6. While Allowable Stress Design (ASD) is typically more conservative and used in timber design, we are confident in our structure's strength and serviceability due our conservative mindset in choosing beam sizes and layouts. 60d nails were chosen to attach the deck to the 6x12 beams due to their high available shear strength, cost-effectiveness, and simple constructibility. For the 6x12 beam attachment to the

5x22 Glulam stringers, a more complex connection was designed. The connection is typically used for an end post beam but when inverted, becomes ideal for securing the 6x12 beams. It is important to note that while these connections suffice at 180 degrees, the 12 degree angle of the arched stringers may impose further stresses on the connection and should be thoroughly checked by a professional engineer. See Figures No. 11-15 in the AutoCAD section of this report for further details of this design.

5.2.3 Constructibility

In order to implement this bridge, we will need to look at getting equipment to the site. A mini-excavator will be used to strip excavate the area to clear for the foundation installation. A full construction plan can be seen in the attached AutoCAD files, labeled "Construction Details". We decided phasing would be the easiest way to go about the construction process, because it would be impossible to think a bridge could be built at the same time as a foundation is poured. Our process has four phases, and we predict it could take anywhere between 1 to 2 weeks to complete. We recommend for the safety and acceleration of the project that the members of the bridge be prefabricated.

In order to mitigate any risk, we will ensure careful watch over all construction processes that take place at the site, whether by professional engineer or contractor. It is important that all materials used are approved by the local standards, and more importantly, the ecological standards we will be following. The outcome of this project solely reflects our reputations to this committee so we believe our final design shows our dedication to the committee and wanting to help the growth of the Downtown Manchester area.

5.3 Project Operations and Maintenance Recommendations

Figure 11 shows the preliminary order of operations suggested for this project. This Figure includes both alternatives 1 and 2, and the steps needed to carry out both. These are both mentioned here, because there is a possibility the funds will not be available for the arched bridge, so we need to have a backup plan in place.

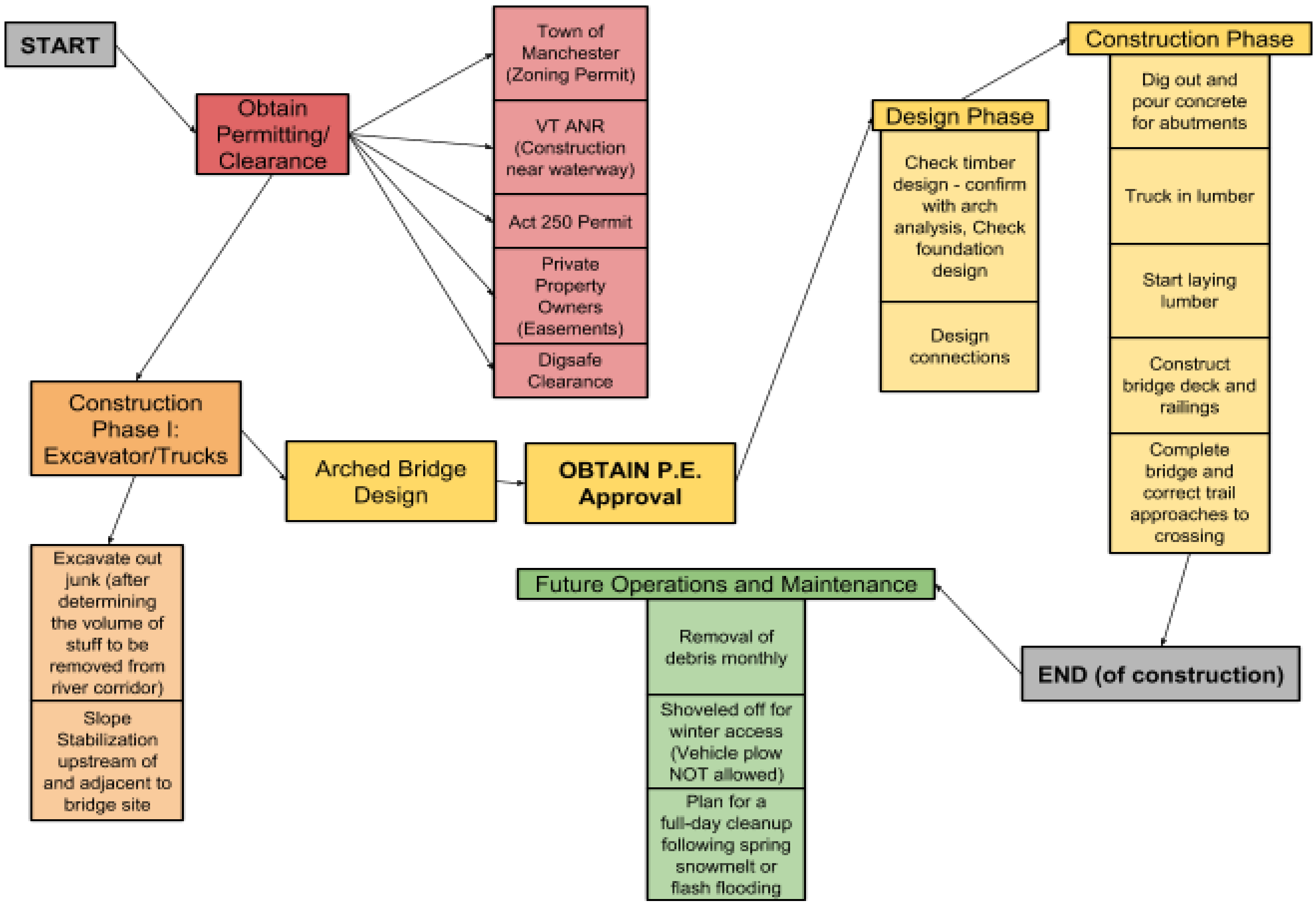

Figure 11: Future Project Operations

REFERENCES

"Chapter 710 - Site Data for Structures - Design Manual M 22-01 - 710.pdf." (n.d.). .

"Eastern White Pine, the Wood Database" (n.d.). <http://www.wood-database.com/eastern-white-pine/> (Mar. 28 2018)

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Manchester Riverwalk Pedestrian Bridge

Design Calculations

University of Vermont

Department of Civil and Environmental Engineering

Prepared for: Manchester Riverwalk Committee

Town of Manchester, VT

Bennington County

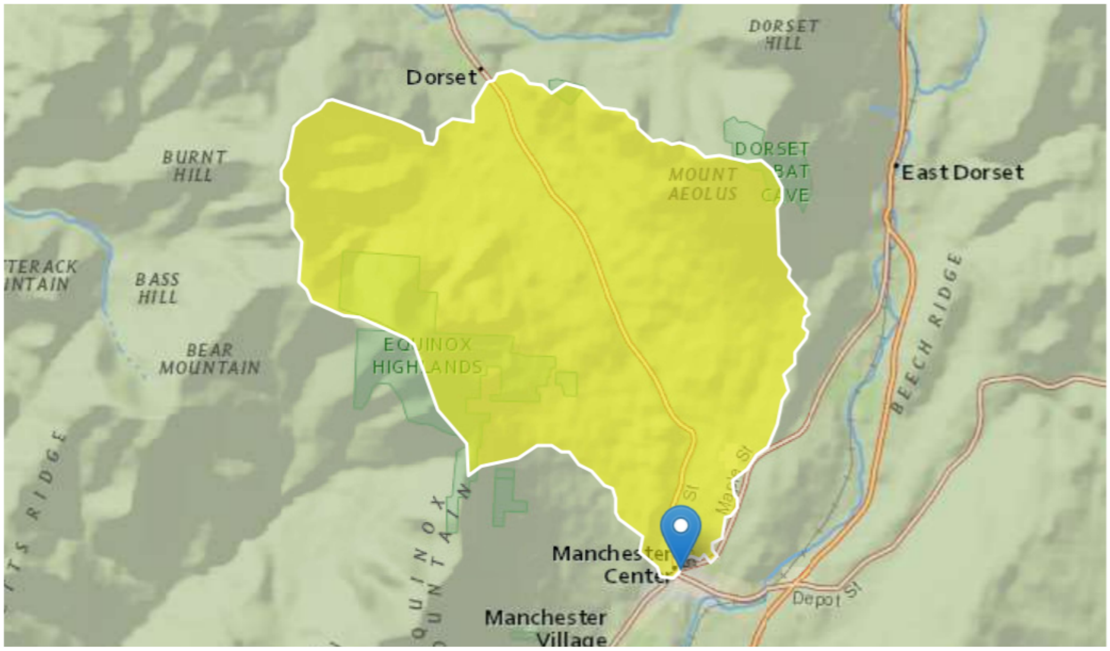
Hydraulic Analysis Calculations

Calculated by: SCR _______________

Calculated by: AJA _______________

Battenkill River Stats Report

Region ID: VT
Workspace ID: VT20171012174705411000
Clicked Point (Latitude, Longitude): 43.17652, -73.05599
Time: 2017-10-12 13:45:28 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	452833.4	
CENTROIDY	Basin centroid vertical (y) location in state plane units	80190.4	
DRNAREA	Area that drains to a point on a stream	18.5	square miles
EL1200	Percentage of basin at or above 1200 ft elevation	49.8	percent
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	53.5	inches
OUTLETY	Basin outlet vertical (y) location in state plane coordinates	75305	
OUTLETX	Basin outlet horizontal (x) location in state plane coordinates	454795	
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	1.51	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	5.4	percent
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	3.56	percent

Design Calculations

Peak-Flow Statistics Parameters [Statewide Peak Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	18.5	square miles	0.18	689
LC06STOR	Percent Storage from NLCD2006	3.56	percent	0	18.5
PRECPRIS10	Mean Annual Precip PRISM 1981 2010	53.5	inches	33.5	70.4

Peak-Flow Statistics Flow Report [Statewide Peak Flow]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
2 Year Peak Flood	681	ft^3/s	389	1190	34.8
5 Year Peak Flood	1070	ft^3/s	600	1900	36.1
10 Year Peak Flood	1370	ft^3/s	738	2530	38.6
25 Year Peak Flood	1810	ft^3/s	925	3530	42.5
50 Year Peak Flood	2180	ft^3/s	1080	4420	44.9
100 Year Peak Flood	2590	ft^3/s	1240	5410	47.3
200 Year Peak Flood	3040	ft^3/s	1380	6670	50.8
500 Year Peak Flood	3710	ft^3/s	1590	8650	55.2

Peak-Flow Statistics Citations

Olson, S.A.,2014, Estimation of flood discharges at selected annual exceedance probabilities for unregulated, rural streams in Vermont, with a section on Vermont regional skew regression, by Veilleux, A.G.: U.S. Geological Survey Scientific Investigations Report 2014–5078, 27 p. plus appendixes. (http://pubs.usgs.gov/sir/2014/5078/)

The above report is obtained from the U.S. Geological Survey and is used to approximate basin characteristics.

Design Calculations

Below, the U.S. Geological Survey Regression Equation Method was used to calculate more accurate flow values. These values were compared to the values that were created by StreamStats.

USGS Regression Equation Method — VERMONT AGENCY OF TRANSPORTATION

Town	Manchester, Vermont	Stream	W. Branch Batten Kill
Project Number		Tributary to	
Highway		Structure	
Name and Date		Checked By	
Weather		Date	

Reference: USGS, 2014. Estimation of Flood Discharges at Selected Annual Exceedance Probabilities for Unregulated, Rural Streams in Vermont. Scott A. Olson. Scientific Investigations Report 2014-5078. Reston, Virginia.
http://pubs.usgs.gov/sir/2014/5078/pdf/sir2014-5078.pdf

Applicability:
- The drainage area to the site is between 0.2 and 700 square miles (130 – 448,000 acres).
- Less than 20% of the drainage area to the site is covered by wetlands or open water.
- Average annual precipitation across the drainage area to the site is between 34 and 70 inches.

Variable	Units	Description
Q_P	cfs	The estimated flood discharge corresponding to the P% annual exceedance probability.
A	mi²	The drainage area of the basin. = 17.55 m²
w	%	The percentage of the drainage basin with land cover categorized as wetlands or open water. = 3.56 %
P	in	The basin-wide mean of the average annual precipitation. = 53.5 in
W	%	The percentage of the drainage basin with land cover categorized as wetlands or open water, plus 1.0%. 4.56 %

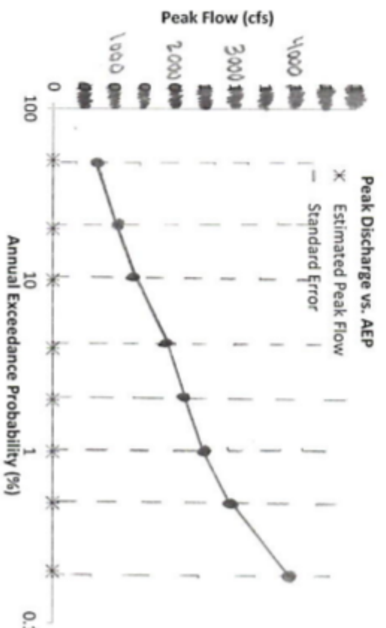
AEP (%)	Peak Discharge Functions
50%	$Q_{50} = 0.145\,A^{0.900}\,W^{-0.274}\,P^{1.569}$
20%	$Q_{20} = 0.179\,A^{0.884}\,W^{-0.277}\,P^{1.642}$
10%	$Q_{10} = 0.199\,A^{0.875}\,W^{-0.280}\,P^{1.685}$ – Design
4%	$Q_{4} = 0.219\,A^{0.866}\,W^{-0.286}\,P^{1.740}$
2%	$Q_{2} = 0.237\,A^{0.860}\,W^{-0.291}\,P^{1.774}$
1%	$Q_{1} = 0.251\,A^{0.854}\,W^{-0.297}\,P^{1.809}$
0.5%	$Q_{0.5} = 0.266\,A^{0.849}\,W^{-0.301}\,P^{1.840}$
0.2%	$Q_{0.2} = 0.289\,A^{0.844}\,W^{-0.309}\,P^{1.876}$

Variable	Units	Value
A	mi²	0.0
W	%	1.0
P	in	0.0

Results

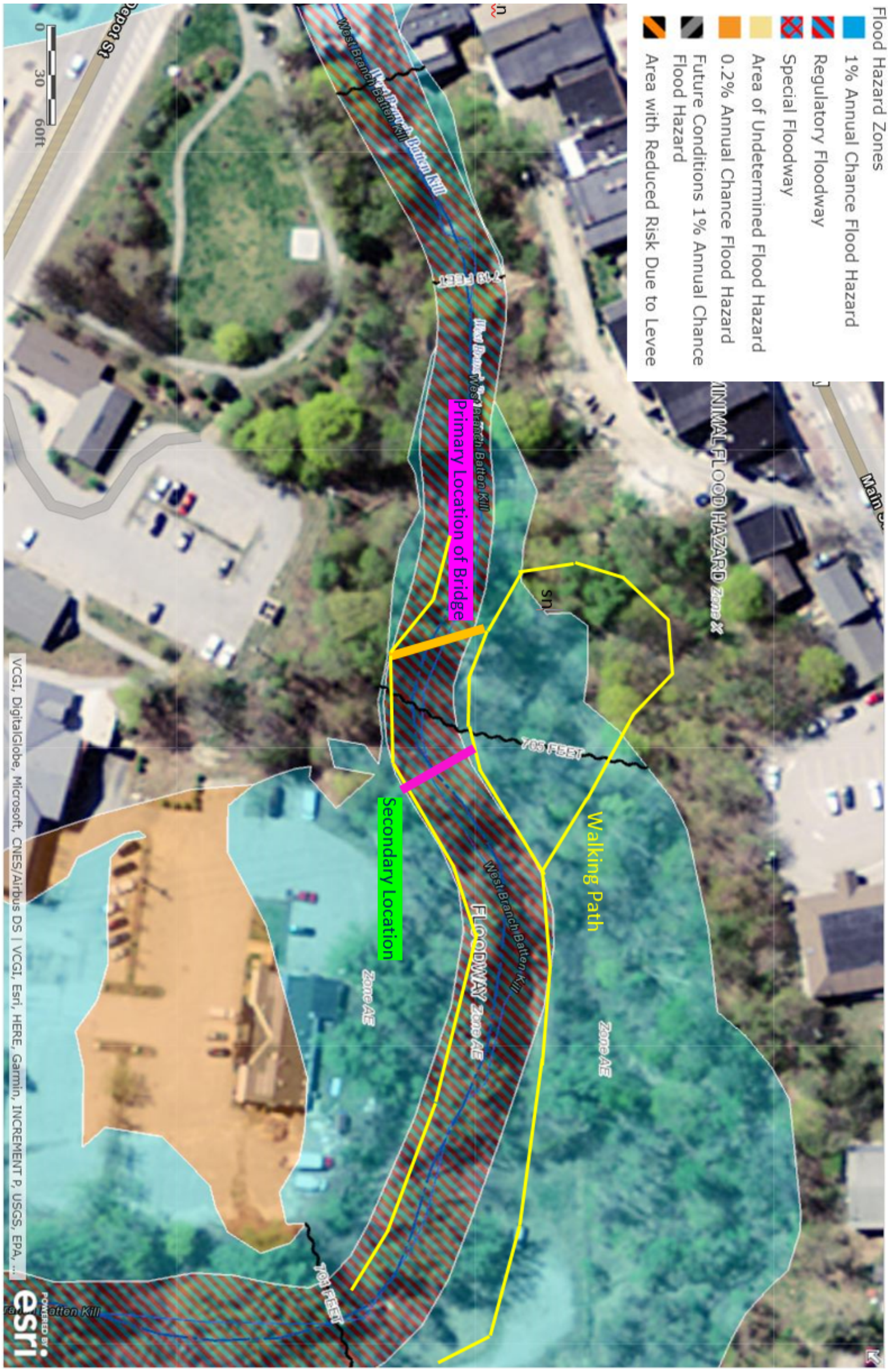
AEP (%)		Q_P
50	Q_2 =	687.5
20	Q_5 =	1070.3
10	Q_{10} =	1369.1
4	Q_{25} =	1810.2
2	Q_{50} =	2187.1
1	Q_{100} =	2547.5
0.5	Q_{200} =	3044.6
0.2	Q_{500} =	3716.7

Note: Round results to two significant figures for use in hydraulic design



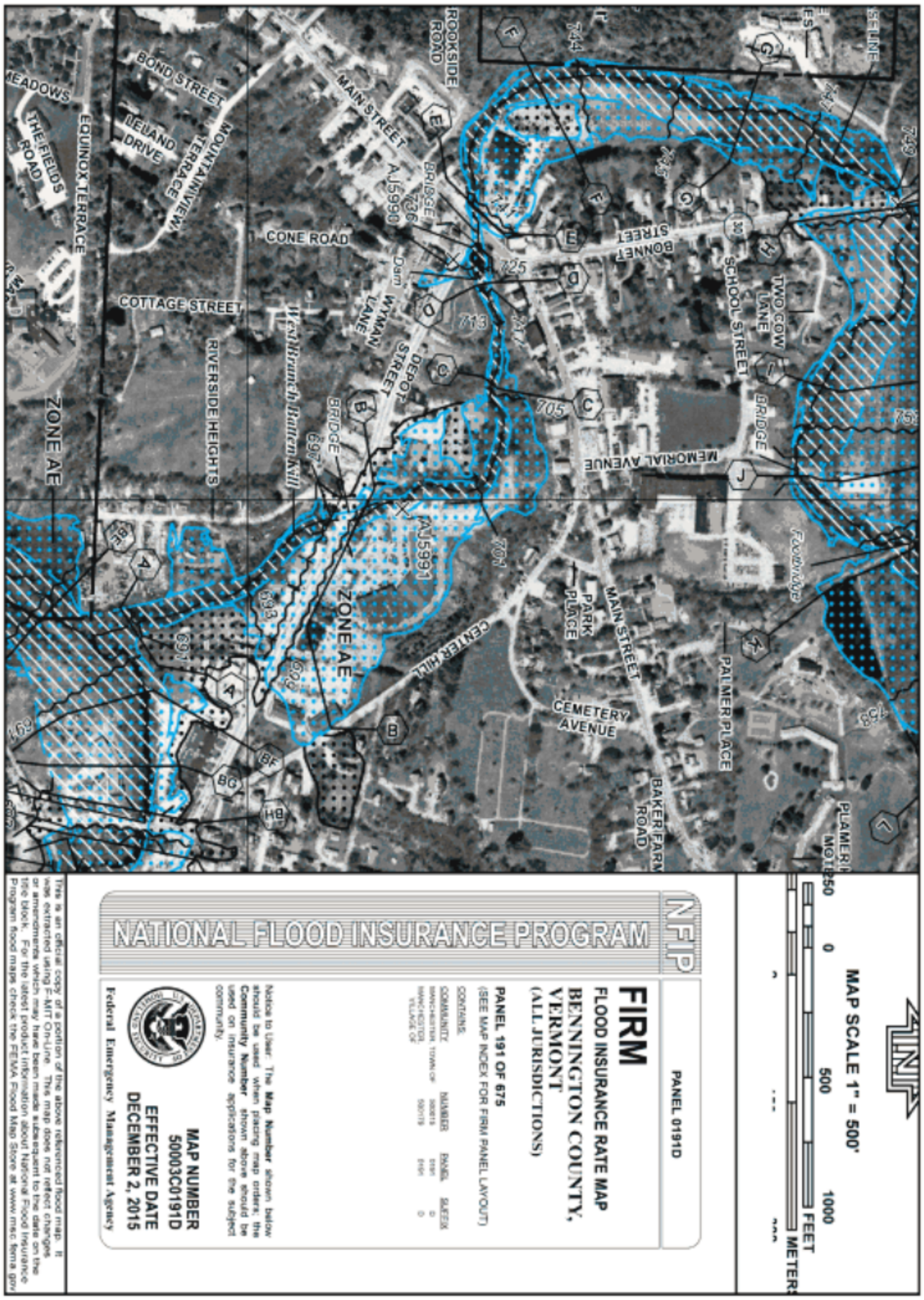
Design Calculations

The following image is obtained from the Federal Emergency Management Agency (FEMA) and it maps the flood hazard areas surround the bridge site.

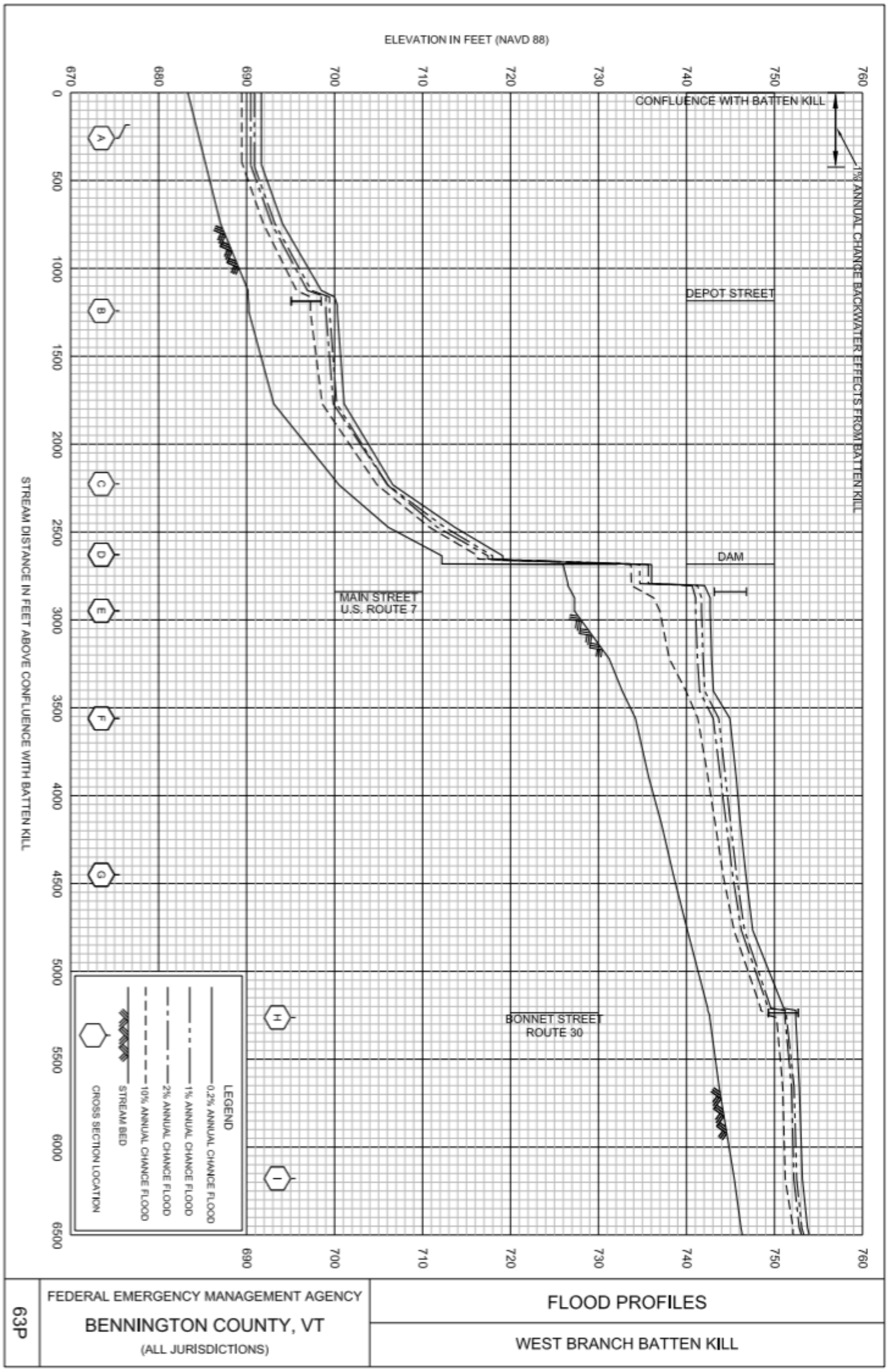


Design Calculations

Below, is also obtained from FEMA and represents the zones which are prone to flooding.



Design Calculations



The above image is the flood profile for the W. Branch of the Battenkill. It is used to estimate the water level of the river after different storm events. The following table is the data that was inputted into the above chart.

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
WARM BROOK								
U	27,733[1]	79	166	2.0	776.0	776.0	776.8	0.8
V	28,702[1]	77	156	2.1	778.8	778.8	779.3	0.5
W	29,767[1]	75	124	2.7	781.3	781.3	782.2	0.9
WEST BRANCH BATTEN KILL								
A	181[2]	127	510	4.8	690.9	689.2[3]	689.2	0.0
B	1,245[2]	100	356	6.8	699.4	699.4	700.0	0.6
C	2,229[2]	45	210	11.6	706.0	706.0	706.4	0.4
D	2,633[2]	51	213	11.4	717.9	717.9	718.0	0.1
E	2,948[2]	42	480	5.1	741.7	741.7	741.8	0.1
F	3,558[2]	120	770	3.2	743.6	743.6	744.4	0.8
G	4,448[2]	200	904	2.7	745.7	745.7	746.1	0.4
H	5,260[2]	277	789	3.0	751.4	751.4	752.2	0.8
I	6,179[2]	265	1,004	2.4	752.5	752.5	753.3	0.8
J	6,565[2]	135	567	4.5	755.4	755.4	756.0	0.6
K	7,161[2]	156	965	2.5	757.3	757.3	757.9	0.6
L	7,944[2]	204	872	2.7	757.9	757.9	758.9	1.0
M	8,766[2]	206	768	3.1	760.1	760.1	761.0	0.9

[1]Feet above confluence with Roaring Brook

[2]Feet above confluence with Batten Kill

[3]Elevations computed without consideration of backwater effects from Batten Kill

TABLE 7

FEDERAL EMERGENCY MANAGEMENT AGENCY

BENNINGTON COUNTY, VT

ALL JURISDICTIONS

FLOODWAY DATA

WARM BROOK – WEST BRANCH BATTEN KILL

Design Calculations

The below sheet is the field data sheet that was used to gather data at the site.

Hydraulics Field Worksheet Vermont Agency Of Transportation One National Life Drive, Davis Building Montpelier, VT 05633-5001		Town:	Manchester	Landmark:	
		Highway:	—	Date:	10/25/17
		Structure:	Riverwalk	Weather:	Sunny
		Stream:	W. Branch Battenkill	Project No:	
Type of Structure:	Abutments only	**Upstream**		Stream Type:	Perennial / Intermittent
hydraulic Clear Span:	⊥ to flow 44' 10"	Flood Plains:		Flow Class:	Subcritical / Supercritical
Clear Height:	4.5'	Land Use:		Sinuosity:	Straight / Sinuous / Meandering
Invert Condition:	—	Slope:		Bed Material	Cl / Si / Sa / Gr / Co / Bo
No. of Spans:	1	BFW:	32'-33'	Material Shape:	Rounded / Fractured
Abutment Type:	Marble	BFD:	2'	Mannings:	0.03 - 0.035
Superstructure Depth:	—	CBW:	27'-29'	Ponding:	—
Length of Pipe:	—	**Downstream**		Debris:	manmade / wood
Skew:	~ 30°	Flood Plains:	yes, Riverleft parking lot	Channel Erosion:	incised - little
Width of Road:	—	Land Use:	community commercial	OLW:	0.6'
Vertical Alignment:	Sag / Crest / Level / Sloped	Slope:	1-2% / 4%	OHW:	~2'
Super Elevated:	Inlet / Normal Crown / Outlet	BFW:	21-24'	Tributary To:	
Stone Fill:	None right now	BFD:	2-4'	ANR BFW:	
Scour:	2-4" Abut. 2	CBW:	14-18'	ANR BFD:	
U/S Structure	VHB Structure				
Town / TH No:	Manchester	Bridge No:		Distance:	~300'
Clear Span:		Clear Height:		Waterway Area:	
D/S Structure	N/A				
Town / Bridge No:	—	Roadway No:	—	Distance:	—
Clear Span:	—	Clear Height:	—	Waterway Area:	—

Notes: Abutment span 43'6" - BW Surface elevation : 0.75'
CBW @ Bridge = 31'10"

Upstream Notes:	Rod open:	Downstream Notes:	Rod open:
Collapsing Slope ~200' above falling trees & concrete in River class I rapid ~50' above		Small change in elevation ~25' below	

Inlet/Upstream Cross Section:	WWA:	Outlet/Downstream Cross Section:	WWA:
Configuration: Projecting / Mitered / Square		Configuration: Projecting / Mitered / Square	
Headwall:	Wingwalls:	Headwall:	Wingwalls:
Streambed to Road:	Cover:	Streambed to Road:	Cover:
Invert to Road:	Vertical Drop:	Invert to Road:	Vertical Drop:
WSE to Invert:	Headwater:	WSE to Invert:	Tailwater:

*NOTE: plan view and additional notes on the reverse side

Design Calculations

Stream Data Collected at Location of the Existing Abutments

Cross section at abutments			
Span width (ft)	**Pole height (ft)**	**Corrected height (ft)**	**Terrain**
0	6.9	3.7	Land
3	7.9	-1.8	Land
6	9.3	-3.2	Land
9	9.8	-3.7	Land
12	10.1	-4.0	Stream
15	10.8	-4.7	Stream
18	10.6	-4.5	Stream
21	10.7	-4.6	Stream
24	10.7	-4.6	Stream
27	10.6	-4.5	Stream
30	10.3	-4.2	Stream
33	10.2	-4.1	Stream
36	10.4	-4.3	Stream
39	10.7	-4.6	Stream
42	8.4	-2.3	Stream
45	8.6	-2.5	Land
48	7.2	-1.1	Land
51	5.5	0.6	Land
54	4.8	1.3	Land

Design Calculations

Stream Data Collected ~100 ft below the Abutments

Cross section of Downstream			
Span Width (ft)	**Pole height (ft)**	**Corrected height (ft)**	**Terrain**
0	3.7	2.4	Land
14	4.5	1.6	Land
19	5.9	0.2	Land
22	6.3	-0.2	Stream
26	6.8	-0.7	Stream
29	7.0	-0.9	Stream
33	7.3	-1.2	Stream
35	7.6	-1.5	Stream
38	6.4	-0.3	Land
42	5.1	1.0	Land
45	4.5	1.6	Land
57	3.9	2.2	Path
65	1.6	4.5	Land
83	2.2	3.9	Edge Parking Lot
95	5.6	0.5	Parking Lot

Collected Data for Bankfull Width, Bankfull Depth, Channel Bank Width

Upstream 1 Data		Downstream 1 Data		Downstream 2 Data	
BFW	32-33'	BFW	23-24'	BFW	21-23'
BFD	2-3'	BFD	2-4'	BFD	2-3'
CBW	27-29'	CBW	14-16'	CBW	17-18'

Calculated Slopes at Three Points surrounding the Existing Abutment Location

Slope			
	Length	**Elev. Change**	**%**
Abutments (A)	50'	0.5'	1.0
Abutments (B)	100'	1.3'	1.3
Downstream (C)	95'	4.3'	4.5

Design Calculations

The above data that was collected on-site, which was then inputted into the program HEC-RAS, which is shown below.

```
                              HECRAS Report

                  HEC-RAS HEC-RAS 5.0.3 September 2016
                    U.S. Army Corps of Engineers
                   Hydrologic Engineering Center
                         609 Second Street
                         Davis, California

 X     X  XXXXXX   XXXX        XXXX      XX      XXXX
 X     X  X       X    X       X   X    X  X    X
 X     X  X       X            X   X   X    X   X
 XXXXXXX  XXXX    X      XXX   XXXX    XXXXXX    XXXX
 X     X  X       X            X  X    X    X        X
 X     X  X       X    X       X   X   X    X        X
 X     X  XXXXXX   XXXX        X    X  X    X   XXXXX


     PROJECT DATA
     Project Title: Battenkill model
     Project File : Battenkillmodel.prj
     Run Date and Time: 2/20/2018 1:41:42 PM

     Project in English units
```

```
FLOW DATA

Flow Title: 10-year flow
Flow File : C:\Users\Shaun\OneDrive\CE 185\Battenkillmodel.f01

Flow Data (cfs)

  River           Reach           RS                    PF 1
  Battenkill      West Branch     2                     1370


Boundary Conditions


  River           Reach           Profile                     Upstream
    Downstream


  Battenkill      West Branch     PF 1                     Normal S = 0.013
  Normal S = 0.03
```

Cross-section data downstream of the site

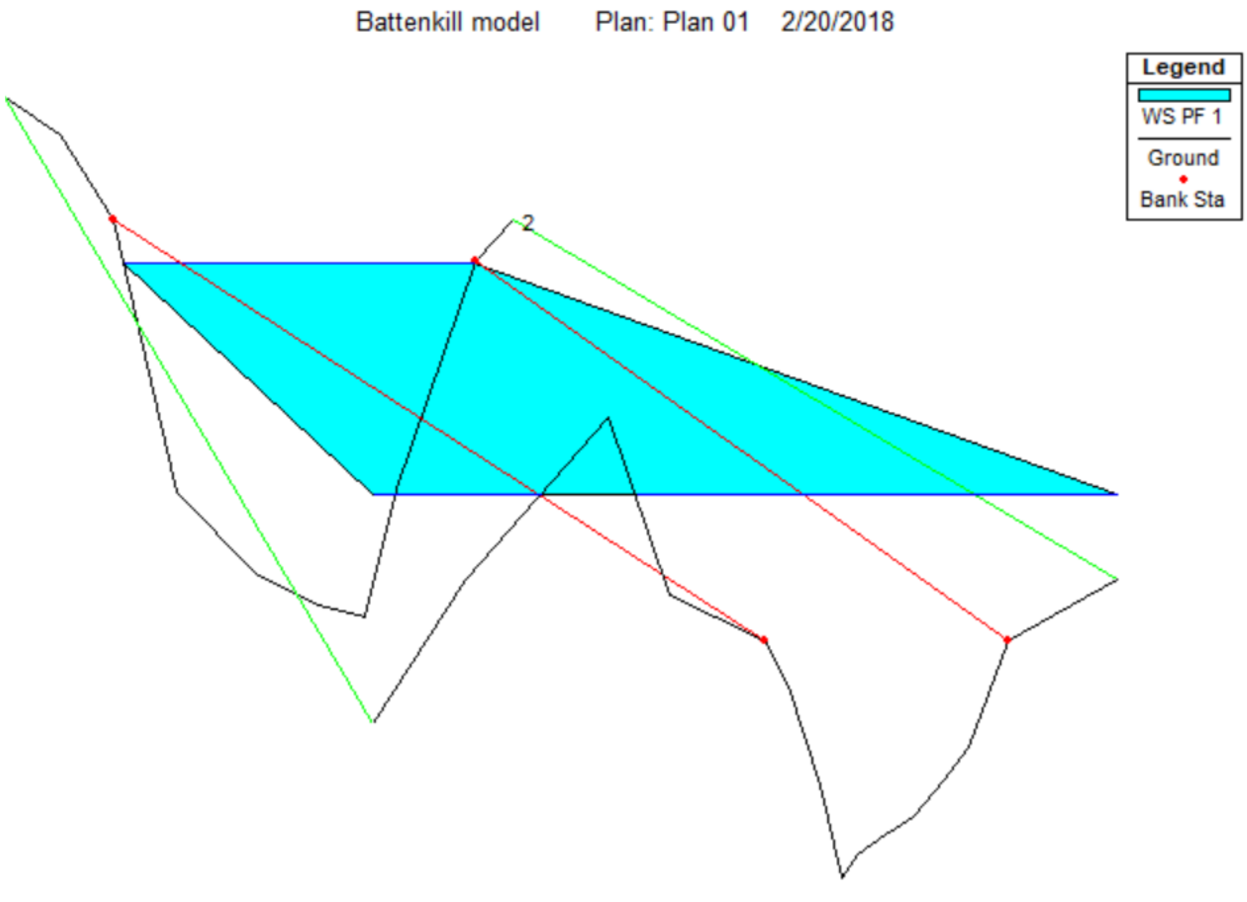
```
CROSS SECTION OUTPUT  Profile #PF 1


  E.G. Elev (ft)            707.47    Element                  Left OB    Channel
Right OB
  Vel Head (ft)               1.56    Wt. n-Val.                           0.030

  W.S. Elev (ft)            705.92    Reach Len. (ft)          100.00     100.00
 100.00
  Crit W.S. (ft)            705.92    Flow Area (sq ft)                   136.94

  E.G. Slope (ft/ft)      0.009571    Area (sq ft)                        136.94

  Q Total (cfs)            1370.00    Flow (cfs)                         1370.00

  Top Width (ft)             44.69    Top Width (ft)                       44.69

  Vel Total (ft/s)           10.00    Avg. Vel. (ft/s)                     10.00

  Max Chl Dpth (ft)           4.64    Hydr. Depth (ft)                      3.06

  Conv. Total (cfs)        14003.5    Conv. (cfs)                        14003.5

  Length Wtd. (ft)          100.00    Wetted Per. (ft)                     46.16

  Min Ch El (ft)            701.28    Shear (lb/sq ft)                      1.77

  Alpha                       1.00    Stream Power (lb/ft s)               17.73

  Frctn Loss (ft)             0.80    Cum Volume (acre-ft)       0.02       0.29
   0.06
  C & E Loss (ft)             0.12    Cum SA (acres)             0.02       0.09
   0.04
```

Cross-section data at the site

E.G. Elev (ft)	704.03	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.15	Wt. n-Val.	0.035	0.030	0.035
W.S. Elev (ft)	702.87	Reach Len. (ft)			
Crit W.S. (ft)	702.87	Flow Area (sq ft)	20.92	112.32	51.71
E.G. Slope (ft/ft)	0.006841	Area (sq ft)	20.92	112.32	51.71
Q Total (cfs)	1370.00	Flow (cfs)	91.23	1067.57	211.21
Top Width (ft)	82.88	Top Width (ft)	14.00	31.00	37.88
Vel Total (ft/s)	7.41	Avg. Vel. (ft/s)	4.36	9.50	4.08
Max Chl Dpth (ft)	4.99	Hydr. Depth (ft)	1.49	3.62	1.37
Conv. Total (cfs)	16563.8	Conv. (cfs)	1103.0	12907.2	2553.6
Length Wtd. (ft)		Wetted Per. (ft)	15.12	31.79	41.29
Min Ch El (ft)	697.88	Shear (lb/sq ft)	0.59	1.51	0.53
Alpha	1.35	Stream Power (lb/ft s)	2.58	14.34	2.18
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

Design Calculations

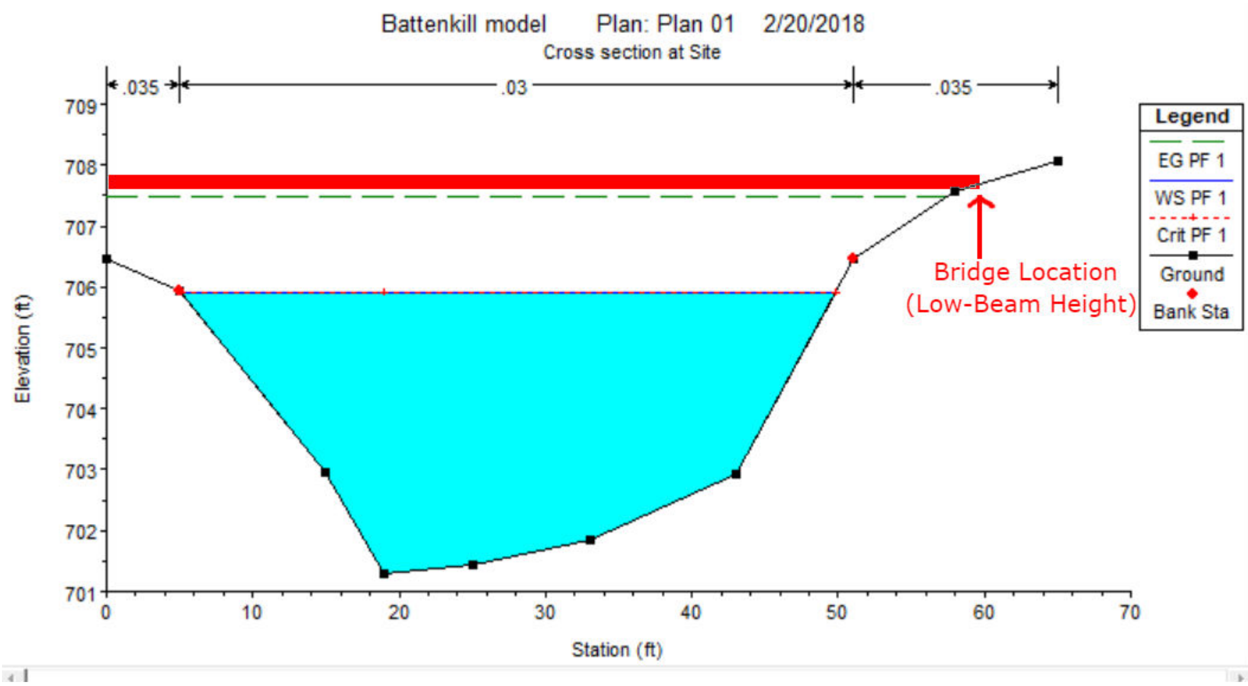
3D view of the cross-sections, looking upstream towards the site

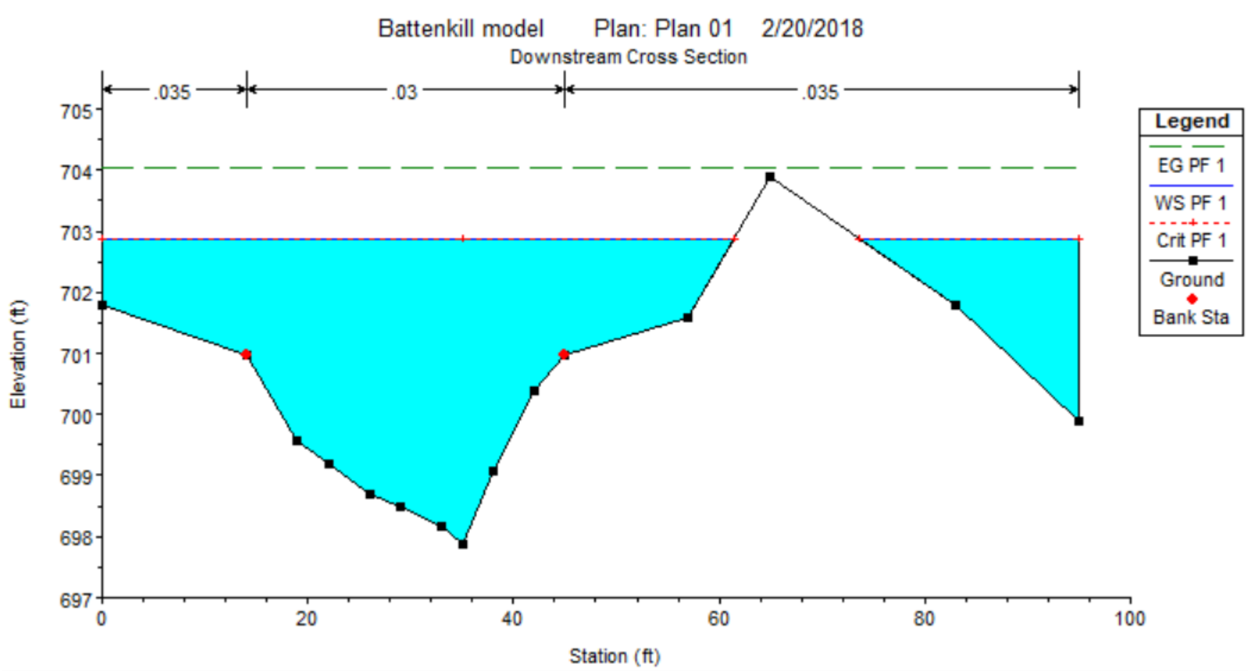


The above image is a three-dimensional model of the Battenkill River between the site of the bridge and 100 feet downstream. The model demonstrates the water elevation in relation to the river cross-sections after a 10-year storm event. The model shows that some of the banks along the river will be overtopped by this storm event, causing water to enter the floodplain.

Design Calculations

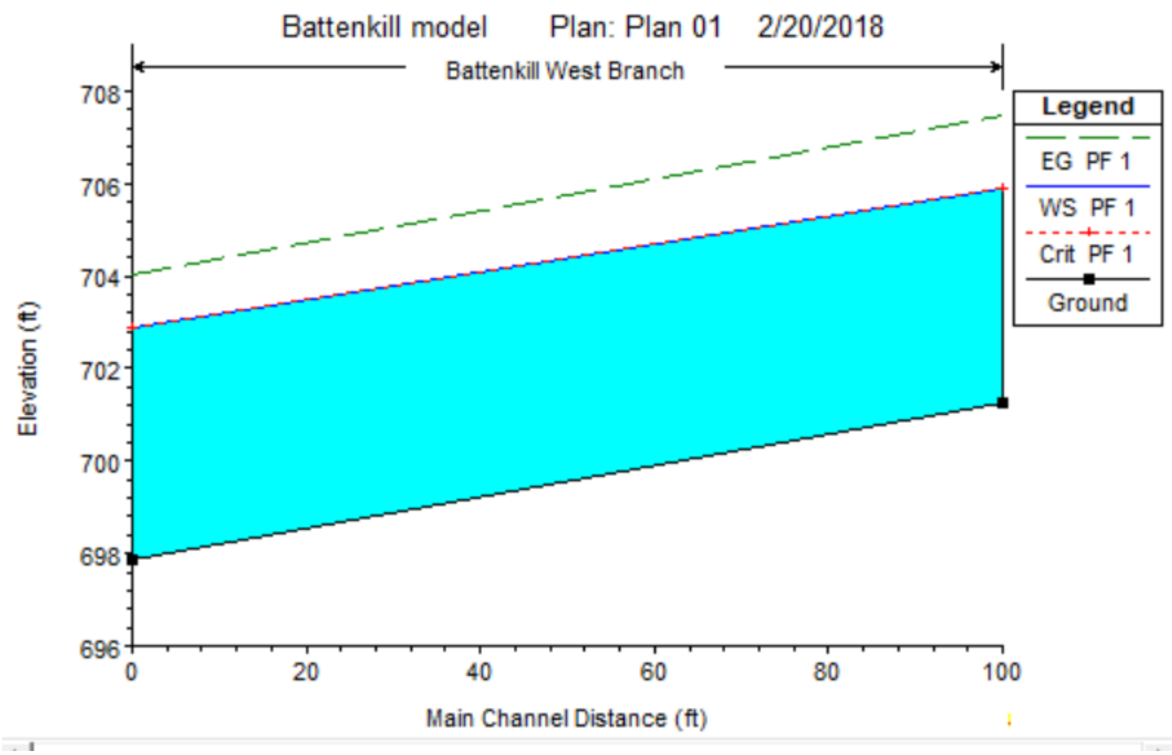
The below image is the cross-section of the riverbed at the location of the bridge. The low-beam height of the bridge is shown by the red line. The blue section represents the depth of water from a 10-year storm event.





Design Calculations

Profile view of the water level at the site

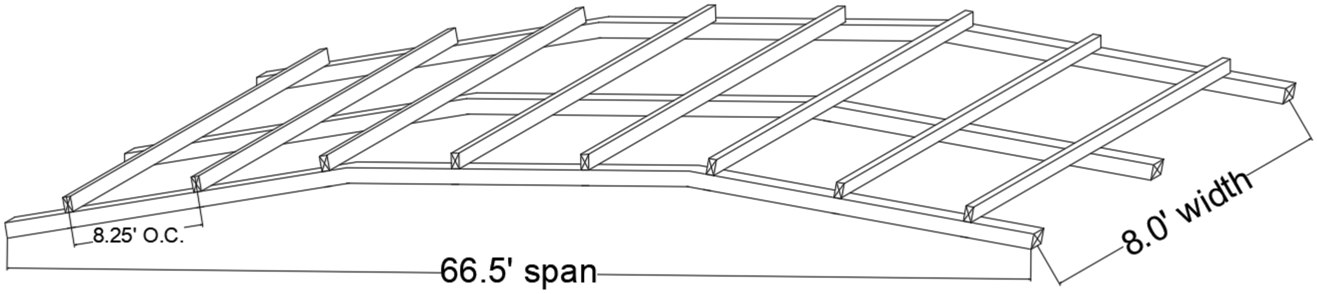


Timber Structure Design Calculations

Calculated by: AKA ____________________
Checked by: KMF ______________________

Design Calculations

BRIDGE STRUCTURAL LAYOUT



- 3 Curved Southern Pine Glulam Stringers to span 66.5 feet each
- 8 Sawn Lumber Beams to span 8 feet each
- Lumber decking to be attached to Beams

ASSUMPTIONS

- All beams/stringers are simply supported
- Loading on beams acts directly perpendicular to x-x axis, thus bending is only about the strong axis
- Each curved glulam beam is to span the entire 66.5' distance, therefore, bracing will be needed for appropriate serviceability conditions (minimize deflection.)
- All given dead and live loads are given from the Vermont Transportation Agency Structure Design Manual
- Southern Pine was the assumed species for the stringers due to lack of availability of information regarding the design of glulam eastern timber species. For a more sustainable design, refer to glulam design of local timber species.
- LRFD was the method chosen for design. While ASD is more conservative, the industry is using LRFD more for economical design alternatives. We are confident that the LRFD method presents a solution that gives an economic beam size while providing sufficient strength and serviceability conditions.
- From the Advanced Mechanics of Materials text (Boresi and Schmidt), Edition 6, a curved beam may be treated as a straight beam such that the ratio of length to depth is greater than 10 (page 165). Since our ratio of length to depth is approximately 17, we may treat the curved glulam stringers as straight beams.

$$\boldsymbol{Length\ to\ depth\ ratio} = \frac{66.5\ feet}{3.9\ feet} = 17.05 > 10$$

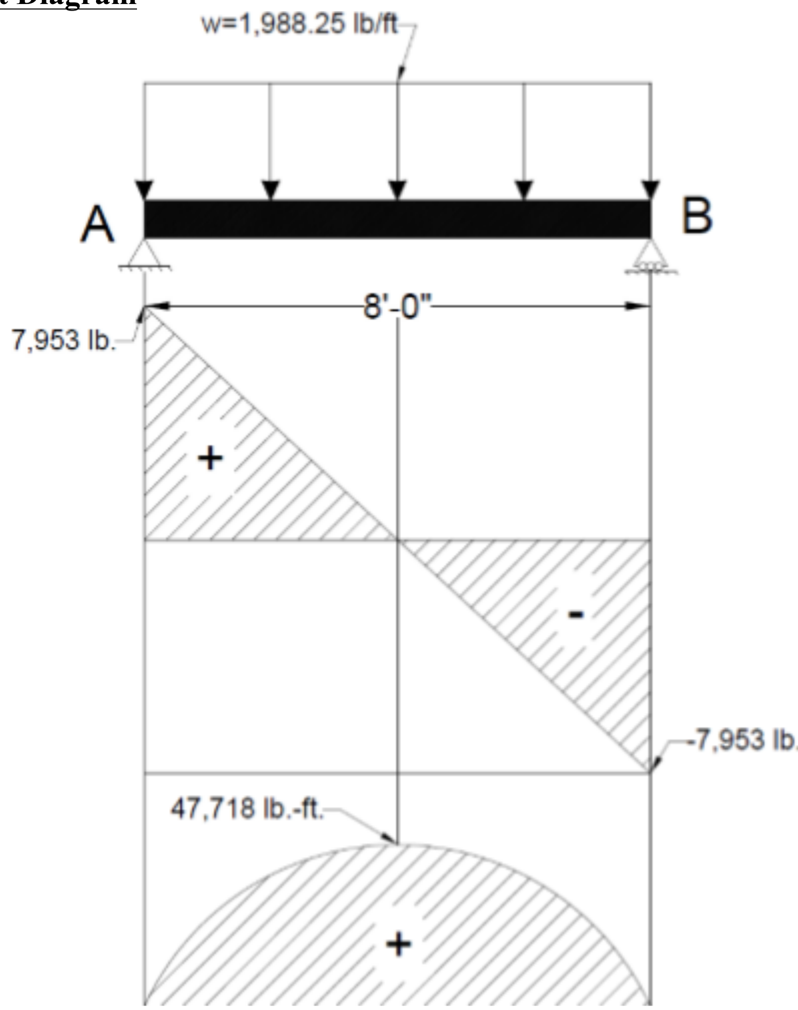
Design Calculations

DESIGN OF BEAMS TO SUPPORT DECK
<u>Loads and Known Dimensions</u>
Pedestrian Live Load = 90 psf
Bridge Dead Load = 60 psf
Snow Load = 50 psf
Span of Pedestrian Bridge = 66 ft (curved = 67 ft)
b = member spacing = 8.25 ft
l = length (width of bridge) = 8 ft
Stress grade and species: Select Structural Eastern White Pine

LRFD Load Combination:
w = 1.2D + 1.6L +0.5S
D = 60 psf (b) = 495 lb/ft
L = 90 psf (b) = 742.5 lb/ft
S = 50 psf (b) = 412.5 lb/ft

w = 1988.25 lb/ft

<u>Shear-Moment Diagram</u>



Design Calculations

Reactions

$$R_{yA} = 7{,}953\ lb.$$

$$R_{yB} = 7{,}953\ lb.$$

$$R_{xA} = 0\ lb.$$

LRFD Adjustment Factors

$C_M = wet\ service\ factor = 1.0$ (Moisture content (MC) < 19%)

$C_t = temperature\ factor = 1.0$

$C_L = beam\ stability\ factor = 1.0$ (Assuming fully braced)

$C_{fu} = flat\ use\ factor = 1.0$ (Assuming no members loaded on weak axis)

$C_F = size\ factor = 1.1$ (For lumber 4" thick and 8" or wider)

Incising factor (assuming readily accepts preservative treatments)	E, E_{min}	F_b, F_t, F_c, F_v	$F_{c\perp}$
C_i	0.95	0.80	1.00

$C_r = repetitive\ member\ factor = 1.0$ (Non-repetitive member)

Factor	F_b	F_t	F_v	F_c	$F_{c\perp}$	E_{min}
K_f	2.54	2.70	2.88	2.40	1.67	1.76
ϕ	0.85	0.80	0.75	0.90	0.90	0.85

$\lambda = 0.80$ (LRFD Load Combination)

Reference Design Values for Select Structural – Eastern White Pine

(Table 4B – NDS Supplement)

$$F_b = 1{,}250\ psi$$
$$F_v = 135\ psi$$
$$F_t = 575\ psi$$
$$F_{c\perp} = 350\ psi$$
$$F_c = 1200\ psi$$
$$E = 1{,}200{,}000\ psi$$

Adjusted Design Values

$$F_b' = 1{,}250\ psi\ \left(C_M C_t C_L C_F C_{fu} C_i C_r K_f \phi\lambda\right) = 1{,}250(1.10 * 0.80 * 2.54 * 0.85 * 0.80)$$
$$= 1899.92\ psi$$

$$F_v' = 140\ psi\ \left(C_M C_t C_i K_f \phi\lambda\right) = 135(0.80 * 2.88 * 0.75 * 0.80) = 186.624\ psi$$

$$F_t' = 575\ psi\ \left(C_M C_t C_F C_i K_f \phi\lambda\right) = 575(1.1 * 0.80 * 2.70 * 0.80 * 0.80) = 1092.96\ psi$$

$$F_{c\perp}' = 350\ psi(1.67 * 0.90) = 526.05\ psi$$

$$F_c' = 1200\ psi(1.1 * 0.80) = 1056\ psi$$

$$E' = 1{,}200{,}000\ psi\ (C_M C_t C_i) = 1{,}200{,}000(0.90) = 1140000\ psi$$

Design Calculations

Size Category

$$M = \frac{wl^2}{8} = \frac{\left(1988.25\frac{lb}{ft}\right)(8\,ft)^2}{8} = 190872\ in - lb$$

$$Required\ S = \frac{M}{F_b'} = \frac{(190872\ in - lb)}{(1899.92\ psi)} = 100.46\ in^3$$

(Table 1B – NDS Supplement)

$$\boxed{Choose\ 6x12\ Beam\ (8\ @\ 8.25'O.C.)}$$

with $S = 121.2\ in^3,\ A = 63.25\ in^2, I = 697.1\ in^4$

Allowable Deflections

$$\Delta_{allow\ (live\ laod)} = \frac{l}{360} = \frac{8ft * \left(\frac{12in}{ft}\right)}{360} = 0.26\ in$$

$$\Delta_{allow\ (total\ load)} = \frac{l}{240} = \frac{8ft * \left(\frac{12in}{ft}\right)}{240} = 0.40\ in$$

Actual Stresses & Deflection

$$f_b = \frac{M}{S} = \frac{197872\ in - lb}{121.2\ in^3} = 1574.85\ psi$$

$$V = \frac{wl}{2} = \frac{1988.25 * 8}{2} = 7953\ lb$$

$$f_v = \left(\frac{3}{2}\right)\left(\frac{V}{A}\right) = \left(\frac{3}{2}\right)\left(\frac{7953\ lb}{63.25\ in^2}\right) = 188.61\ psi$$

Reduced Shear (V')

$$V' = V - \left(\frac{wd}{12}\right) = 7953lb - \frac{(1988.25\frac{lb}{ft} * \left(12in * \left(\frac{1ft}{12in}\right)\right)}{12} = 7787.31\ lb$$

$$f'_v = \left(\frac{3}{2}\right)\left(\frac{V'}{A}\right) = \left(\frac{3}{2}\right)\left(\frac{7787{,}31lb}{63.25in^2}\right) = 184.68\ psi$$

Design Calculations

$$\Delta_{max,live\ load} = \frac{-5wl^4}{384EI} = \left(-\frac{5\left(1188\frac{lb}{ft} * \frac{1ft}{12in}\right)\left(8ft * \frac{12in}{1ft}\right)}{384 * 1{,}200{,}000 * 697.1in^4} \right) = -0.1378\ in$$

$$\Delta_{max,total\ load} = \frac{-5wl^4}{384EI} = \left(-\frac{5\left(1988.25\frac{lb}{ft} * \frac{1ft}{12in}\right)\left(8ft * \frac{12in}{1ft}\right)}{384 * 1{,}200{,}000 * 697.1in^4} \right) = -0.2478\ in$$

<u>Check</u>

Bending

$$F_b' > f_b$$

$1899.92\ psi > 1575.85\ psi$ ☑ O.K.

Shear

$$F_v' > f'_v$$

$186.624\ psi > 184.68\ psi$☑ O.K.

Deflection

Live Load

$$\frac{l}{360} \geq \Delta_{max,live\ load}$$

$0.26\ in \geq 0.1378\ in$ ☑ O.K.

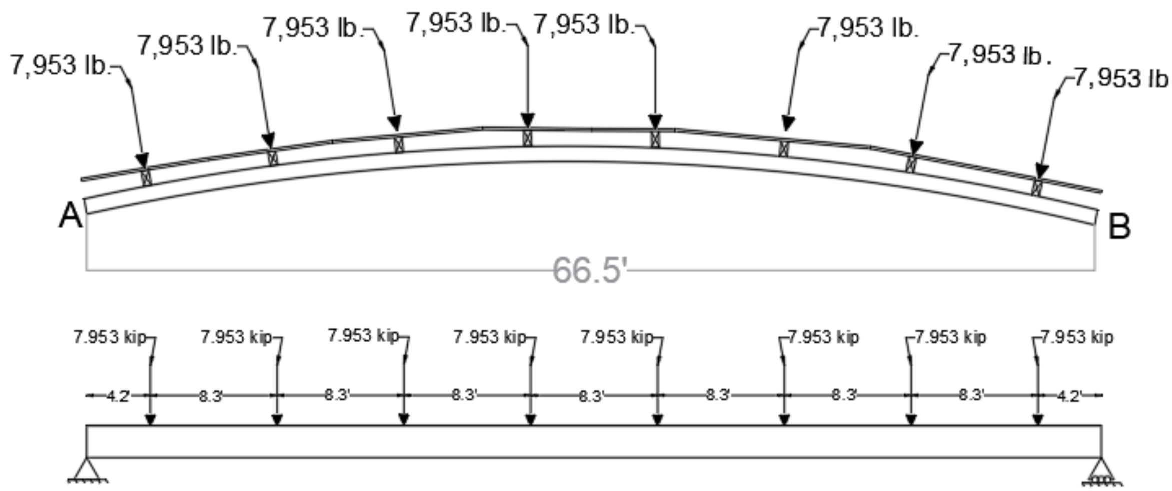
Total Load

$$\frac{l}{240} \geq \Delta_{max,total\ load}$$

$0.40\ in \geq 0.2478\ in$ ☑ O.K.

Design Calculations

DESIGN OF STRINGERS
(3 parallel arches (*side view below*), each with 8 point loads of 7.953 kip. Since the depth to width ratio is greater than 10, this curved beam can be idealized as a simply-supported, straight beam.



Loads and Known Dimensions
6x12 Eastern White Pine Structural Beam (Quantity: 8) = 7.953 kip (each)
Span of Pedestrian Bridge = 66 ft.
b = member spacing = 2.67 ft.
Stress grade and species: Southern Pine Glulam

Reactions
(Simply Supported Beam)

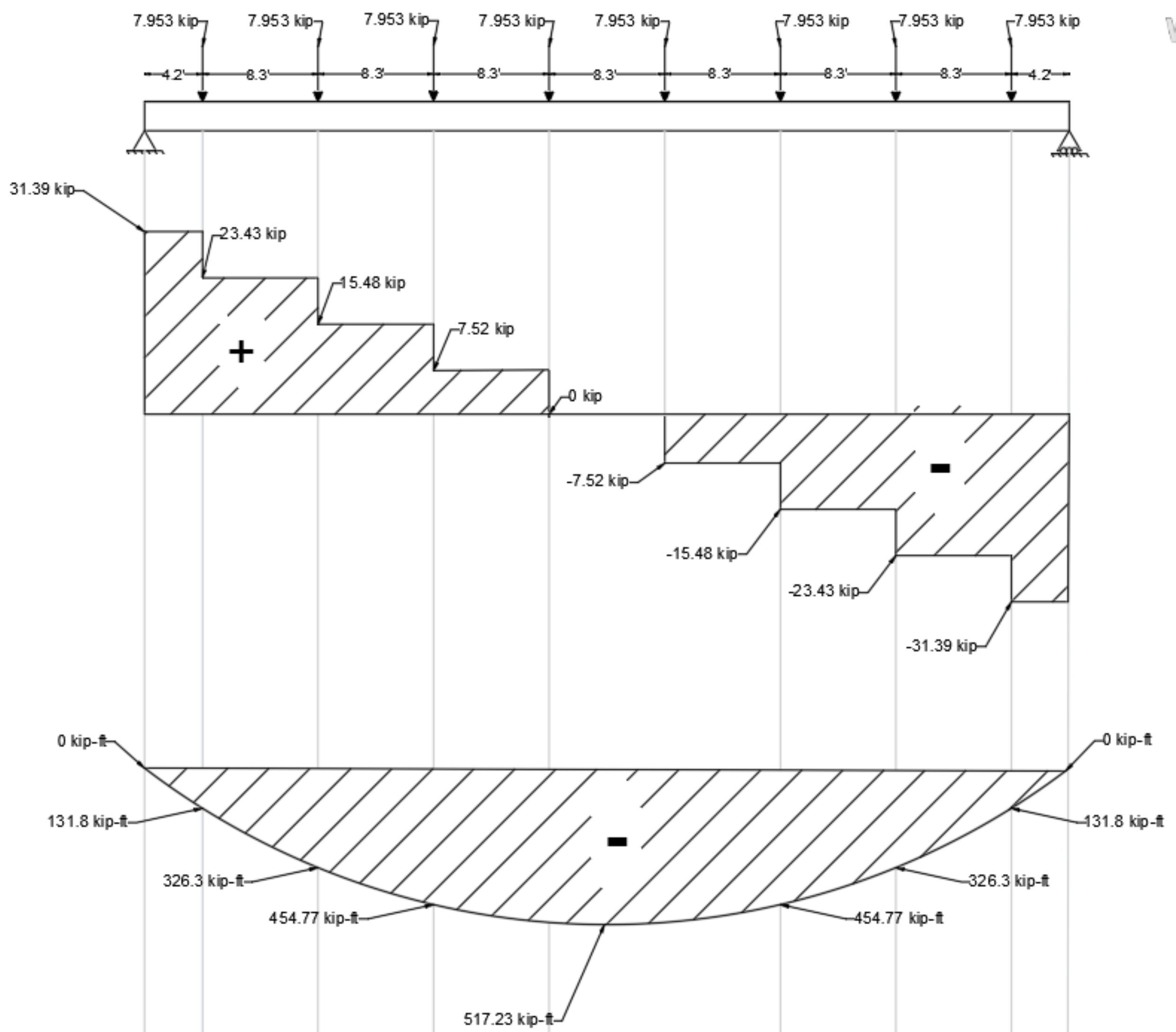
$$R_{yA} = R_{yB} = 31.39\ kip$$

Allowable Deflections
Note: live load deflection not calculated because only dead load supported by stringer

$$\Delta_{allow,total\ load} = \frac{l}{240} = \frac{66ft * \left(\frac{12in}{ft}\right)}{240} = 3.3\ in.$$

Design Calculations

<u>**Shear-Moment Diagram**</u>



Actual Moment (M_u)

$$M_u = 517.23\ kip - ft.$$

<u>**LRFD Adjustment Factors**</u>

$C_M = wet\ service\ factor = 1.0$ (Moisture content (MC) < 19%)

$C_t = temperature\ factor = 1.0$

$C_L = beam\ stability\ factor = 1.0$ (Assuming fully braced, lateral buckling prevented by effective connection)

$C_F = size\ factor = 0.9$ (wider than 12")

$C_{fu} = flat\ use\ factor = 1.0$

$C_i = incising\ factor$
$= 0.80\ (for\ bending, tension, compression\ parallel\ to\ grain, and\ shear)$

$C_V = volume\ factor = \left(\frac{21}{L}\right)^{\frac{1}{10}} \left(\frac{12}{d}\right)^{\frac{1}{10}} \left(\frac{5.125}{b}\right)^{\frac{1}{10}}$ (Assume 0.82 and verify later)

Design Calculations

$$C_r = repetitive\ member = 1.0$$
$$\lambda = 0.80 \text{ (LRFD Load Combination)}$$

<u>Reference Design Values for Glulam Southern Pine</u>
(NDS Supplement)

$$F_{bx}{}^{+} = 2{,}400\ psi$$
$$F_{vx} = 265\ psi$$
$$E_x = 1{,}800{,}000\ psi$$

<u>Bending</u>
Lateral stability

$$F'_{bxn} = F_{bxn}(\emptyset_b)(\lambda)(C_M)(C_t)(C_L)$$

Volume effect

$$F'_{bxn} = F_{bxn}(\emptyset_b)(\lambda)(C_M)(C_t)(C_V)$$

$$F_{bxn} = F_{bx}(K_f) = 2{,}400(2.54) = 6{,}096\ psi$$
$$F'_{bxn} = F_{bxn}\left(C_M C_t C_V C_L C_F C_{fu} C_i C_r \phi\lambda\right)$$
$$= 6{,}096(1.0 * 1.0 * 0.82 * 1.0 * 0.9 * 1.0 * 0.8 * 1.0 * 0.85 * 0.8)$$
$$= 2{,}477.37\ psi$$
$$Required\ S = \frac{M_u}{F'_{bn}} = \frac{517.23\ kip - ft}{2{,}477.37\ psi} = 231.27\ in^3$$

(Table 5A – NDS Supplement)

$Choose\ 5\ x\ 22\ inch\ Southern\ Pine\ Structural\ Glue\ Laminated\ Beam$ $(3\ @\ 2.67'O.C.)$

with $S = 403.3\ in^3,\ A = 110\ in^2, I = 4437\ in^4$

$$C_V = volume\ factor = \left(\frac{21}{L}\right)^{\frac{1}{10}}\left(\frac{12}{d}\right)^{\frac{1}{10}}\left(\frac{5.125}{b}\right)^{\frac{1}{10}} = \left(\frac{21}{792}\right)^{\frac{1}{10}}\left(\frac{12}{22}\right)^{\frac{1}{10}}\left(\frac{5.125}{5}\right)^{\frac{1}{10}} = 0.66 < 0.82$$
$$F'_{bxn} = F_{bxn}\left(C_M C_t C_V C_L C_F C_{fu} C_i C_r \phi\lambda\right)$$
$$= 6{,}096\ (1.0 * 1.0 * 0.66 * 1.0 * 0.9 * 1.0 * 0.8 * 1.0 * 0.85 * 0.8)$$
$$= 1{,}969.84\ psi = 1.97\ ksi$$
$$M'_n = F'_{bxn}(S) = 1.97\ ksi * 403.3\ in^3 = 794.44\ kip - ft. > 517.23\ kip - ft.$$

Considering moment, the 5 x 22 is O.K ☑

<u>Shearing</u>
Ignore the reduction of shear given by V^4 $(conservative). \phi_v = 0.75, K_f = 2.88$
Actual Shear Force (V_u)

$$V_u = 31.39\ kip$$
$$F_{vn} = F_v(K_f) = 265\ psi\ (2.88) = 763\ psi$$
$$F'_{vn} = F_{vn}\phi_v\lambda C_M C_t C_i = 763\ psi\ (0.75)(1.0)(1.0)(0.8) = 457.8\ psi$$
$$V'_n = \left(\frac{2}{3}\right)(F'_{vn})(A) = \left(\frac{2}{3}\right)(457.8\ psi)(110\ in^2) = 33.6\ kip > 31.39\ kip, O.K.$$ ☑

Design Calculations

Deflection

Several deflection cases were considered and the one that produced the greatest vertical deflection was used. This deflection of a simply-supported beam with a uniformly distributed load is given by:

$$\Delta_{max} = \frac{5wL^4}{384EI}$$

The 8 point loads were converted to a uniformly distributed load (for *deflection purposes only*, this cannot be done for bending or shear calculations.)

$$w = \frac{(8\ kip)(8)}{66.5\ ft.} = 0.962\frac{k}{ft} = 80.2\frac{lb}{in}$$

$$\Delta_{max} = \frac{5\left(80.2\frac{lb}{in}\right)(33.25' * 12"/1')}{384 * 1.8x10^6 psi * 4437\ in^4} = 53\ inches$$

Total load only

$$\frac{l}{240} \geq \Delta_{max}$$

$1.1\ in \leq 53\ in$ ***NOT O.K. – Bracing must be added.*** *1"x6' studs @ 24" O.C.*
(See Appendix 4 – Cost Estimations)

Foundation Design Calculations

Calculated by: KMF ____________________
Checked by: AKA ______________________

Design Calculations

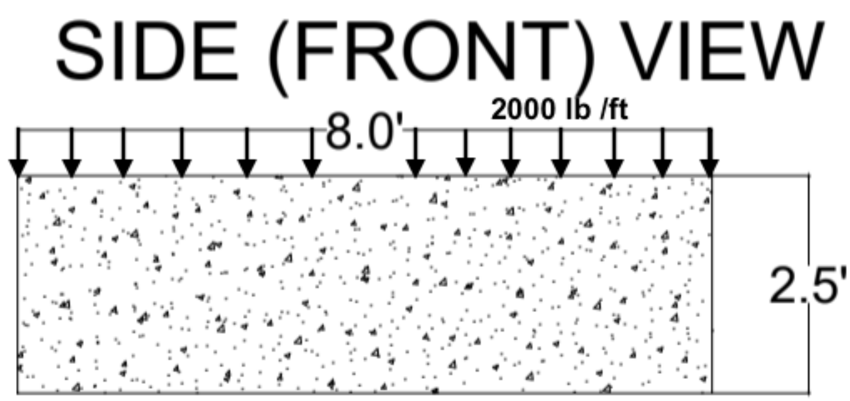
Introduction.

Background:

These calculations were carried out in an Excel program, in order for multiple footing widths to be evaluated at once. Screenshots of the Excel with the equation used shown are provided in this calculations packet, along with step-by-step instructions of how these answers were arrived at.

Assumptions:

1. Meyerhoff Method Used
2. Gravel Fill = 120 psf
3. Cohesionless soil
4. Df is 4.5’
    a. Measured field value was around 2.5’ with hand auger, but frost line is at 4.5’ so we used that
5. Bf varies from 3’-10’ with 0.5’ increments
    a. Realistically do not want a width less than 3’ or more than 5’
        i. 3-ft is the chosen width, so long it works with the calculations
6. Total Load is 2000 lb/ft
    a. See Timber Calculations for details on how this number was calculated
7. Want a foundation with similar dimensions of existing abutments which are about 2’x3’x5’ which is 30 cubic feet times two abutments so a total of 60 cubic feet we can use for two new abutments
    a. Use 8-ft for Length because it matches the width of the bridge
    b. 2.5 for depth
    c. 160 cubic feet, need 100 cubic feet taken out elsewhere
8. Bore logs averaged and just one analyzed for footing size – we want them to be the same size



Design Calculations

Calculations

SPT N-Value

The SPT N Value is calculated from the sum of the second and third blow in each of the bore-logs.

SUM | f_x =B4+B5

A	B	C	D	E	F	G
B1						
Depth	**Blows / 6"**	**SPT N Value**	**Corrected N**	**TS (psf)**	**U (psf)**	**ES (Tsf)**
0	6			0	0	0
0.5	7	=B4+B5	32.616	60	0	0.03
1	8		29.139	120	0	0.06
1.5	6		27.105	180	0	0.09
2	7		25.662	240	0	0.12
2.5	9		24.543	300	0	0.15
3	10		23.628	360	0	0.18
		Average Corrected N	27.116			

$N1_{60}$ Value

Next, calculate the total stress and effective stress for each depth. There is no pore water pressure here because we are above the groundwater table. We want effective stress in tons.

SUM | f_x =120*A3

A	B	C	D	E	F	G
B1						
Depth	**Blows / 6"**	**SPT N Value**	**Corrected N**	**TS (psf)**	**U (psf)**	**ES (Tsf)**
0	6			=120*A3	0	0
0.5	7	15	32.616	60	0	0.03
1	8		29.139	120	0	0.06
1.5	6		27.105	180	0	0.09
2	7		25.662	240	0	0.12
2.5	9		24.543	300	0	0.15
3	10		23.628	360	0	0.18
		Average Corrected N	27.116			

Design Calculations

SUM | fx | =E3*0.0005

A	B	C	D	E	F	G
B1						
Depth	**Blows / 6"**	**SPT N Value**	**Corrected N**	**TS (psf)**	**U (psf)**	**ES (Tsf)**
0	6			0	0	=E3*0.0005
0.5	7	15	32.616	60	0	0.03
1	8		29.139	120	0	0.06
1.5	6		27.105	180	0	0.09
2	7		25.662	240	0	0.12
2.5	9		24.543	300	0	0.15
3	10		23.628	360	0	0.18
		Average Corrected N	27.116			

The CN value can be calculated once the effective stress is calculated in tons, by using the following equation:

$$CN = 0.77 * \left(Log\left(\frac{20}{ES}\right)\right)$$

SUM | fx | =0.77*(LOG(20/G3))

A	B	C	D	E	F	G	H
B1							
Depth	**Blows / 6"**	**SPT N Value**	**Corrected N**	**TS (psf)**	**U (psf)**	**ES (Tsf)**	**CN Value**
0	6			0	0	0	G3))
0.5	7	15	32.616	60	0	0.03	2.1744
1	8		29.139	120	0	0.06	1.9426
1.5	6		27.105	180	0	0.09	1.8070
2	7		25.662	240	0	0.12	1.7108
2.5	9		24.543	300	0	0.15	1.6362
3	10		23.628	360	0	0.18	1.5752
		Average Corrected N	27.116				

After the CN value is calculated, this is multiplied with the SPT N value to get the corrected N values.

Design Calculations

SUM | fx =$C$4*H4

A	B	C	D	E	F	G	H
B1							
Depth	**Blows / 6"**	**SPT N Value**	**Corrected N**	**TS (psf)**	**U (psf)**	**ES (Tsf)**	**CN Value**
0	6			0	0	0	#DIV/0!
0.5	7	15	=$C$4*H4	60	0	0.03	2.1744
1	8		29.139	120	0	0.06	1.9426
1.5	6		27.105	180	0	0.09	1.8070
2	7		25.662	240	0	0.12	1.7108
2.5	9		24.543	300	0	0.15	1.6362
3	10		23.628	360	0	0.18	1.5752
		Average Corrected N	27.116				

Bearing Capacity from NHI Volume 2

$$q_{ult} = c(N_c) + q(N_q) + 0.5(\gamma)(B_f)(N_\gamma) \qquad 8\text{-}1$$

"Cohesion" term — "Surcharge" term — Foundation soil "Weight" term

Where: c is zero, so the first term cancels out

$q = q_{appl} + \gamma Df$

$q_{appl} = 0$

γ =0.12 ksf

Df = 5.5-ft

q	
qapl (ksf)	0
gamma a (kcf)	0.12
Df (ft)	4.5
q	=J4*J5

Bf varies from 3'-10', with increments of 0.5'

Nq is found from φ which is interpolated from table 8-11 NHI Manual Volume 2

N_γ is found from chapter 8 NHI Manual Volume 2

Design Calculations

Putting the information into Excel yields:

```
=(($J$6*$L$3)+(0.5*$M$3*O3*$N$3))/6
```

I	J	K	L	M	N	O	P
q		**φ**	**Nq**	**gamma**	**Ngamma**	**Bf (ft)**	**Qult (Tsf)**
qapl (ksf)	0	36.75	42.9	0.12	66.2	3	$N$3))/6
gamma a (kcf)	0.12	37				3.5	6.178
Df (ft)	4.5					4	6.509
q	0.54					4.5	6.84
						5	7.171
						5.5	7.502
						6	7.833
						6.5	8.164
						7	8.495
						7.5	8.826
						8	9.157
						8.5	9.488
						9	9.819
						9.5	10.15
						10	10.481

Meyerhoff from NHI Volume 2

For Meyerhoff equation:

$$\rho = \frac{5p}{(N-1.5)C_B}$$

N = minimum average SPT-N Value calculated = 27.1

$$p = \frac{(\gamma floor)}{(Af)} * 0.0005(tons)$$

A_F = Area of the footing = 8’ x (varies)

Design Calculations

B3 fx =(0.0005*2000)/((8*A3))

A	B	C	D	E
Meyerhoff				
Footing Width (ft)	bearing pressure (p) (tons)	N	Cb	rho
2	0.0625	27.1	1	0.012207031
2.5	0.05		1	0.009765625
3	0.041666667		1	0.008138021
3.5	0.035714286		1	0.006975446
4	0.03125		1	0.006103516
4.5	0.027777778		0.95	0.005710892
5	0.025		0.95	0.005139803
5.5	0.022727273		0.95	0.004672548
6	0.020833333		0.95	0.004283169
6.5	0.019230769		0.95	0.003953694
7	0.017857143		0.95	0.003671288
7.5	0.016666667		0.95	0.003426535
8	0.015625		0.9	0.003390842
8.5	0.014705882		0.9	0.003191381
9	0.013888889		0.9	0.003014082
9.5	0.013157895		0.9	0.002855446
10	0.0125		0.85	0.002872243
10.5	0.011904762		0.85	0.002735469
11	0.011363636		0.85	0.00261113
11.5	0.010869565		0.85	0.002497602
12	0.010416667		0.8	0.002543132
12.5	0.01		0.8	0.002441406
13	0.009615385		0.8	0.002347506
13.5	0.009259259		0.8	0.002260561
14	0.008928571		0.8	0.002179827
14.5	0.00862069		0.8	0.002104661
15	0.008333333		0.8	0.002034505
15.5	0.008064516		0.8	0.001968876
16	0.0078125		0.8	0.001907349

Design Calculations

E3 =((5*B3)/(($C$3-1.5)*D3))

A	B	C	D	E
Meyerhoff				
Footing Width (ft)	bearing pressure (p) (tons)	N	Cb	rho
2	0.0625	27.1	1	0.012207031
2.5	0.05		1	0.009765625
3	0.041666667		1	0.008138021
3.5	0.035714286		1	0.006975446
4	0.03125		1	0.006103516
4.5	0.027777778		0.95	0.005710892
5	0.025		0.95	0.005139803
5.5	0.022727273		0.95	0.004672548
6	0.020833333		0.95	0.004283169
6.5	0.019230769		0.95	0.003953694
7	0.017857143		0.95	0.003671288
7.5	0.016666667		0.95	0.003426535
8	0.015625		0.9	0.003390842
8.5	0.014705882		0.9	0.003191381
9	0.013888889		0.9	0.003014082
9.5	0.013157895		0.9	0.002855446
10	0.0125		0.85	0.002872243
10.5	0.011904762		0.85	0.002735469
11	0.011363636		0.85	0.00261113
11.5	0.010869565		0.85	0.002497602
12	0.010416667		0.8	0.002543132
12.5	0.01		0.8	0.002441406
13	0.009615385		0.8	0.002347506
13.5	0.009259259		0.8	0.002260561
14	0.008928571		0.8	0.002179827
14.5	0.00862069		0.8	0.002104661
15	0.008333333		0.8	0.002034505
15.5	0.008064516		0.8	0.001968876
16	0.0078125		0.8	0.001907349

Design Calculations

Meyerhoff				
Footing Width (ft)	bearing pressure (p) (tons)	N	Cb	rho
2	0.0625	27.1	1	0.012207031
2.5	0.05		1	0.009765625
3	0.041666667		1	0.008138021
3.5	0.035714286		1	0.006975446
4	0.03125		1	0.006103516
4.5	0.027777778		0.95	0.005710892
5	0.025		0.95	0.005139803
5.5	0.022727273		0.95	0.004672548
6	0.020833333		0.95	0.004283169
6.5	0.019230769		0.95	0.003953694
7	0.017857143		0.95	0.003671288
7.5	0.016666667		0.95	0.003426535
8	0.015625		0.9	0.003390842
8.5	0.014705882		0.9	0.003191381
9	0.013888889		0.9	0.003014082
9.5	0.013157895		0.9	0.002855446
10	0.0125		0.85	0.002872243
10.5	0.011904762		0.85	0.002735469
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11.5	0.010869565		0.85	0.002497602
12	0.010416667		0.8	0.002543132
12.5	0.01		0.8	0.002441406
13	0.009615385		0.8	0.002347506
13.5	0.009259259		0.8	0.002260561
14	0.008928571		0.8	0.002179827
14.5	0.00862069		0.8	0.002104661
15	0.008333333		0.8	0.002034505
15.5	0.008064516		0.8	0.001968876
16	0.0078125		0.8	0.001907349

We chose to use a footing width of 3-ft. The settlement of this width, with a length of 8-ft and depth of 2.5-ft, is minimal. We believe anything smaller than 3-ft width could cause problems, and anything larger we are afraid would be too hard to implement into our site.

Our foundation will have a 1-inch thick layer of ¾" crushed gravel underneath it in order to prevent scour, unless during excavation it appears 2.5-ft down will be directly on bedrock. In which case, no scour prevention methods will have to take place.

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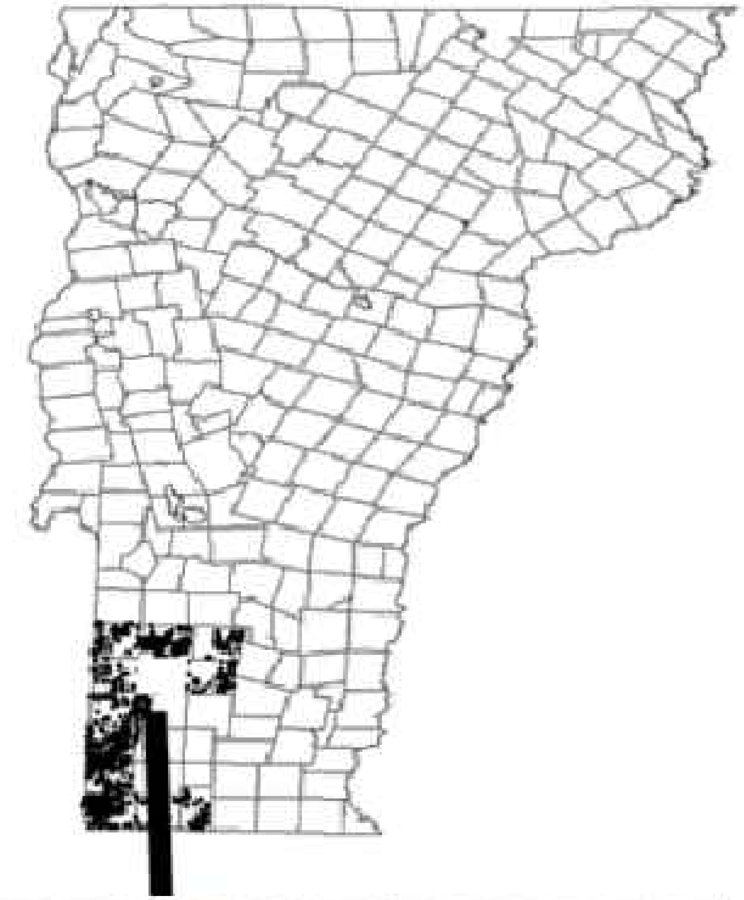
UNIVERSITY OF VERMONT
SENIOR CAPSTONE DESIGN
PEDESTRIAN BRIDGE DESIGN PROJECT
TOWN OF MANCHESTER
COUNTY OF BENNINGTON
MANCHESTER RIVERWALK COMMITTEE

ANDREA AMEDEN, *STRUCTURAL ENGINEER*
AUGUST ARLES, *HYDRAULIC ENGINEER*
KAITLYN FULLER, *GEOTECHNICAL ENGINEER*
SHAUN ROBERTS, *HYDRAULIC ENGINEER*

Table of Contents

The University of Vermont
COLLEGE OF ENGINEERING & MATHEMATICAL SCIENCES



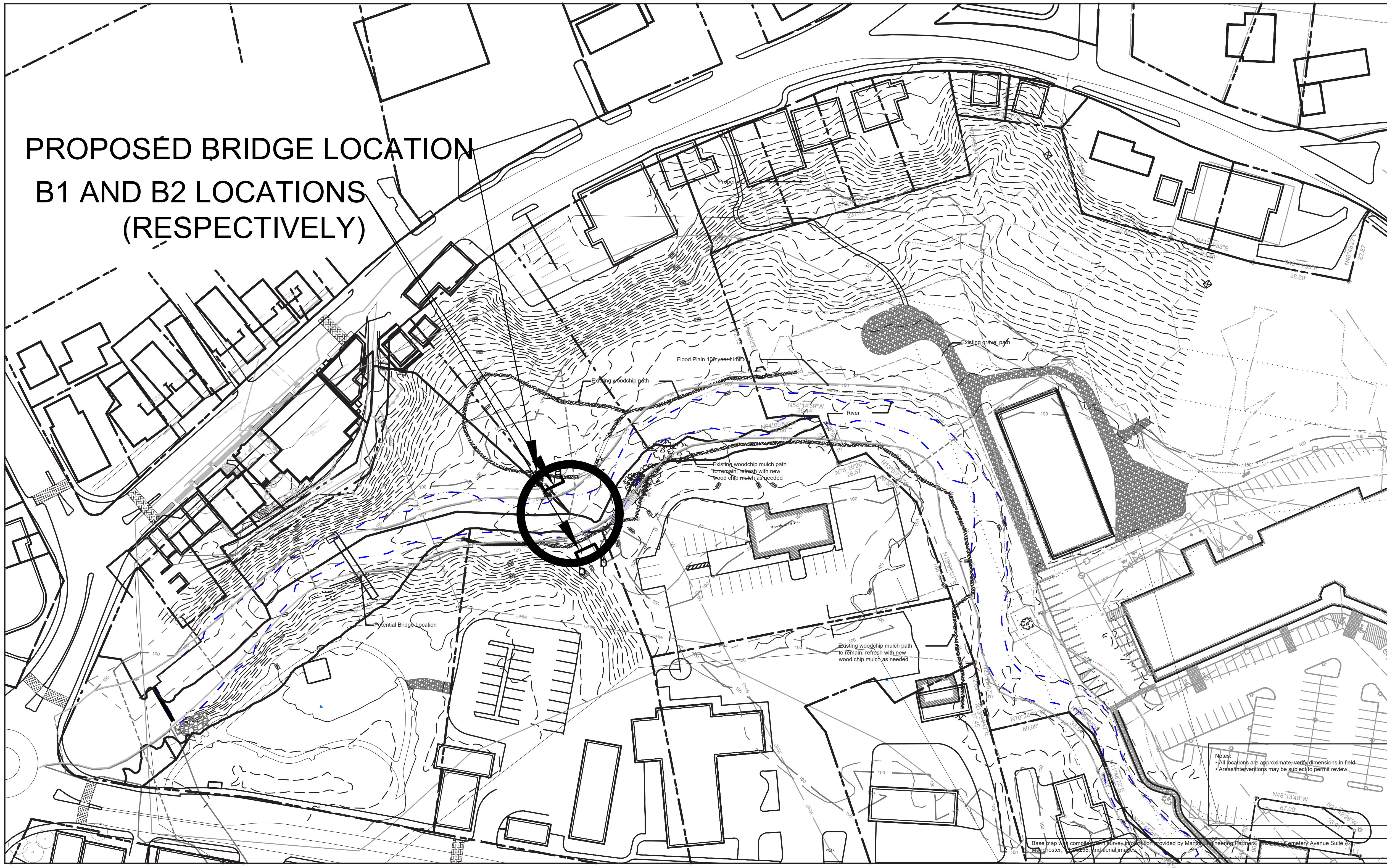
**DISCLAIMER* IT IS IMPORTANT TO NOTE THESE DESIGNS WERE PREPARED BY SENIOR LEVEL ENGINEERING STUDENTS AND IN NO WAY SHOULD BE REPLICATED OR USED UNTIL CHECKED AND APPROVED BY A PROFESSIONALLY LICENSED ENGINEER.*

COVER SHEET

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: AKA	PROJECT NO: MRC	
DRAWN BY: KF	DATE: 03/24/2018	DRAWING SCALE: NONE

RIVERWALK manchester vermont



PLAN
Base Map with Aerial

DRAFT

September 2017
Scale: 1" = 50'-0"

0' 50'

FIGURE NO. 1
EXISTING SITE CONDITIONS

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

DRAWN BY:
MANCE ENGINEERING W. MARKUPS FROM KF

DATE:
03/24/2018

PROJECT NO:
MRC

DRAWING SCALE:
SEE DRAWING

RIVERWALK
manchester vermont

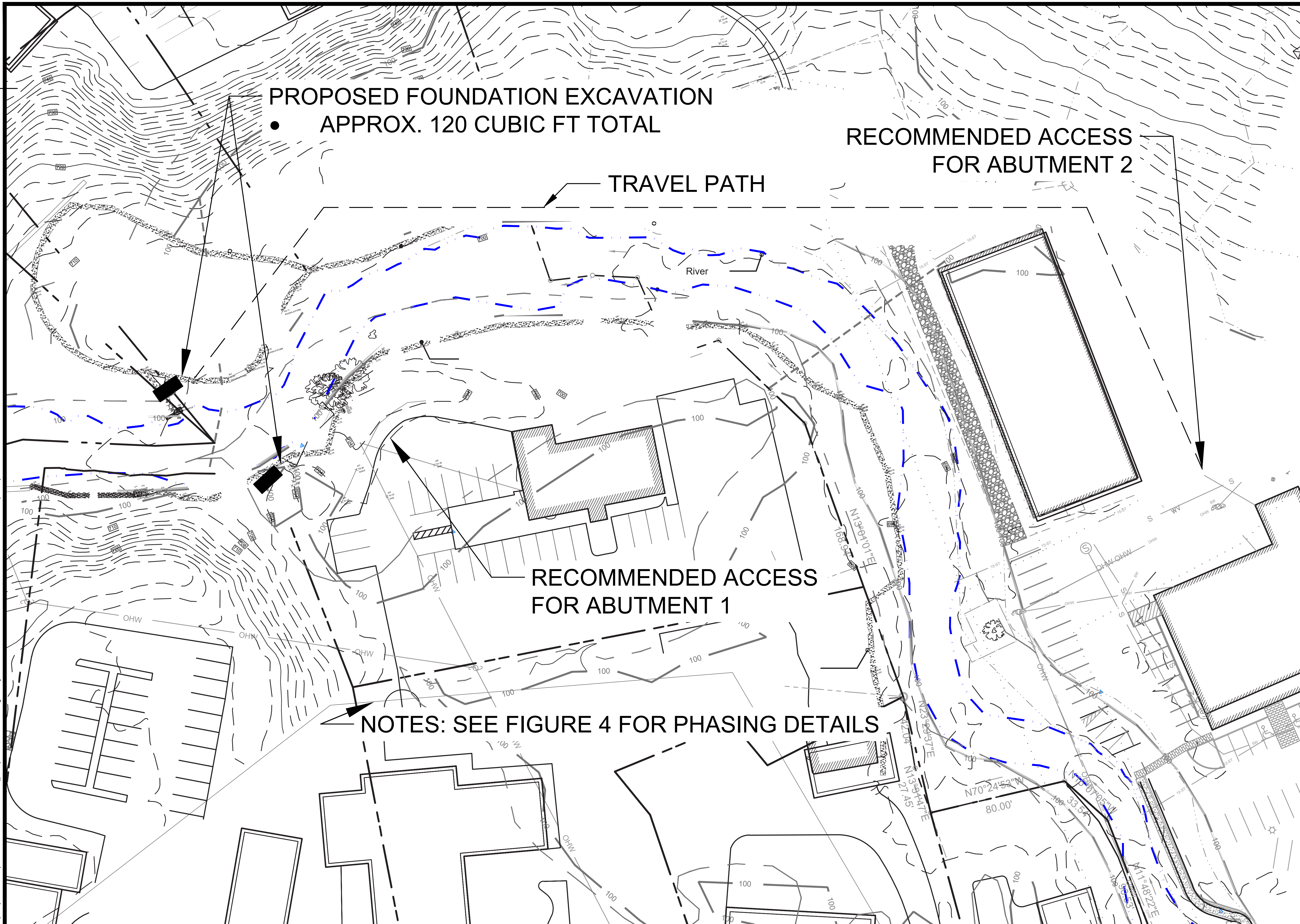


FIGURE NO. 2
PROPOSED CONSTRUCTION DETAILS

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

DRAWN BY: KMF	CHECKED BY: AKA
DATE: 03/24/2018	PROJECT NO: MRC
DRAWING SCALE: NTS	

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NOTES:

- PHASE 1 (BID-2 DAYS INTO CONSTRUCTION)
  - CLEARING AND GRUBBING OF ANY TREES / PLANTS OVERHANGING INTO PROPOSED CONSTRUCTION SITE
  - PROVIDING CLEAR PATHWAY ON BOTH SIDES OF RIVER FOR HEAVY MACHINERY TO ACCESS SAFELY
  - SITE VISIT BY CONTRACTOR TO ENSURE EQUIPMENT WILL BE ABLE TO ACCESS SITE

- PHASE 2 (2-3 DAYS)
  - REMOVAL OF OLD ABUTMENTS AND TRANSPORTATION TO NEW LOCATION - OFFSITE
  - EXCAVATION OF FOUNDATION LOCATION
    - 3'X8'X2.5'
  - PLACEMENT OF 6-INCH THICK LAYER OF $\frac{3}{4}$" GRAVEL ON BOTTOM OF TRENCH
- PHASE 3 (2-3 DAYS)
  - MIX DESIGN OF 4000PSI CONCRETE ON SITE
  - POUR CONCRETE FOR BOTH FOUNDATIONS
  - WAIT 24-48 HOURS FOR COMPLETE CURING
- PHASE 4 (5-10 DAYS)
  - DELIVERY OF PRE-FAB BRIDGE OR ALL TIMBER ASSEMBLY FOR NEWLY DESIGNED BRIDGE
  - START BRIDGE CONSTRUCTION
  - ONCE COMPLETE, ENSURE CLEAN UP OF SITE IS ADMINISTERED

FIGURE NO. 3
PROJECT CONSTRUCTION DETAILS

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

DRAWN BY: KF
CHECKED BY: AA
DATE: 03/24/2018
PROJECT NO: MRC
DRAWING SCALE:
DRAWING SCALE

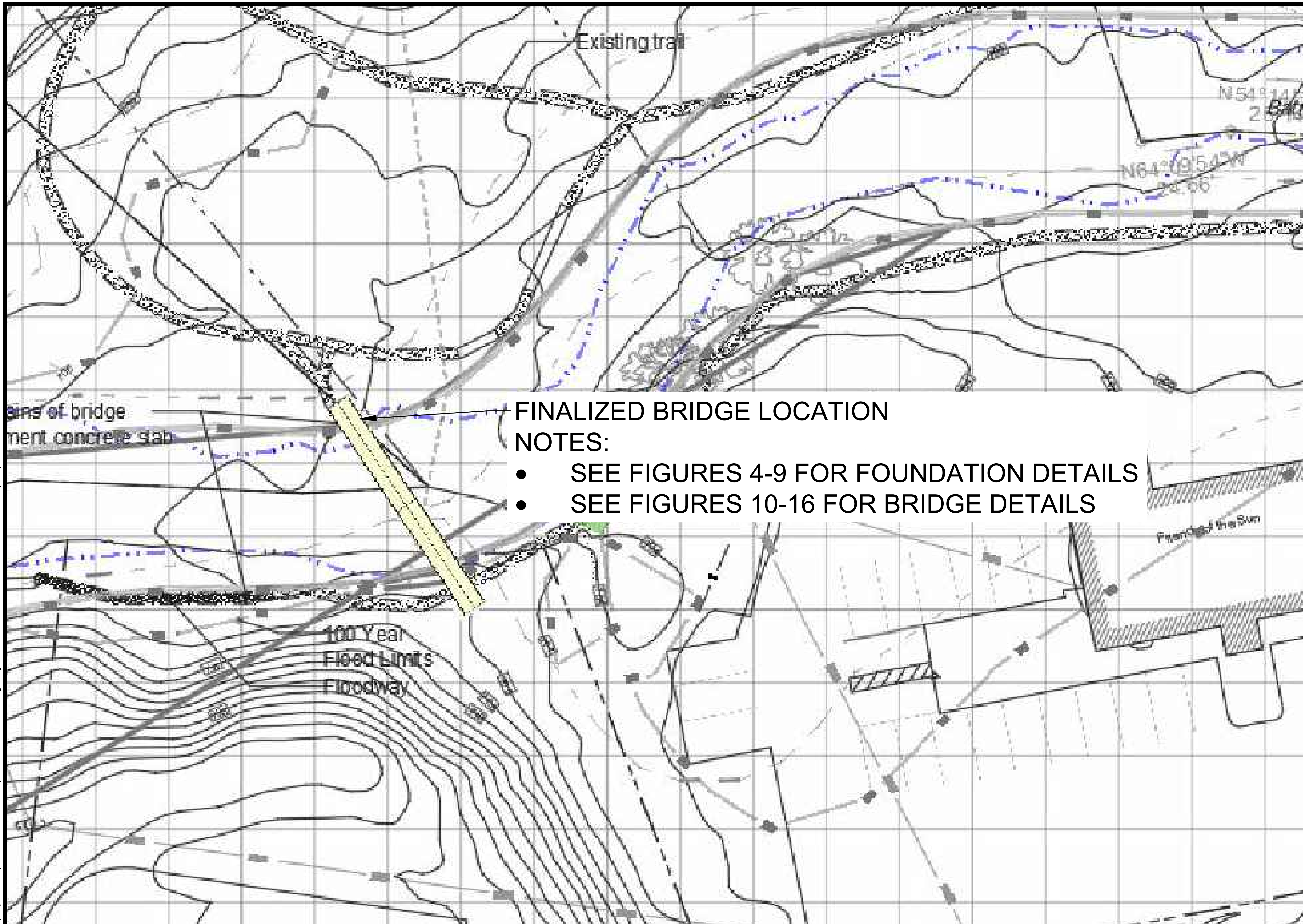

FIGURE NO. 5
POST CONSTRUCTION

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

DRAWN BY: KF	CHECKED BY: AA	
DATE: 03/24/2018	PROJECT NO: MRC	
DRAWING SCALE: NTS		

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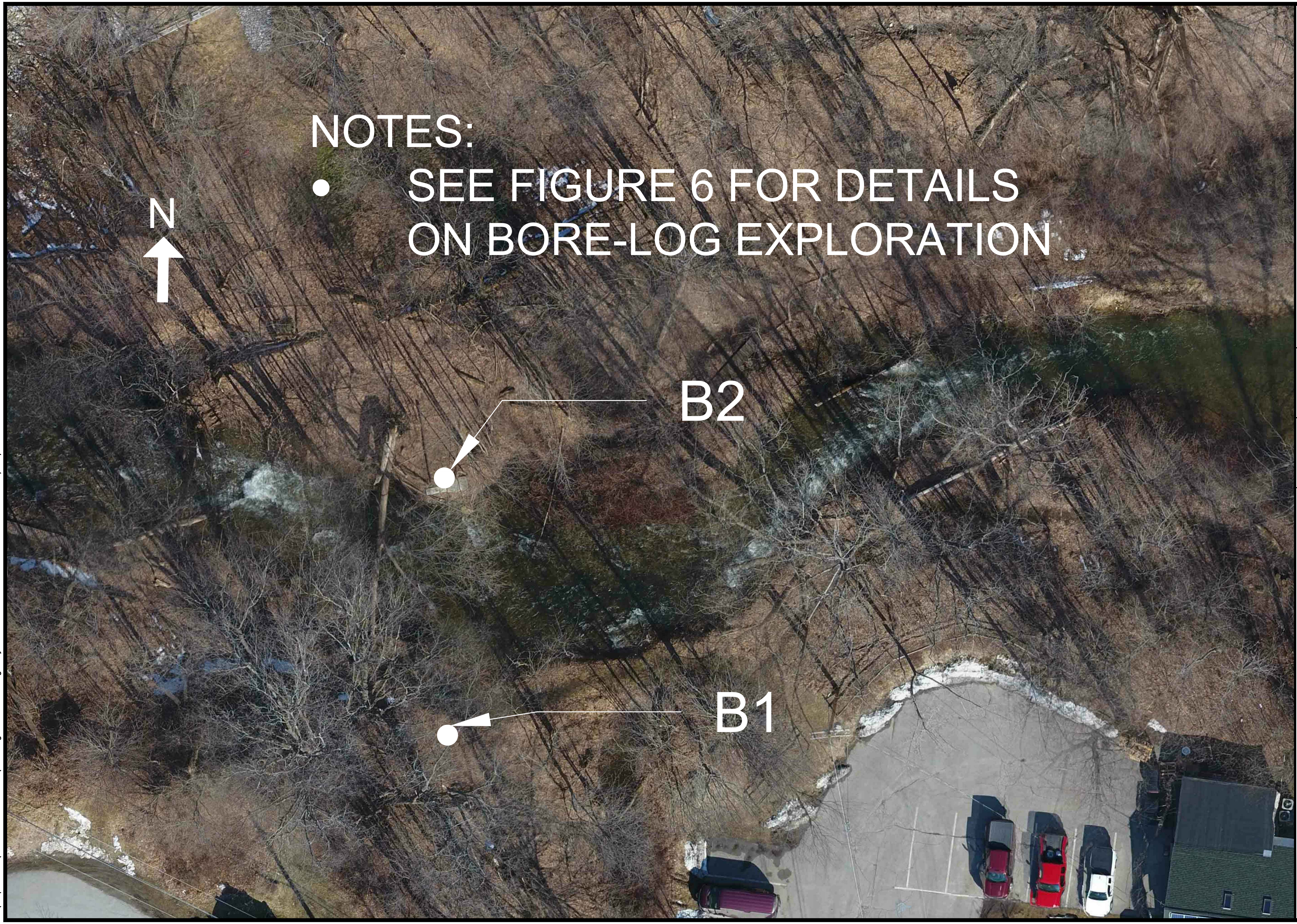

FIGURE NO. 5
BORE-LOG LOCATION

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

DRAWN BY: KF	CHECKED BY: AA
DATE: 03/24/2018	PROJECT NO: MRC
DRAWING SCALE: NTS	

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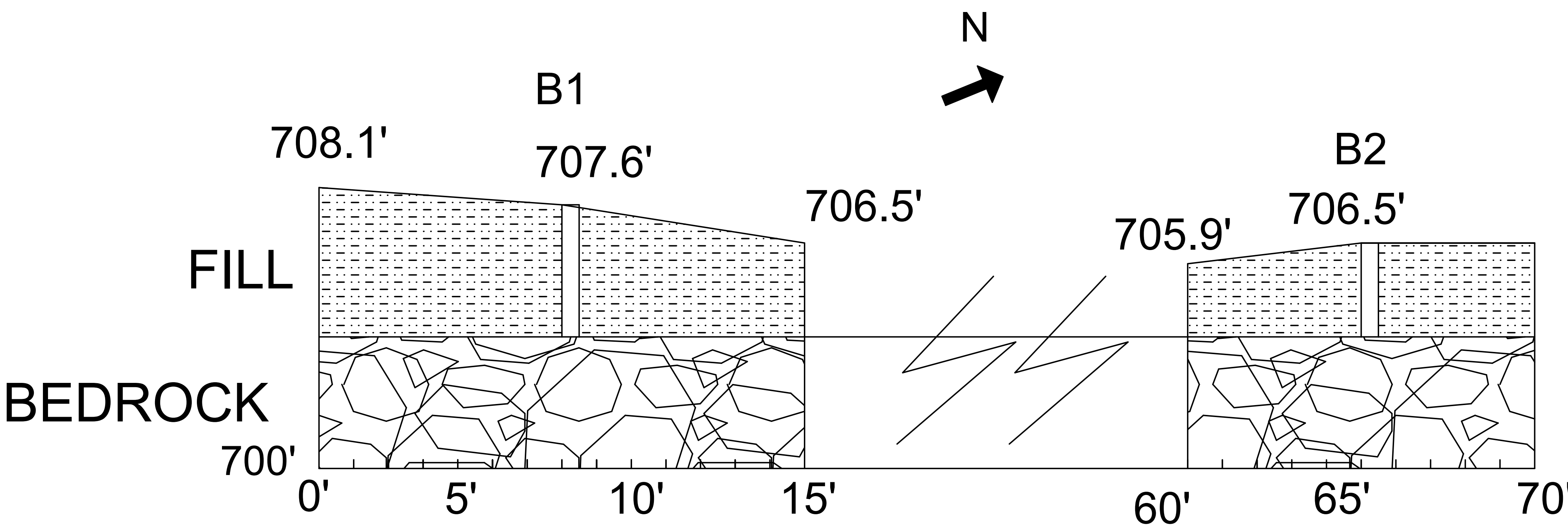

NOTES:

- ONLY ONE BORELOG TAKEN FOR EITHER SIDE OF THE RIVER
- SUBSURFACE CONDITIONS ARE CONSISTENT WITH UPSTREAM BORES
- B1 AND B2 DUG WITH 6" HAND AUGER
- SUBSURFACE CONSISTED OF FILL FOR THE FIRST 0-3 FT, THEN WE HIT WHAT WE ASSUMED TO BE BEDROCK, RECOMMEND HIRING A BORING COMPANY TO INVESTIGATE

- B1

DEPTH (FT)	BLOWS W/ HAND AUGER / 6"
0	7
0.5	7
1.0	5
1.5	6
2.0	6
2.5	7

- B2

DEPTH (FT)	BLOWS W/ HAND AUGER / 6"
0	5
0.5	7
1.0	6
1.5	6
2.0	8
2.5	9

FIGURE NO. 6
BORELOG SECTION VIEW

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: AA
PROJECT NO: MRC
DRAWN BY: KF
DATE: 03/24/2018
DRAWING SCALE: NTS

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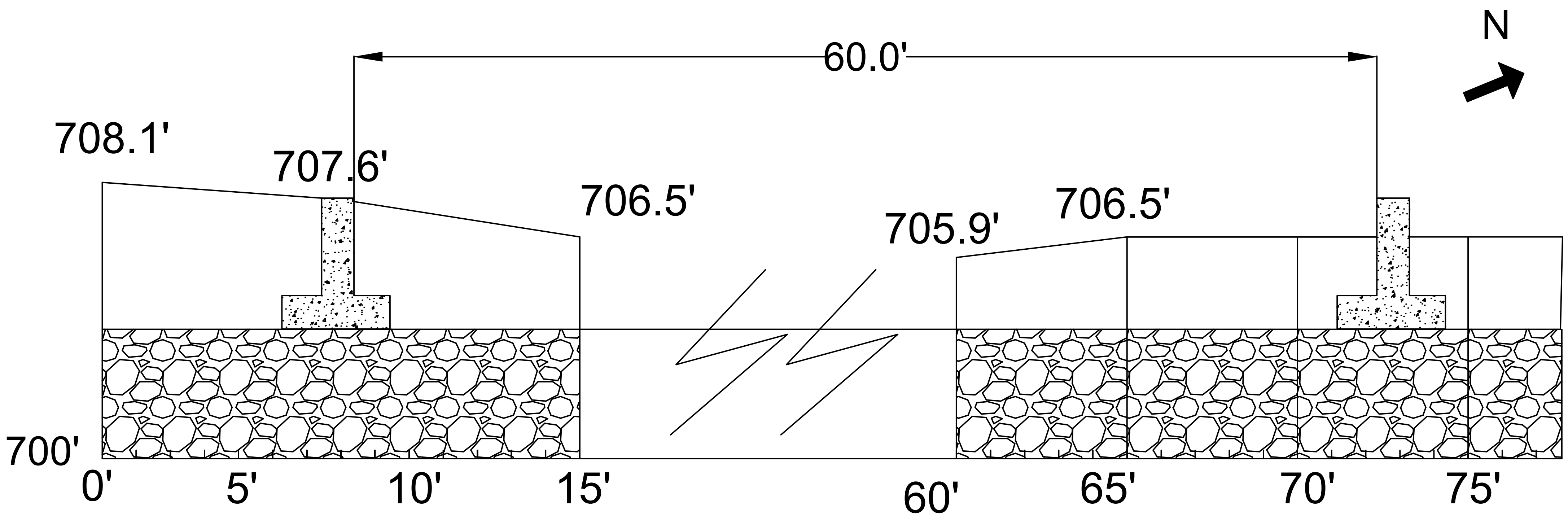

ABUTMENT 1

ABUTMENT 2

NOTES:

- DISTANCE FROM INNER FACE OF ABUTMENTS IS 60 FT
- EXCAVATION NEEDED FOR BOTH ABUTMENTS, BACKFILLED WITH GRAVEL TO PREVENT SCOUR, THEN CONCRETE ABUTMENTS PUT INTO PLACE
- EXACT AMOUNT OF FILL TO BE TAKEN OUT AND REPLENISHED IS NOT KNOWN AT THIS TIME
- SEE ABUTMENT DETAILS FOR MORE VIEWS

FIGURE NO. 7
ABUTMENT ELEVATIONS

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: AA
PROJECT NO: MRC
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DRAWING SCALE: NTS

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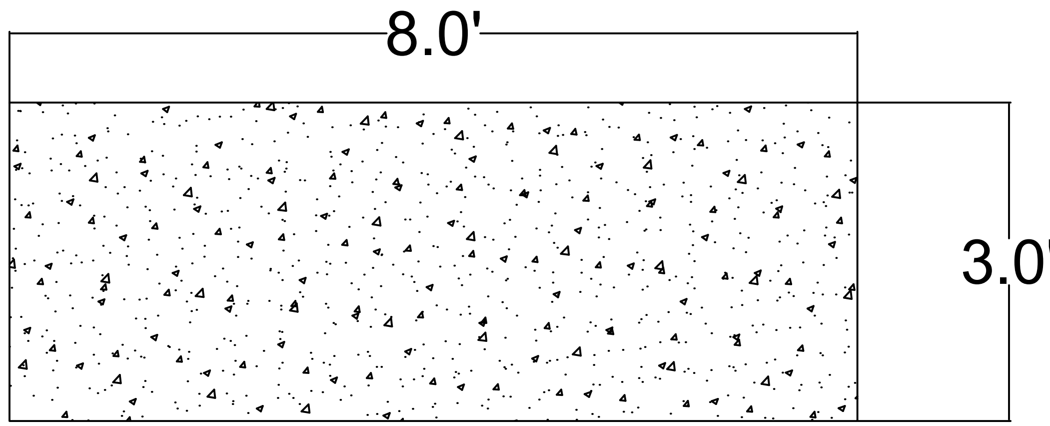
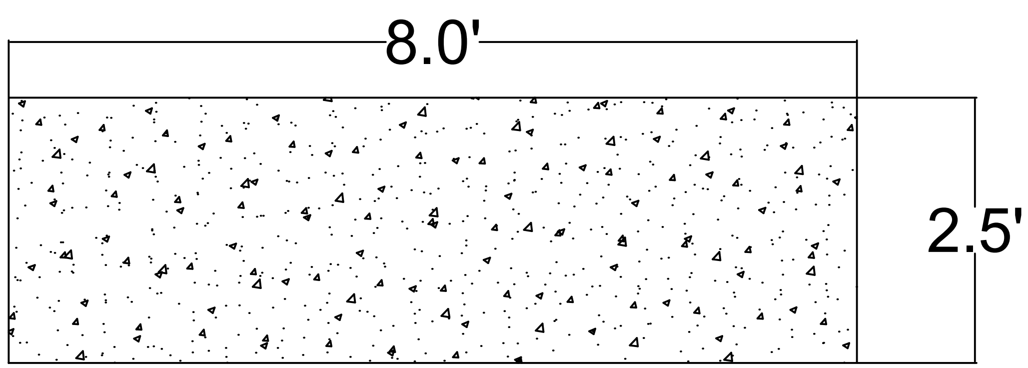
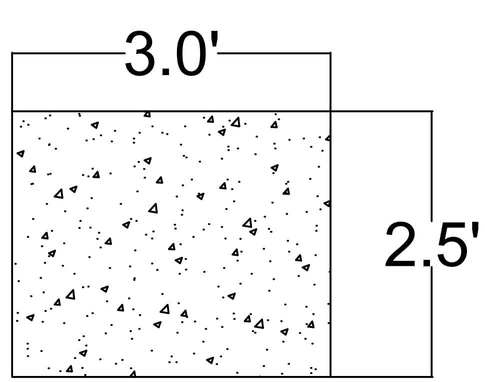
PLAN VIEW



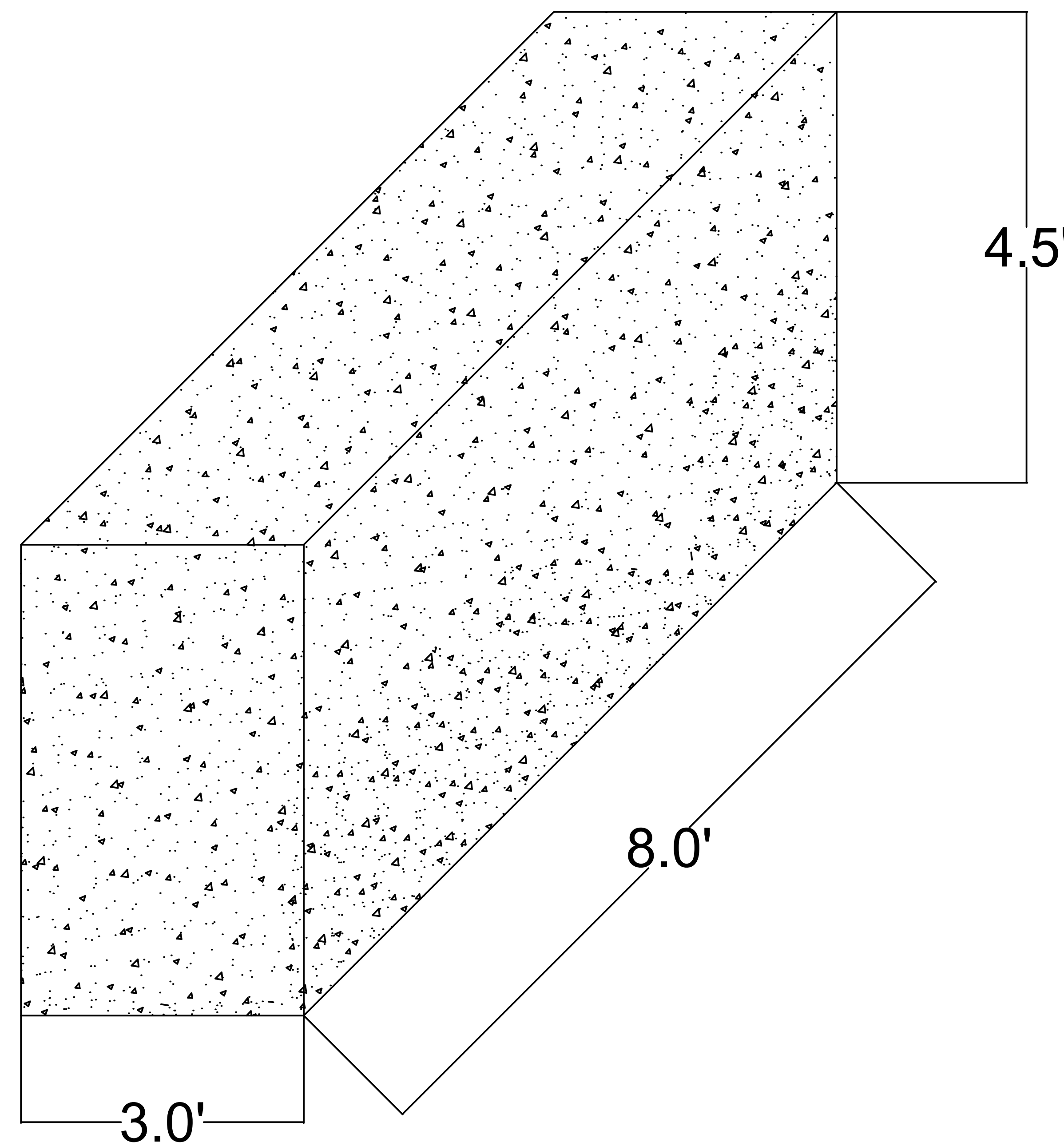
SIDE (FRONT) VIEW



SIDE (X-SEC) VIEW



ISO VIEW



NOTES:

- ABUTMENTS 1 AND 2 SHALL BE SAME VOLUME
- WIDTH OF ABUTMENT WAS CHOSEN TO MATCH THE LANDING OF THE BRIDGE WIDTH
- SEE PROPOSED SITE FOR PLAN VIEW OF POST CONSTRUCTION
- EXCAVATION TO BE BACKFILLED WITH THIN LAYER OF $\frac{3}{4}$" STONE BEFORE POURING OF CONCRETE TO PREVENT SCOUR

FIGURE NO. 8
ABUTMENT DETAILS

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: AA
PROJECT NO: MRC
DRAWN BY: KF
DATE: 03/24/2018
DRAWING SCALE: NTS

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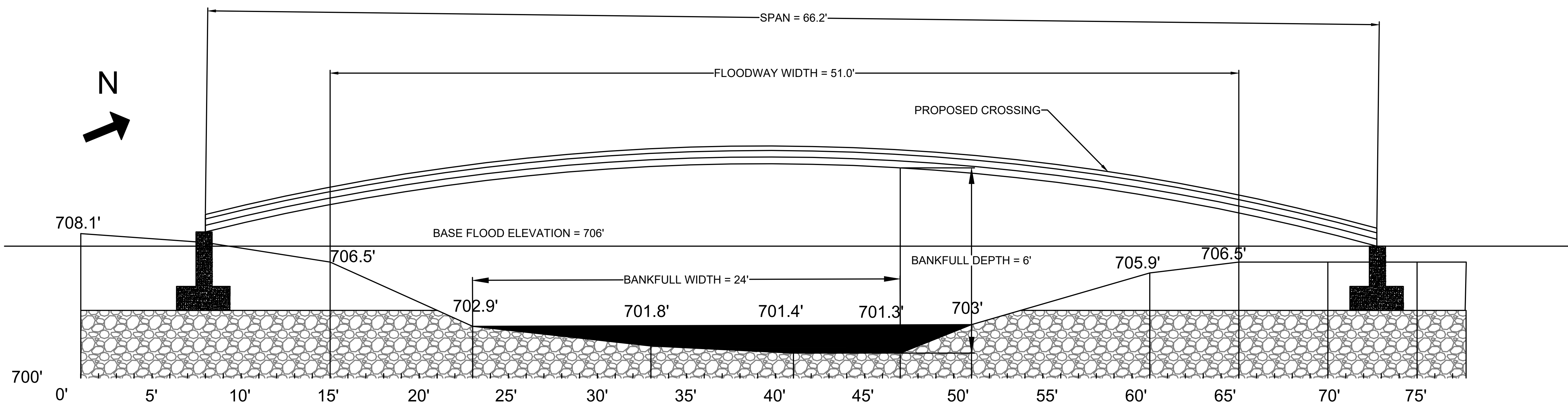

NOTES:

- NEW CONCRETE ABUTMENTS = + 120 CUBIC FT
- ABUTMENTS THAT CURRENTLY EXIST TO BE REMOVED = -60 CUBIC FT
- SOIL REMOVED TO PLACE NEW ABUTMENTS ~ -120 CUBIC FT
- ADDITION OF BACKFILL / STONE DRAINAGE FOR SCOUR PREVENTION ~ +60 CUBIC FT
- NET VOLUME CHANGE = 0 CUBIC FT
- SEE ABUTMENT DETAILS AND ABUTMENT ELEVATIONS FOR DETAILS
- LEFT ABUTMENT NOTED AS ABUTMENT 1, RIGHT ABUTMENT IS NOTED AS ABUTMENT 2

0' 3.5' 7'

FIGURE NO. 9
FINAL FOUNDATION DESIGN

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: AA
PROJECT NO: MRC
DRAWN BY: KF
DATE: 03/24/2018
DRAWING SCALE: SEE DRAWING

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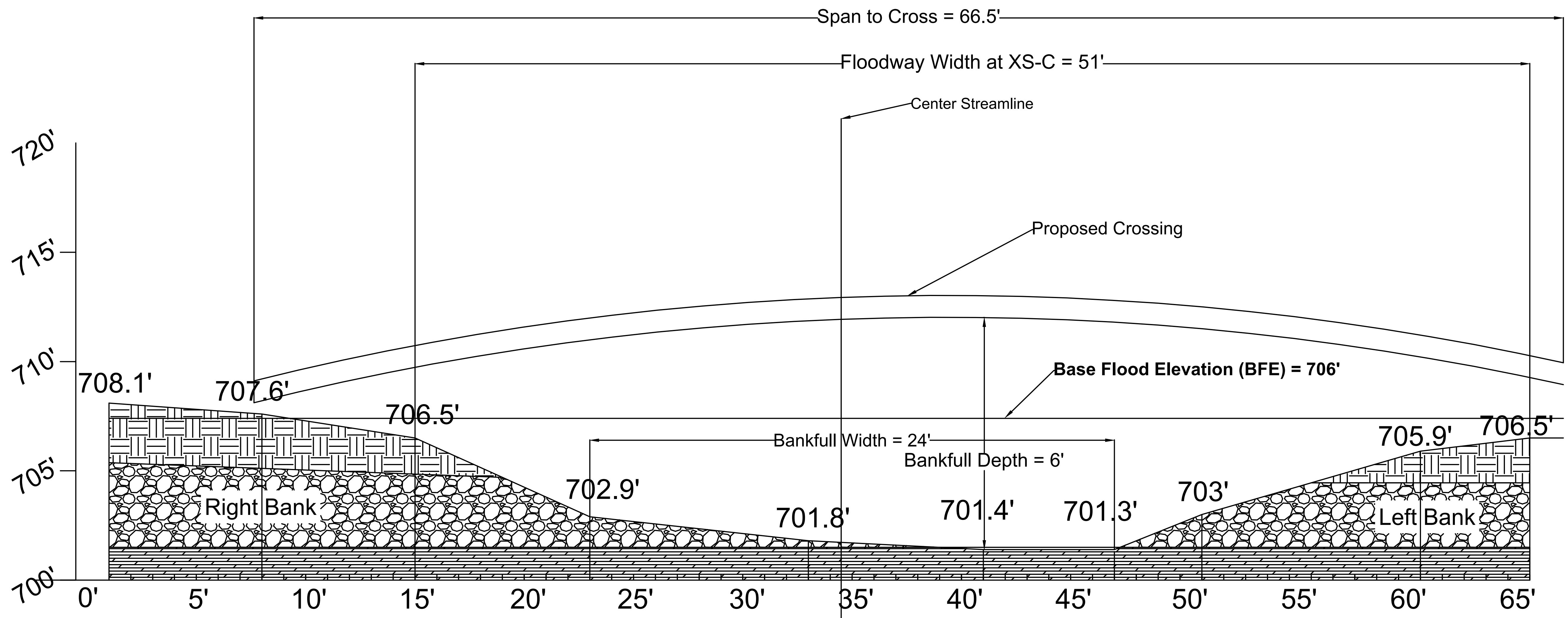

NOTES:

1. **Survey Completed 2/24/2018 using a Transit Level and Grade Rod**
2. **Bankfull width, Bankfull depth, and Channel base width measured on site and compared to calculated value from Cassidy Cote (VTrans Hydraulics)**
3. **B.F.E. = Base Flood Elevatiom**
4. **Subsurface Conditions are N.T.S. - See Figures No. 6 for boring information and and subsurface conditions**
5. **Elevations tied in with benchmark at elevation 699.2 feet (Bagel Works, Manchester Center, VT 05255)**

FIGURE NO. 10
CHANNEL CROSS-SECTION AT STREAM CROSSING

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: KF
PROJECT NO: MRC
DRAWN BY: AKA
DATE: 03/24/2018
DRAWING SCALE: NTS

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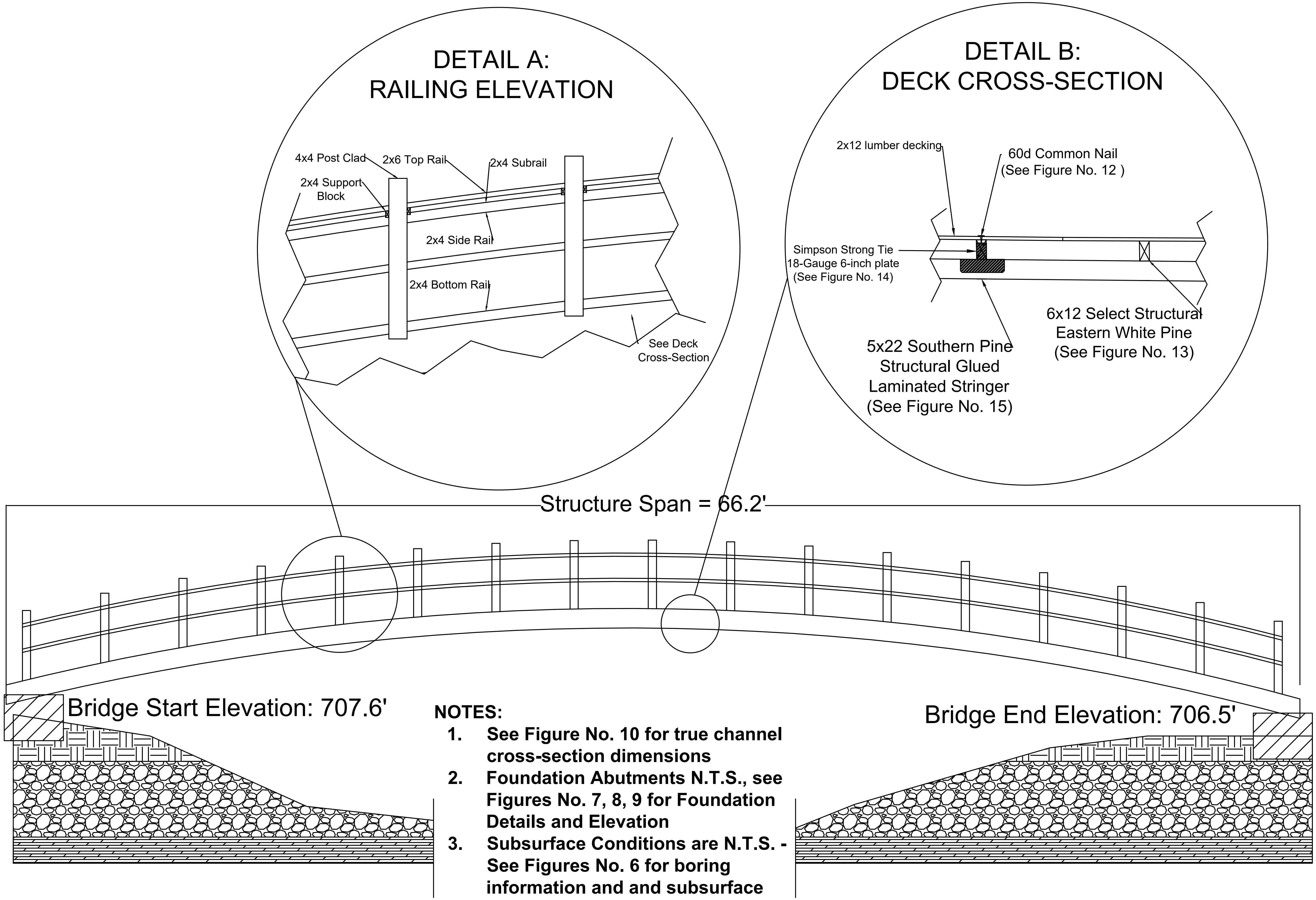

NOTES:

1. **See Figure No. 10 for true channel cross-section dimensions**
2. **Foundation Abutments N.T.S., see Figures No. 7, 8, 9 for Foundation Details and Elevation**
3. **Subsurface Conditions are N.T.S. - See Figures No. 6 for boring information and and subsurface conditions**

FIGURE NO. 11

BRIDGE DECK CROSS-SECTION AND RAILING ELEVATION DETAIL

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

DRAWN BY: AKA	CHECKED BY: KF
DATE: 03/24/2018	PROJECT NO: MRC
DRAWING SCALE: NTS	

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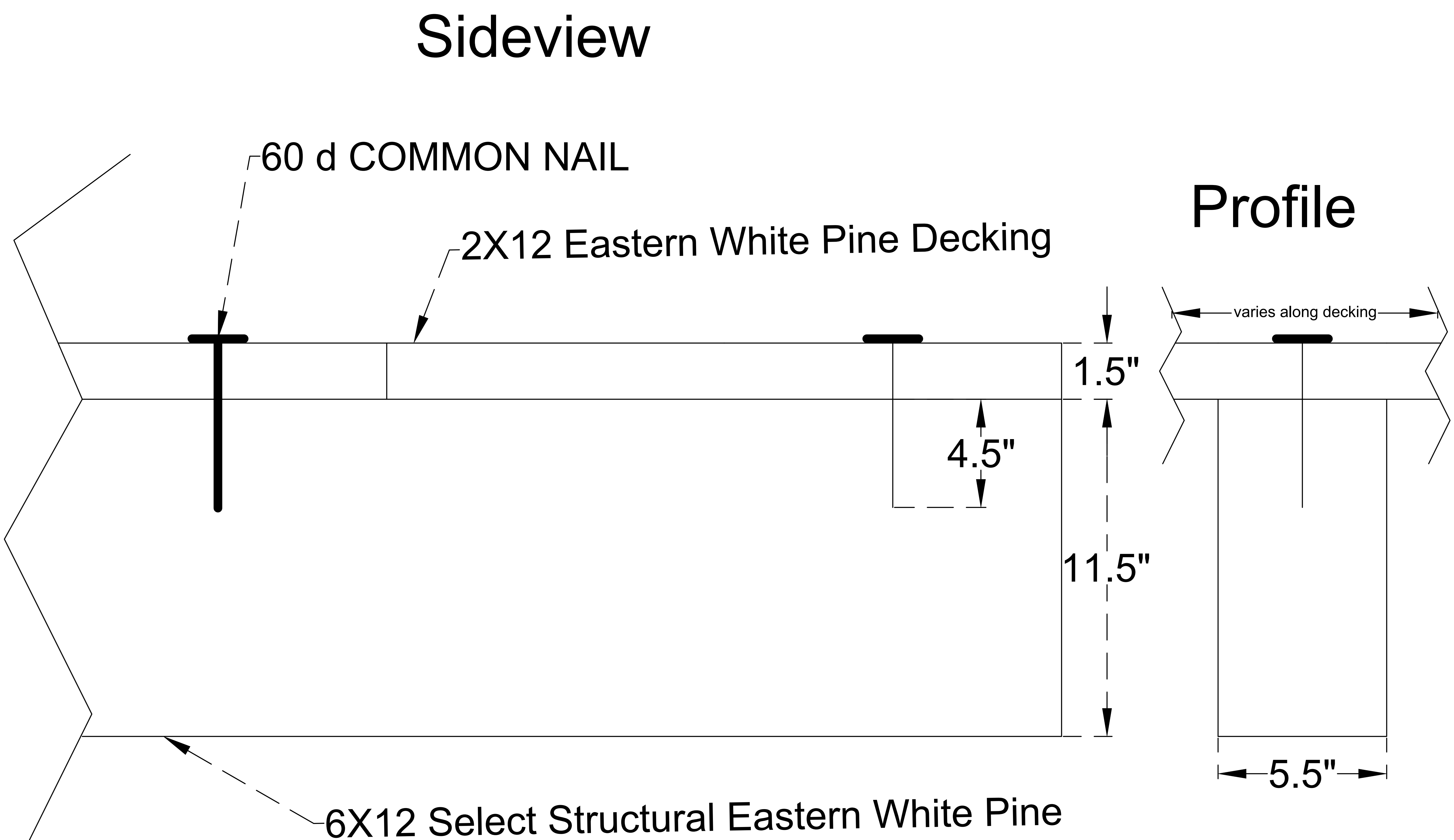

NOTES:

1. **Connection standard design from Design of Wood Structures ASD/LRFD, Seventh Edition**
2. **Connection strength has not been evaluated with member stresses and must be checked before construction begins**

FIGURE NO. 12
CONNECTION DETAIL – DECKING TO BEAM

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: KF
PROJECT NO: MRC
DRAWN BY: AKA
DATE: 03/24/2018
DRAWING SCALE: NTS

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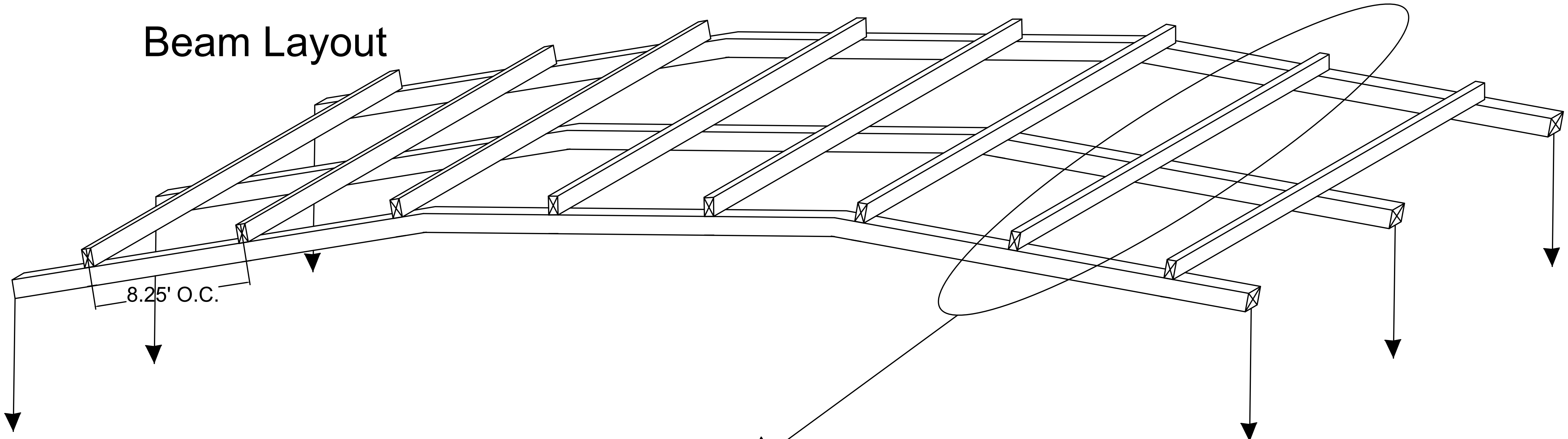
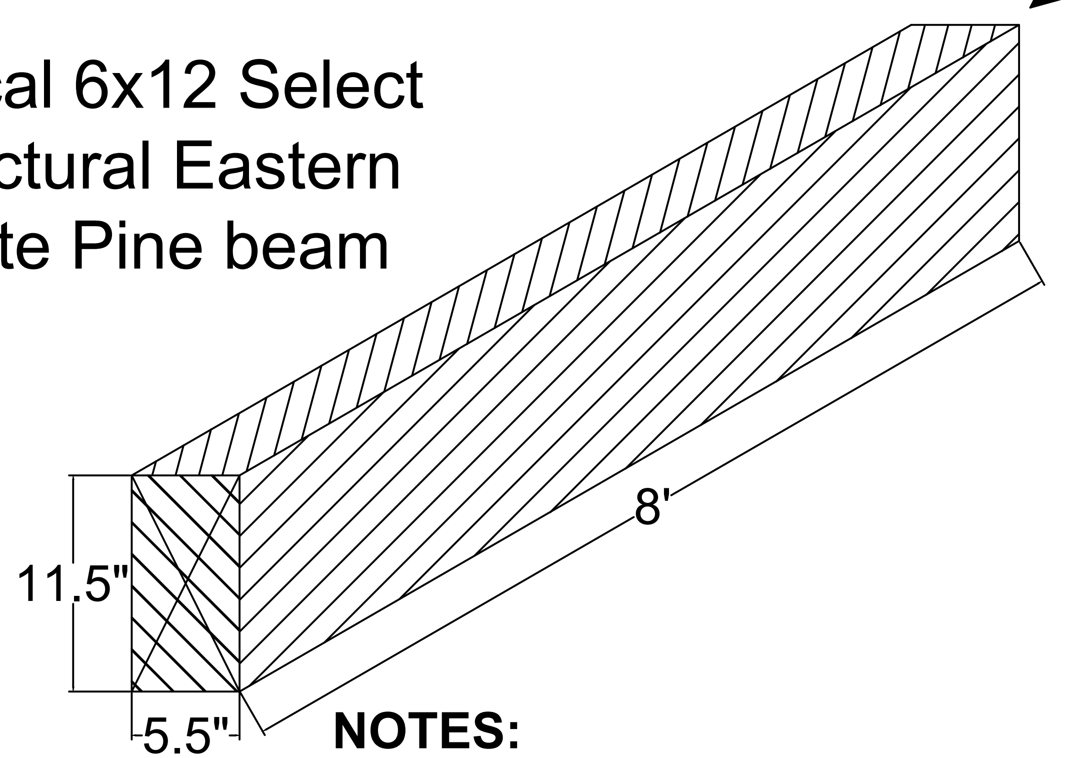
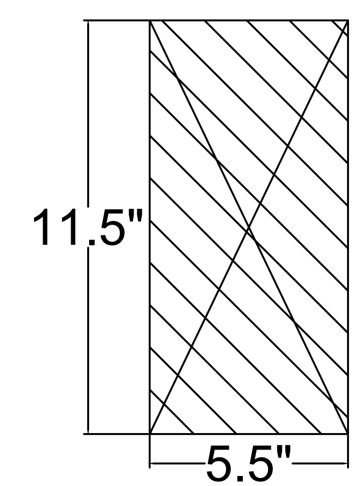
Beam Layout



Typical 6x12 Select Structural Eastern White Pine beam



Front View



NOTES:

1. **Timber design from LRFD method from Design of Wood Structures ASD/LRFD, Seventh Edition**
2. **Beam layout load to be transferred to foundation (see Figure No. 9)**

FIGURE NO. 13
Beam Detail and Layout

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: KF	PROJECT NO: MRC
DRAWN BY: AKA	DATE: 03/24/2018
DRAWING SCALE: NTS	

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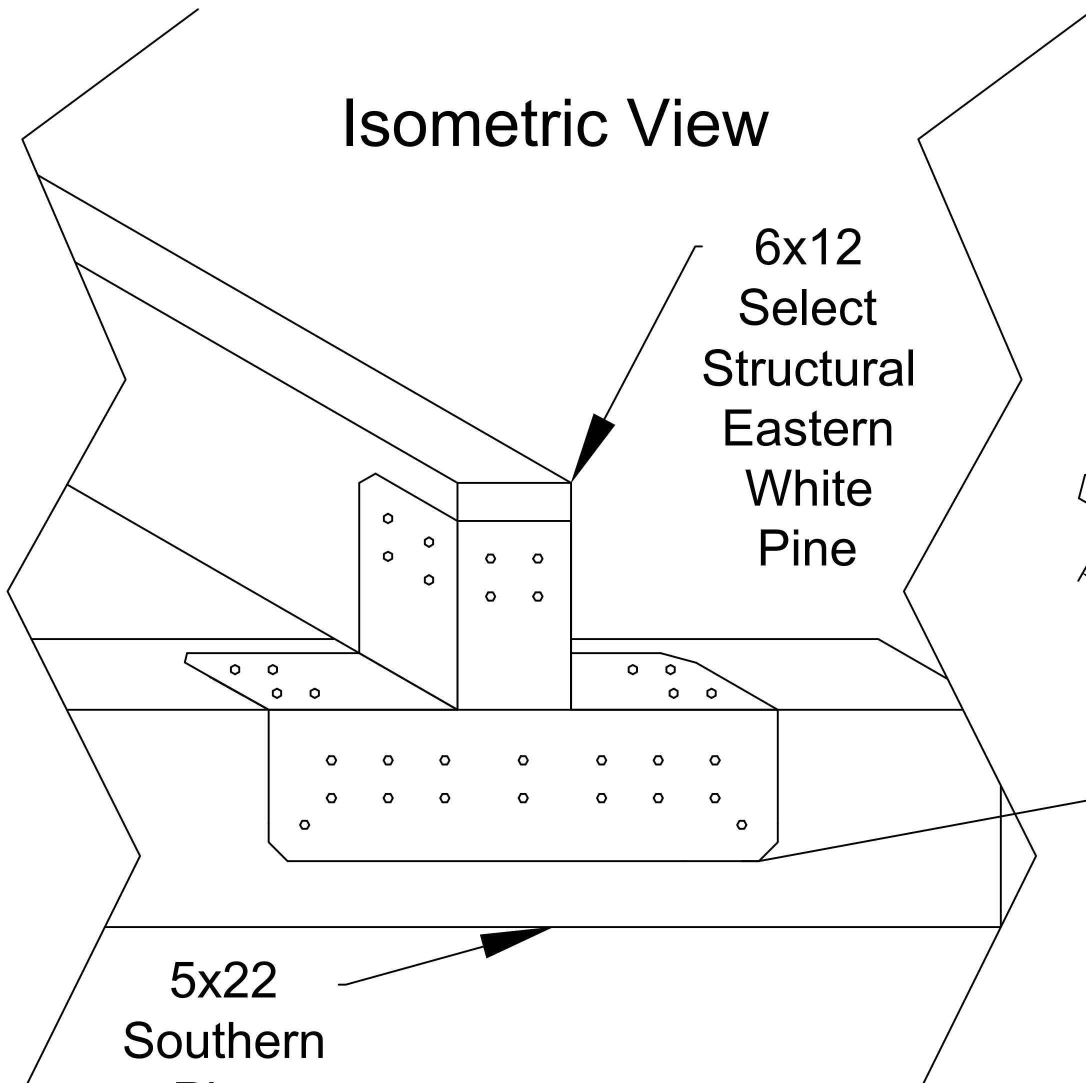
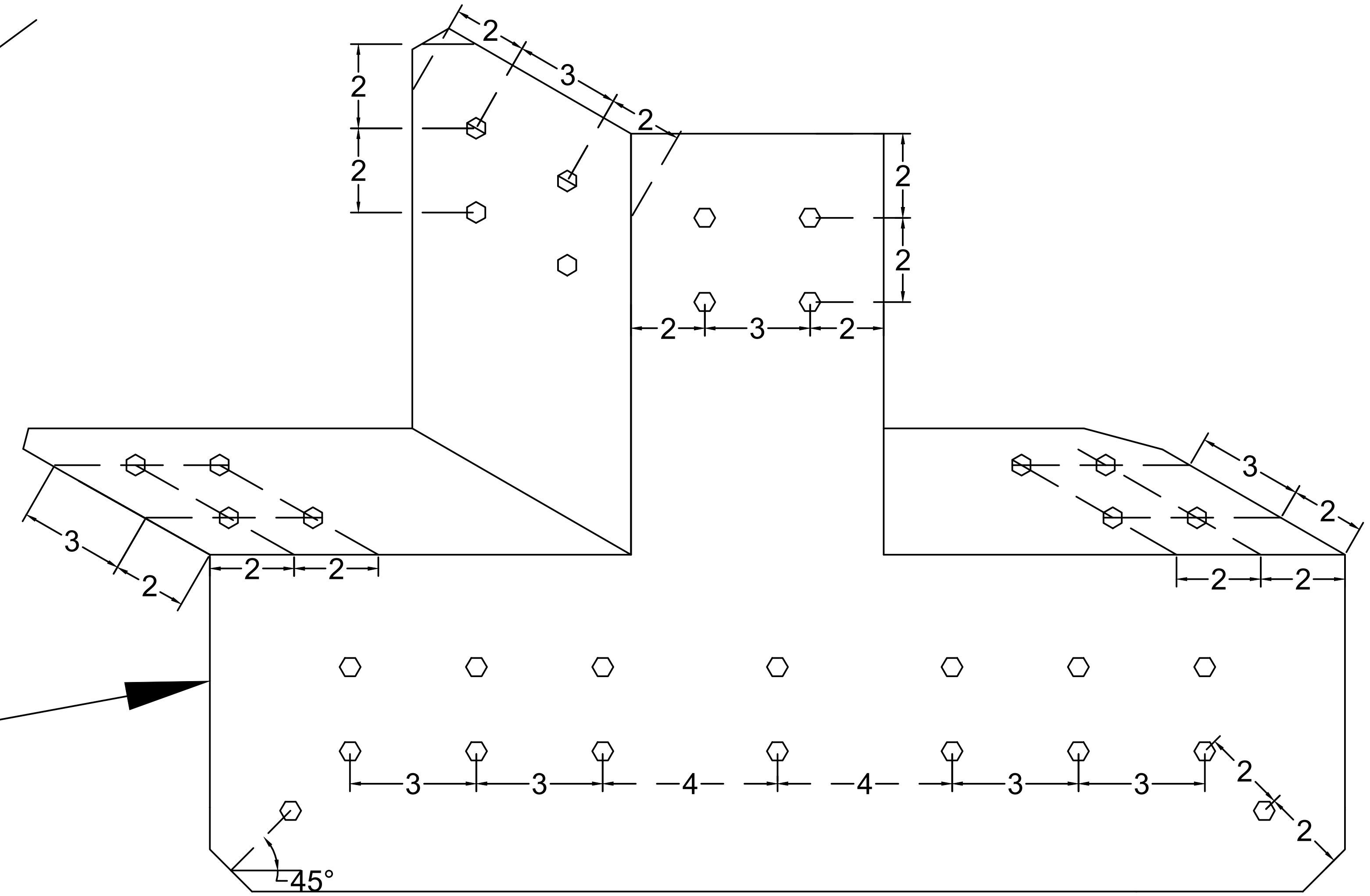
Isometric View



Connection Detail Dimensions



NOTES:

1. **Connection standard design from Simpson Strong Tie Wood Construction Connectors**
2. **Connection strength has not been evaluated with member stresses and must be checked before construction begins**
3. **All dimensions in inches unless otherwise specified**

FIGURE NO. 14
CONNECTION DETAIL – BEAM TO STRINGER

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: KF
PROJECT NO: MRC
DRAWN BY: AKA
DATE: 03/24/2018
DRAWING SCALE: NTS

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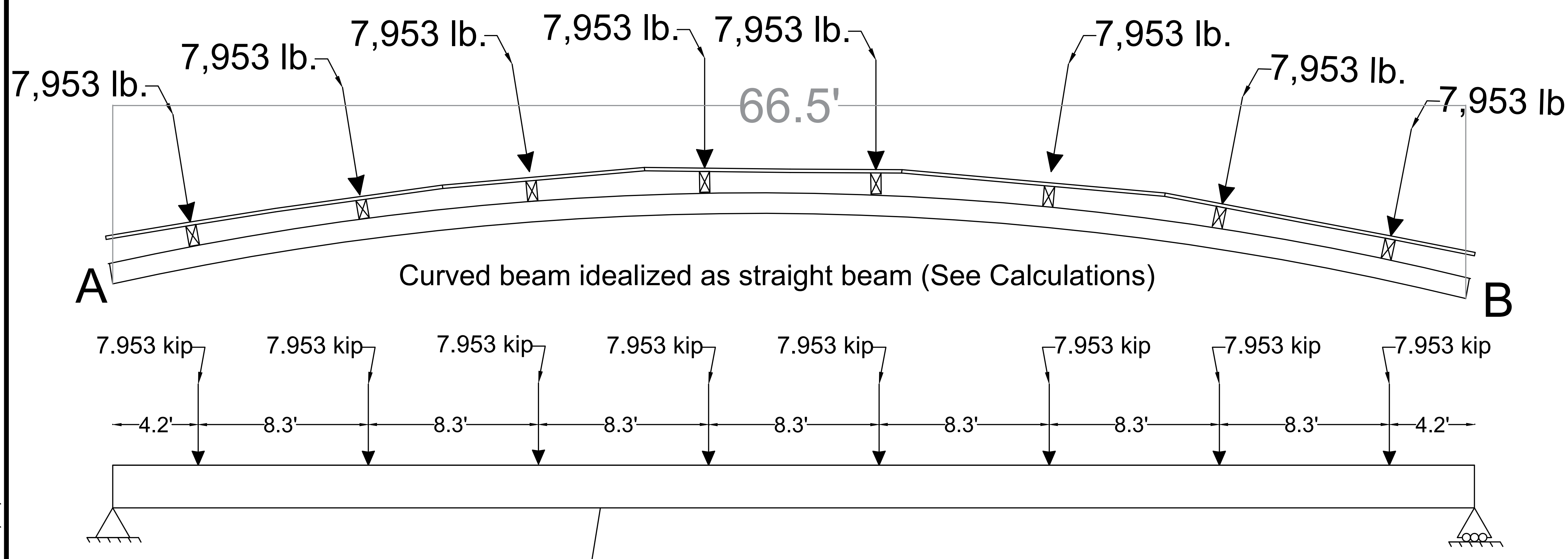

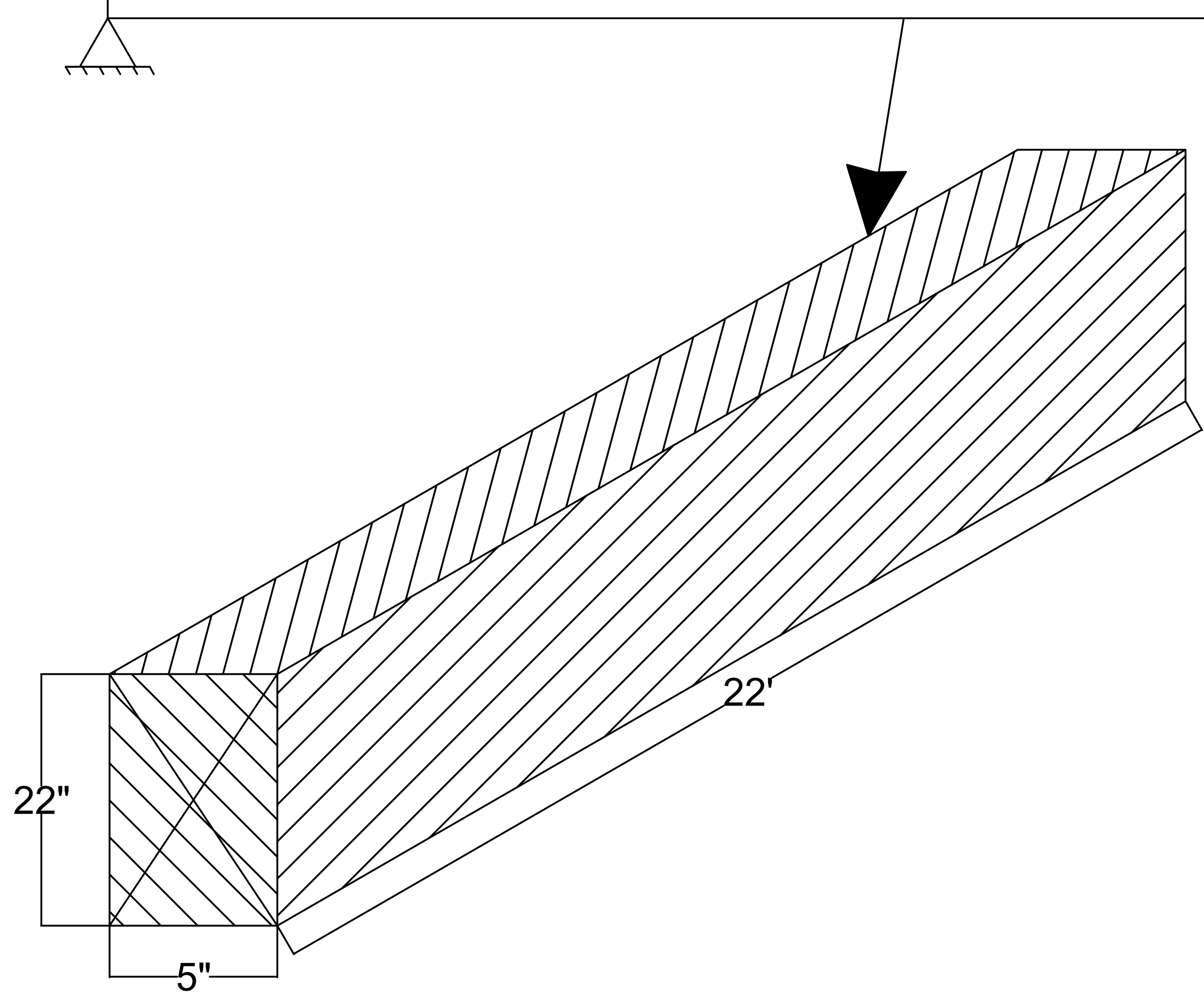

NOTES:

1. **Timber design from LRFD method from Design of Wood Structures ASD/LRFD, Seventh Edition**
2. **Due to the complex nature of an arch analysis, the pedestrian bridge's main supports (6x22 stringers) were idealized in three section**
3. **Proposed Bridge/Idealized Structure Load to be transferred to foundation (see Figure No. 9)**

FIGURE NO. 15
Stringer Detail and Layout

Manchester Riverwalk Pedestrian Bridge
Manchester Riverwalk Committee
Manchester
VT

CHECKED BY: KF
PROJECT NO: MRC
DRAWN BY: AKA
DATE: 03/24/2018
DRAWING SCALE: NTS

RIVERWALK manchester vermont

Appendix I - Client Agreement
Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

November 6, 2017

APPENDIX I

UVM Project Team Manchester Riverwalk
213 Votey Hall
33 Colchester Avenue
Burlington, VT 05405

November 6, 2017

Mr. Bill Laberge
Manchester Riverwalk
5046 Main St.
Manchester, VT

Re: Manchester Riverwalk *with* UVM CEE Senior Capstone Design Students
Project Objectives, Deliverables, Scope of Services, and Schedule Agreement

Dear Mr. Laberge:

We are looking forward to assisting you on the referenced project. This letter outlines our proposed agreement with you to meet the stated objectives with our proposed deliverables, scope of services, and schedule on the project. This reflects our understanding of the project after reviewing your preliminary project outline, and our subsequent preliminary evaluation of the requirements to meet your objectives.

Please review this proposed agreement to confirm that it meets your needs for the project and return a signed copy to us at your earliest convenience. If you find that we need to modify this proposal to address your needs, we would be glad to discuss that with you. Please contact Andrea Ameden by phone at (802-558-6439) or by email at (akameden@uvm.edu) so we can promptly arrange the discussion.

Please return a signed copy of this agreement to Andrea, as noted above.

Objectives

We understand the overall project objectives to be:

1. Provide design recommendations for a
    a. lower leven bridge crossing
    b. associated pathway designs
2. Preserve the Battenkill river ecology
3. Produce an opportunity to reuse a VTrans truss

Deliverables

We will provide the following:

1. Conditions and data inventory for:
    a. Topographic data of pertinent features including:
        i. Prior and current stream and drainage channel locations.
        ii. Soils and geomorphic evaluation relevant to the scour risk mitigation options.
        iii. Bridge and abutment engineering
        iv. Geometric design of the pathway and bridge alignments
2. Evaluate alternatives and prepare conceptual design drawings.
    a. Alternatives could possibly include:
        i. Try to design a bridge to use other than a VTrans truss bridge

ii. Design of pathway to wrap around and avoid going over the river
iii. Not implementing a bridge all together

3. Visualizations pertaining to our design created in AutoCad or other similar software
4. Summary report explaining the history, issues, design criteria, and recommendations. Including:
    a. Calculations
    b. Expected Costs
        i. Implementation cost
        ii. Upkeep cost
        iii. Life Cycle Analysis
    c. Recommendation for construction sequence and long-term maintenance

Scope of Services

We plan on the following scope of services:

1. Applicable design analyses
    a. slope stability
    b. structural analysis for variety of truss options from VTrans Adaptive Reuse Program
    c. hydrologic modeling
    d. geotechnical considerations
2. Alternatives (a. first choice, c. last choice)
    a. Do not use VTrans truss and design bridge unique to conditions.
    b. Redirect trail around river.
    c. Do nothing to existing pathway.
3. Permits necessary to begin work
    a. Zoning Applications (Town of Manchester, VT)
    b. River Management through Agency of Natural Resources (special permitting)
4. Review design and perform constructability evaluation.
5. Develop preliminary construction documents (plans and specifications).
6. Develop an Engineer's cost estimate.
7. Prepare summary design report which includes:
    a. Project history
    b. Site/Design issues
    c. Site conditions/needs
    d. Design criteria
    e. Expected costs
    f. Recommendations for construction and future maintenance.

Schedule:

Our project milestones and associated schedule are as follows:

- Preliminary design (~30% stage) documents and review: By Early December, 2017
- 70% stage design documents and review with community partner: By Mid February, 2018
- Final design submittal and presentation: By Early April , 2018

We will provide you with monthly project status reports.

APPENDIX I

Community partner input:
We request that you assist our student team with obtaining the following:

- Survey/topographical data for the location of the bridge
- Hydrological/geotechnical/ecological data
- Pedestrian traffic data around the area of interest
- Permission to enter private property for site reconnaissance
- Historical information of the land and river around the location
- Provide available design information for the current conceptual design
- Provide traffic control/protection when we perform topographic surveys on or near the roadway

Thank you for providing this opportunity for us to serve your community.

Sincerely,

UVM CEE Project Team Manchester Riverwalk

Andrea Ameden,
Team Project Manager
akameden@uvm.edu
(802)558-6439

August Arles
Kaitlyn Fuller
Shaun Roberts

Acceptance

This Agreement is accepted by ___________________________ on behalf of ____________________________ on __________________, 2017.
Typed name_________________ Typed name_________________

Appendix II - 100% Data Report
Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

Hydraulics + Hydrology

Figure 6 shows the FIRM Report from FEMA that we ran. This data provides us with an overarching flood insurance report and helps us determine the probability of storm flood waters reaching a certain level. This report shows 13 locations for a 100 year storm and the elevation ranges, which are 693 ft to 758 ft.

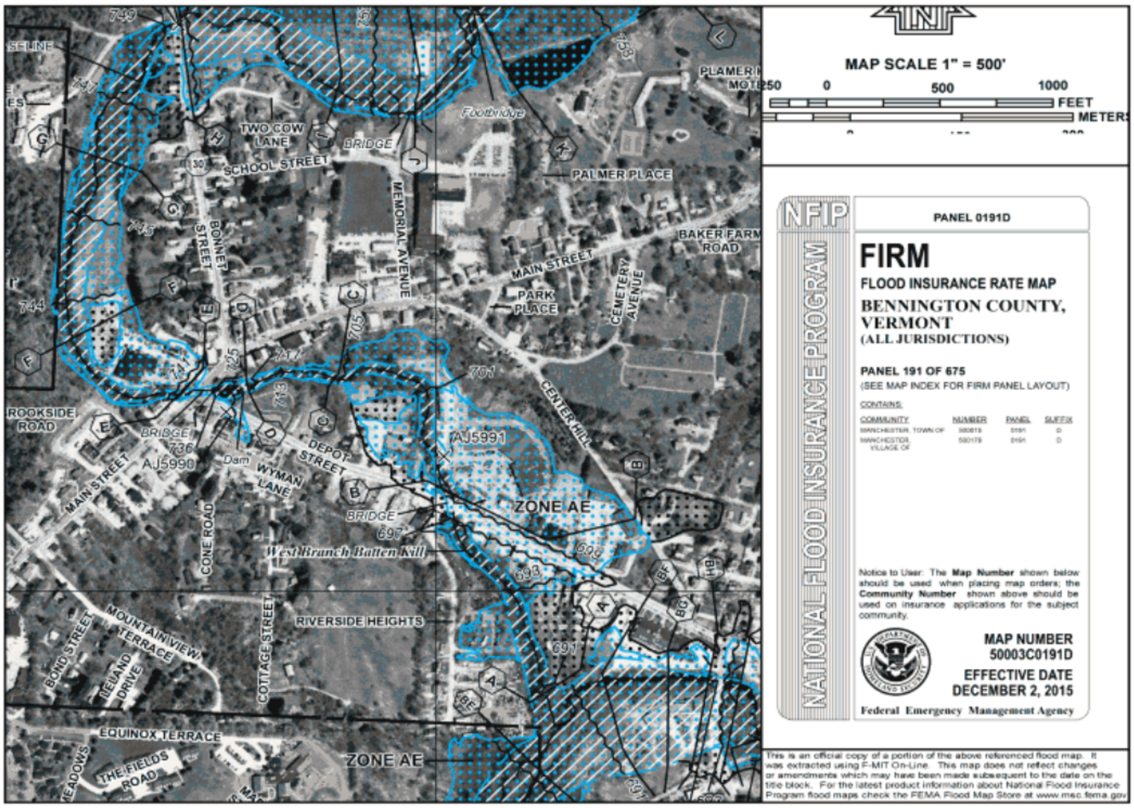

Figure 6: FIRM Report from FEMA

Figure 7 shows the data for flood levels for our particular site on the Battenkill River. This data will be useful, again, for designing for a 100 year flood, to ensure the bridge will hold up under these conditions.

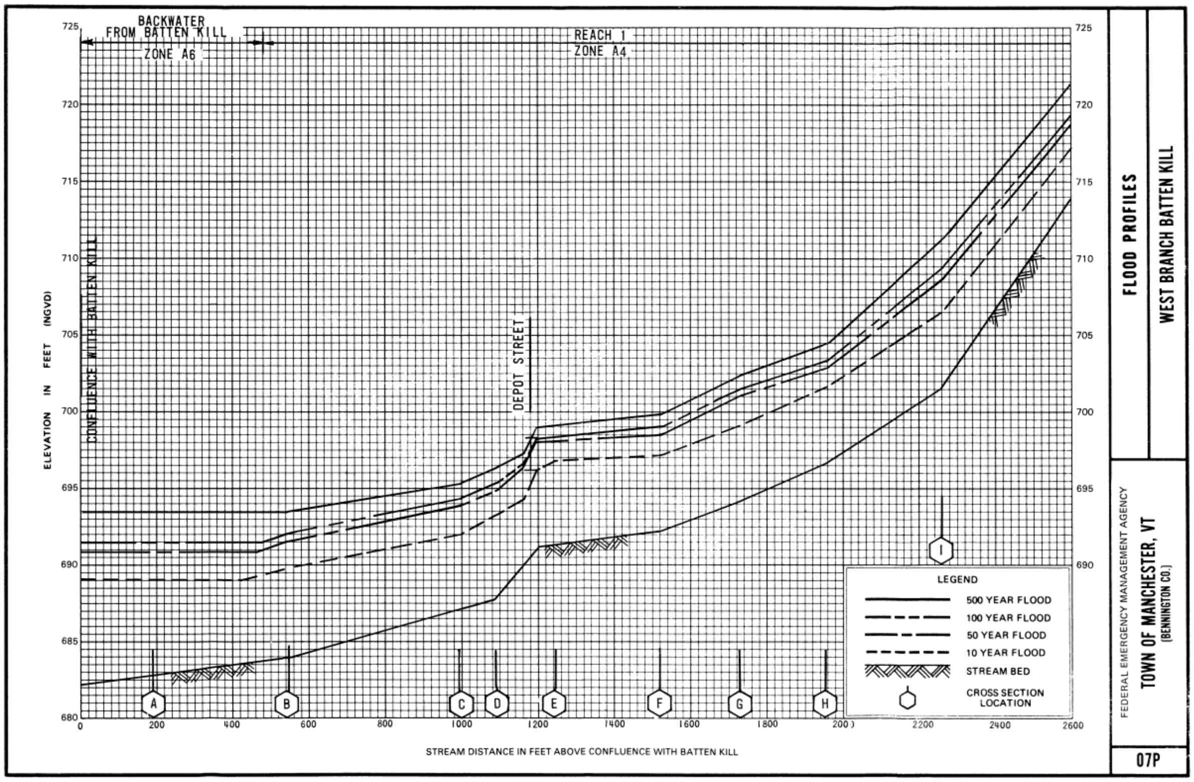

Figure 7: Profile of X-yr Flood Levels on the West Branch of the Battenkill River

Looking at Figures 8 and 9, the topographic maps, we will begin to further understand the flow of the water during massive flow stages. For example, when the snow starts to melt in the spring and the flow begins to rise it is important to understand which way the snow melt will run and how that will affect the volume of flow on the West Branch of the Battenkill River.

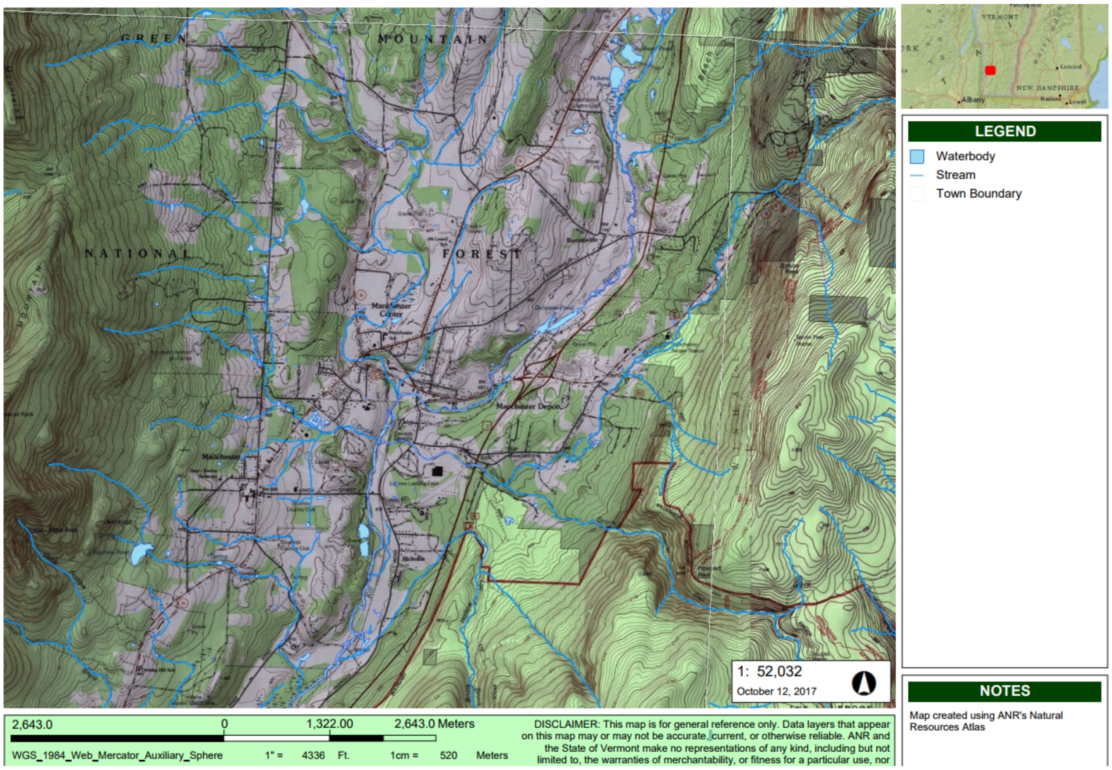

Figure 8: Topographic Mapping With Streams and Water Bodies of Surrounding Area

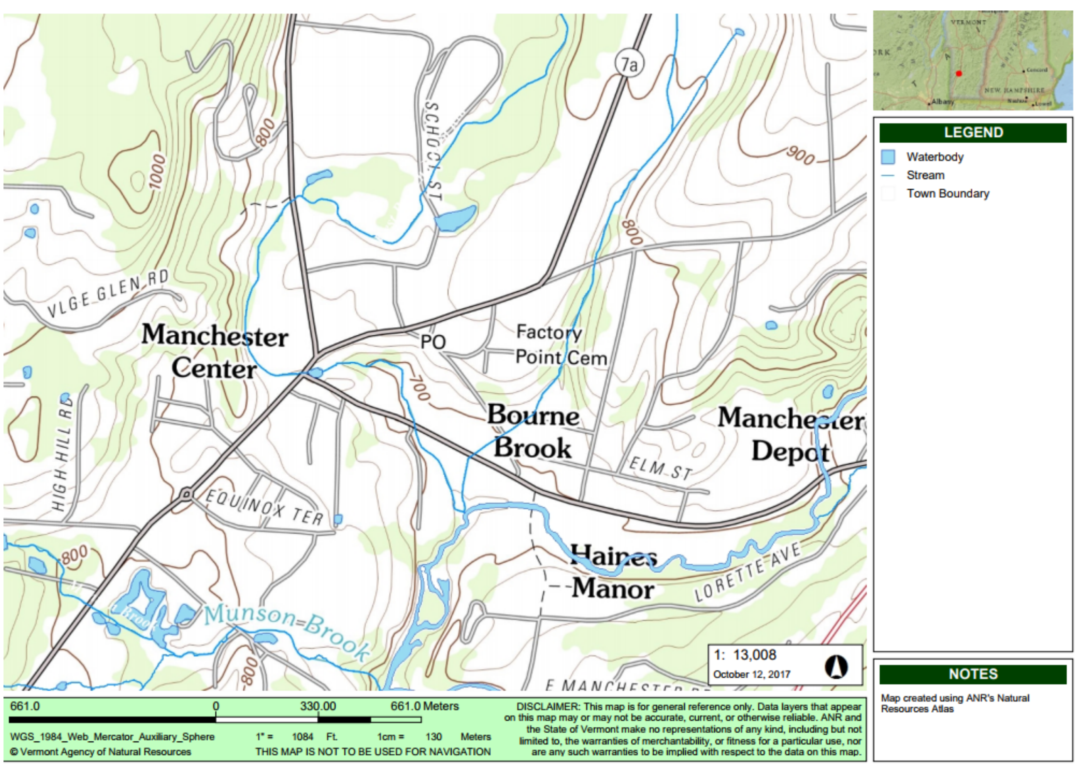

Figure 9: Closer View of Topographic mapping of surrounding area

Using the USGS website for streamstats, Figure 10 was created for the streamstats of the basin feeding into the Battenkill River. The Figure shows the outlined area in which our project falls, the exact location noted by the pin in the lower right.

Battenkill River Stats Report

Region ID: VT
Workspace ID: VT20171012174705411000
Clicked Point (Latitude, Longitude): 43.17652, -73.05599
Time: 2017-10-12 13:45:28 -0400

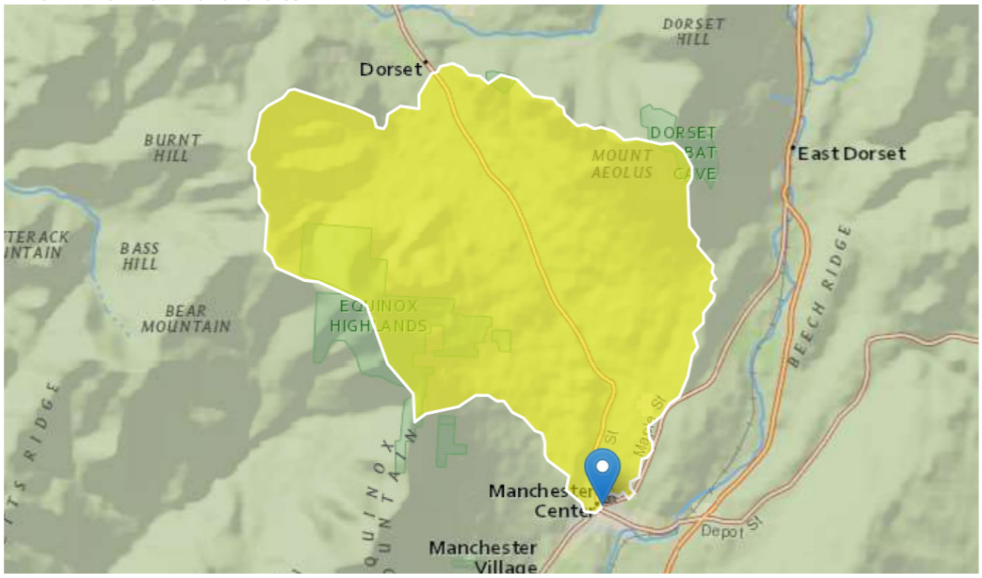

Figure 10: StreamStats Report of the Basin Feeding into the Battenkill River

Figure 11 provides the data table of basin characteristics from streamstats for our location.

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	452833.4	
CENTROIDY	Basin centroid vertical (y) location in state plane units	80190.4	
DRNAREA	Area that drains to a point on a stream	18.5	square miles
EL1200	Percentage of basin at or above 1200 ft elevation	49.8	percent
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	53.5	inches
OUTLETY	Basin outlet vertical (y) location in state plane coordinates	75305	
OUTLETX	Basin outlet horizontal (x) location in state plane coordinates	454795	
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	1.51	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	5.4	percent
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	3.56	percent

Figure 11: Basin Characteristics from Streamstats

Figure 12 describes the flow rate of the river at different storm events. This data is taken from StreamStats and will help with understanding the behavior of the river and what to expect with different storms so we can ensure our design maintains structural integrity.

Peak-Flow Statistics Parameters [Statewide Peak Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	18.5	square miles	0.18	689
LC06STOR	Percent Storage from NLCD2006	3.56	percent	0	18.5
PRECPRIS10	Mean Annual Precip PRISM 1981 2010	53.5	inches	33.5	70.4

Peak-Flow Statistics Flow Report [Statewide Peak Flow]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
2 Year Peak Flood	681	ft^3/s	389	1190	34.8
5 Year Peak Flood	1070	ft^3/s	600	1900	36.1
10 Year Peak Flood	1370	ft^3/s	738	2530	38.6
25 Year Peak Flood	1810	ft^3/s	925	3530	42.5
50 Year Peak Flood	2180	ft^3/s	1080	4420	44.9
100 Year Peak Flood	2590	ft^3/s	1240	5410	47.3
200 Year Peak Flood	3040	ft^3/s	1380	6670	50.8
500 Year Peak Flood	3710	ft^3/s	1590	8650	55.2

Peak-Flow Statistics Citations

Olson, S.A.,2014, Estimation of flood discharges at selected annual exceedance probabilities for unregulated, rural streams in Vermont, with a section on Vermont regional skew regression, by Veilleux, A.G.: U.S. Geological Survey Scientific Investigations Report 2014–5078, 27 p. plus appendixes. (http://pubs.usgs.gov/sir/2014/5078/)

Figure 12: Flow Statistics of the Battenkill at the Site Location.

Table 1. Stream Data Collected at Location of the Existing Abutments

Cross section at abutments			
Span width (ft)	**Pole height (ft)**	**Corrected height (ft)**	**Terrain**
0	6.9	3.7	Land
3	7.9	-1.8	Land
6	9.3	-3.2	Land
9	9.8	-3.7	Land
12	10.1	-4.0	Stream
15	10.8	-4.7	Stream
18	10.6	-4.5	Stream
21	10.7	-4.6	Stream
24	10.7	-4.6	Stream
27	10.6	-4.5	Stream
30	10.3	-4.2	Stream
33	10.2	-4.1	Stream
36	10.4	-4.3	Stream
39	10.7	-4.6	Stream
42	8.4	-2.3	Stream
45	8.6	-2.5	Land
48	7.2	-1.1	Land
51	5.5	0.6	Land
54	4.8	1.3	Land

Table 2. Collected Data for Bankfull Width, Bankfull Depth, Channel Bank Width

Upstream 1 Data		Downstream 1 Data		Downstream 2 Data	
BFW	32-33'	BFW	23-24'	BFW	21-23'
BFD	2-3'	BFD	2-4'	BFD	2-3'
CBW	27-29'	CBW	14-16'	CBW	17-18'

Table 3. Stream Data Collected ~100 ft below the Abutments

Cross section of Downstream			
Span Width (ft)	**Pole height (ft)**	**Corrected height (ft)**	**Terrain**
0	3.7	2.4	Land
14	4.5	1.6	Land
19	5.9	0.2	Land
22	6.3	-0.2	Stream
26	6.8	-0.7	Stream
29	7.0	-0.9	Stream
33	7.3	-1.2	Stream
35	7.6	-1.5	Stream
38	6.4	-0.3	Land
42	5.1	1.0	Land
45	4.5	1.6	Land
57	3.9	2.2	Path
65	1.6	4.5	Land
83	2.2	3.9	Edge Parking Lot
95	5.6	0.5	Parking Lot

Table 4. Calculated Slopes at Three Points surrounding the Existing Abutment Location

Slope			
	Length	**Elev. Change**	**%**
Abutments (A)	50'	0.5'	1.0
Abutments (B)	100'	1.3'	1.3
Downstream (C)	95'	4.3'	4.5

Figure 13 is an image of the cross section of the riverbed at the site of the proposed bridge. A survey rod and a pocket sight level were used to get the depth of the riverbed, from eyesight, at 3 foot increments.

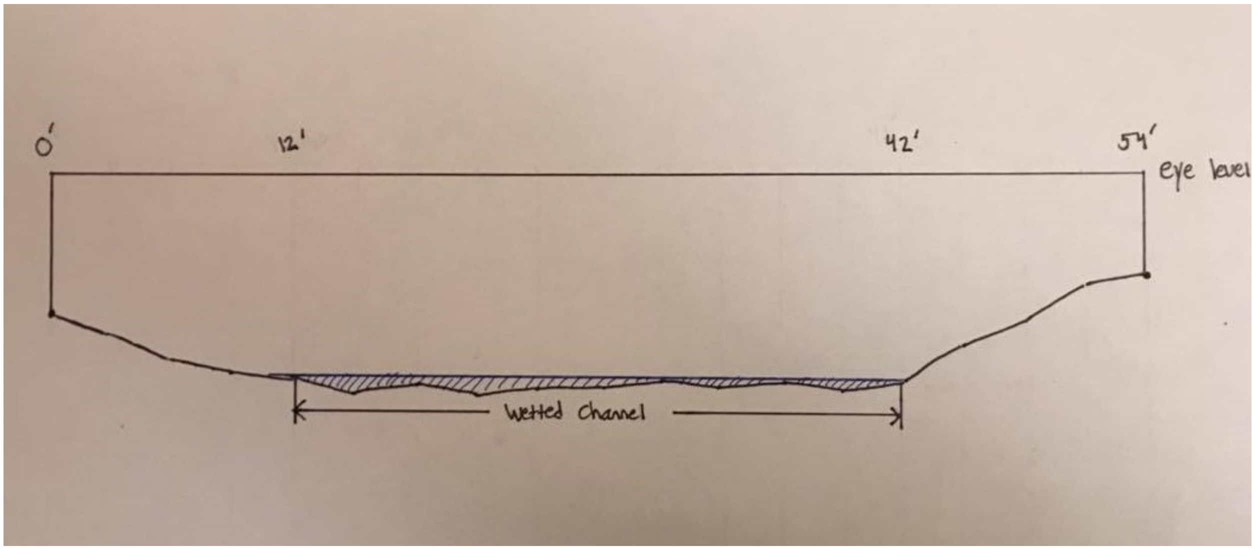

Figure 13: Cross-section of the Battenkill riverbed at the site of the project bridge. Survey was taken at 3 foot increments. Drawn with a scale of 1"=6'

A cross-sectional survey was also performed a few hundred feet downstream from the site. This section was not done with set increments, but at the drastic changes in riverbed elevation. Instead of just getting data of the riverbank, this survey went into the parking lot on the right side of the river. A drawing of this cross-section is shown in Figure 14.

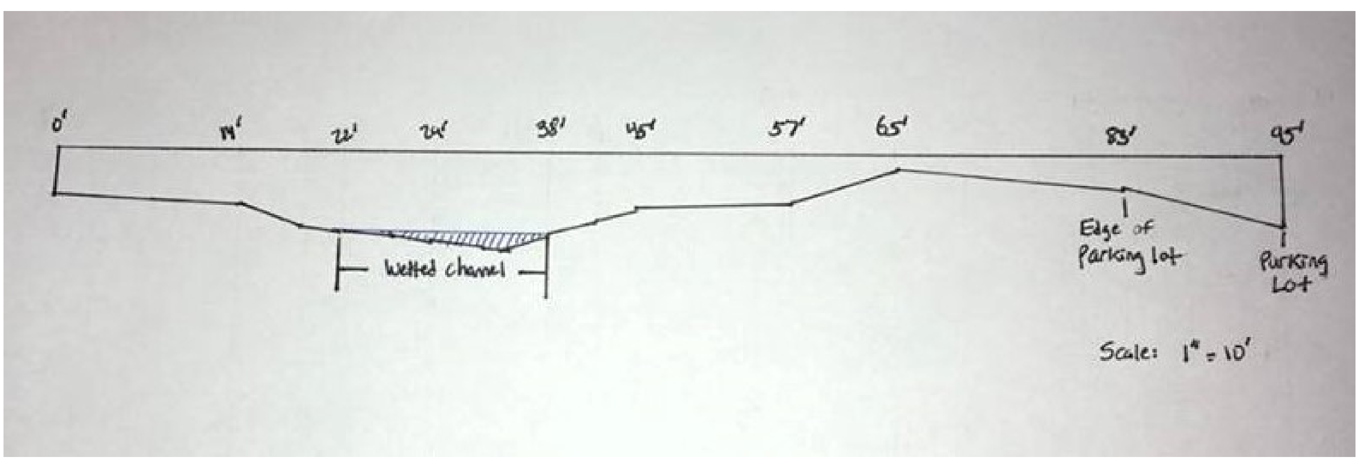

Figure 14: Cross-section of the Battenkill riverbed downstream from the project site. The drawing scale is 1"=10'

Structural

After visiting the site on October 25th, it was decided that a typical bridge structure is not feasible at this location. Therefore, the VTrans Truss Reuse Program is not an option for this project. There are two options that we are exploring for the stream crossing:

1. Nebraska Riverwalk
2. Hapgood Pond "Floating" Bridge (Figure 16 below)

The Nebraska Riverwalk, we have been told, has a unique "stepping-stone-like" crossing that would be perfect for our difficult site conditions. This is a solution we are looking into but there is still some research to be done on its effects on the river hydraulics and surrounding ecosystem, as well as its feasibility and constructability with the Manchester Riverwalk. Professor Richard Downer has reached out and offered his advice regarding this solution.

Hapgood Pond has similar site conditions (see below Figure 15) of a narrow stream channel with a large floodplain. In 2013, a "floating" bridge was implemented at this site (see below Figure 16) using pilings as anchors for the bridge (see below Figure 17). When properly installed, this gives the bridge an excellent chance of staying in place throughout season changes and intense storm conditions.

Figure 15: Hapgood Pond Stream Crossing Location (left) and upstream view of channel width (right) (Photo property of Ken Allard)

Figure 16: Hapgood Pond replacement, "floating" bridge structure (left) and adjustable sleeve piles supporting the structure (right) (Photo property of Ken Allard)

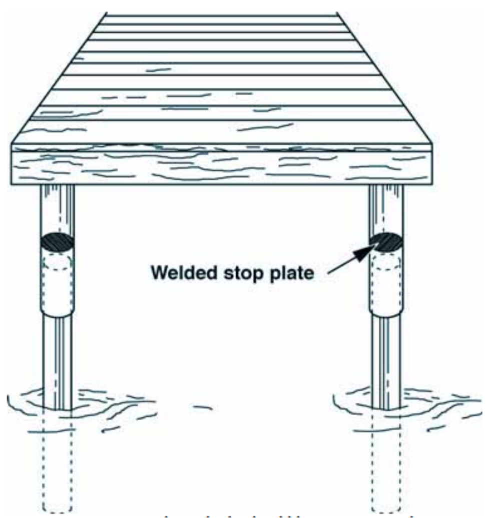

Figure 17: Sleeve piles with a stop on the exterior of the inside pile or on the interior of the outer pile to keep the outer pile (and bridge deck) at desired level.

The way these sleeved piles work is by setting a traditional pile initially and then fitting a hollow pile (with a bearing plate to hold the deck at its normal elevation above the water) over the first pile. As rising water pulls the deck up, the hollow pile will move up with the water and drop back down as the water level recedes. A closer look at the fitting between the two piles is shown in Figure 18 below.

Figure 18: Close-up of pile system: Square plate tops the hollow pile, round pile below anchors the bride (Photo property of Ken Allard)

A cable anchorage system is typically used in floating bridge structures but this was not an option for the Manchester Riverwalk project because the cables require adjustments seasonally (or more frequently) especially in areas with fluctuating water levels. This pile system is an excellent means of support for structures in areas where the water levels are fluctuating or are unpredictable because they allow vertical movement while still providing anchorage. Also, the piles reduce the twisting forces on the shore connections (and on connections between sections of floating structure - should we have a flood event where the bride would be floating).

The next stage to move forward is determining the required depth and diameter of the any pile. This will be dependent on the size of the bridge and the forces acting on it, as well as the geotechnical and hydraulic concerns that must be addressed first.

Geotechnical

On October 25th, we went to the MRC site and gathered soils data and other applicable data to aid the design of the foundation and abutments for the desired bridge. Figure 19 shows the existing scour that we measured on abutment 2. We noted the following from observing the abutments and foundation:

- About 4-inches of existing scour
- Subsurface exploration
    - 0”-6”: woodchip fill
    - 6”-12”: smaller stone fill, less wood chips
    - 12”-18”: very loose gravel
    - 18”-24”: larger stones, more dense
- Bedrock was hit with hand auger
    - Hole measured at 20.5”

Figure 19: Existing Scour on Abutments

Figure 20 shows the erosion on the riverbank. The way this river runs, the water eats down at the sides and causes them to erode. It is important to note the way the river is eroding because when a river starts eating at a bank downward, it exposes more soil that is sensitive and more easily eroded. The upstream conditions of the river were noted:

- Erosion currently about 3-ft high
- Roughly 30-degrees from channel to top of riverbed
- Landslide occurring on left side of river
    - Need some sort of slope stabilization
        - Possible retaining wall

Figure 20: Erosion on the Riverbank with 5' Girl (Kate) for Scale

Table 5 shows the data gathered from the hand auger exploration. Boring 1 was dug on the top of the foundation where the existing abutments are, Boring 2 was dug to the left of the foundation, and Boring 3 was dug on the right side of the river at the top of the riverbank. Notice the auger went further down than was recorded at the end, this is due to the soil being loose and collapsing in on the hole when the sampler was taken out of the whole to gather the soil data.

Table 5. Boring Log Data

Boring 1		**Boring 2**		**Boring 3**	
Depth (ft)	**Blows/6"**	**Depth (ft)**	**Blows/6"**	**Depth (ft)**	**Blows/6"**
0	5	0	6	0	7
0.5	7	0.5	6	0.5	7
1	6	1	7	1	5
1.5	6	1.5	7	1.5	6
2	8	2	4	2	6
2.5	9	2.5		2.5	7
Bedrock hit at 2.5' Hole measured at 20.5"		Bedrock hit at 2' Hole measured at 12"		Hole stopped and measured at 27", soil very consistent	

Appendix III - Task List and Work Breakdown Structure
Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

September 29, 2017

Objective:

To provide the project task list and work breakdown structure for the Fall and Spring Semesters for the Manchester Riverwalk Project.

Summary:

Work Breakdown Structure

Table 1 provides the tasks, descriptions, duration, and precedents that are present in our project. The total amount of days expected to spend on this project are 132; which is flexible to add / take away days where needed. (Projected completion based on 132 days: March 29, 2018)

Table 1. Task List

Task ID	Description	Duration (days)	Precedents
A	Project Selection	3	None
B	Project Identification/Scope	7	A
C	Data Collection (Part 1)	7	A,B
D	Data Synthesis	3	C
E	Data Collection (Part 2)	7	C,D
F	Preliminary Design - Footbridge	15	C,D,E
G	Preliminary Design - Riverwalk Path Modifications	15	C,D,E
H	Preliminary Design - Signage and Ecological Considerations	5	F, G
I	Modify Preliminary Design	10	H
J	Report to Client	30	I
K	Modify Design	20	J
L	Presentation Preparation	10	K

Figure 1 shows the flow of how each task will be approached, and in which order. We can use this information to find our critical path. Our critical path will alter depending on early / late starts, early / late finishes, and the durations of each task.

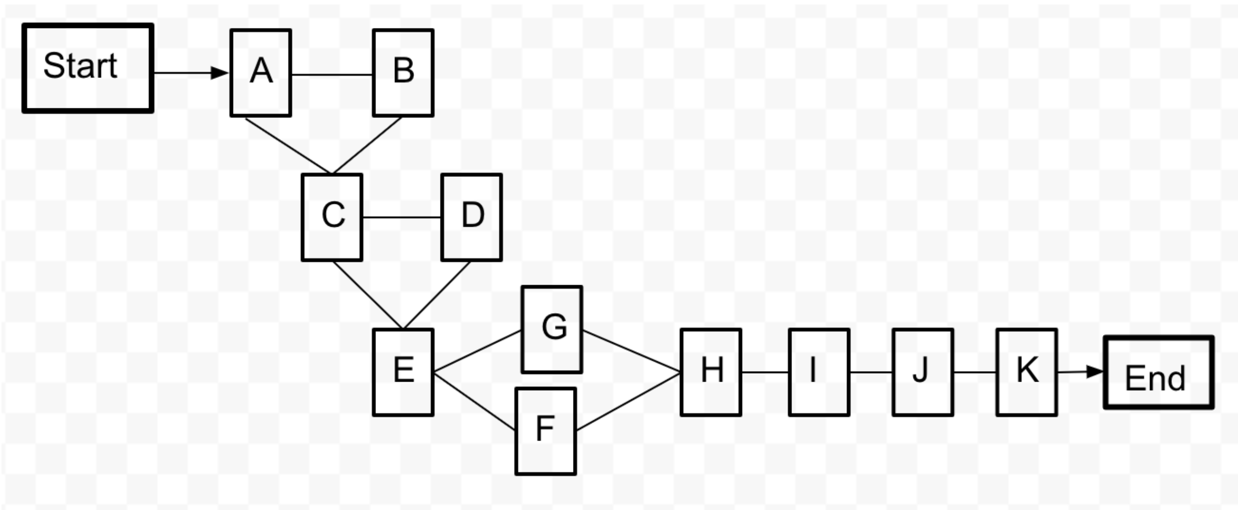

Figure 1. Project Work Plan

Figure 2 shows the iterations that, at this point, we expect to make throughout this semester and next based upon our tasks. These iterations are subject to change.

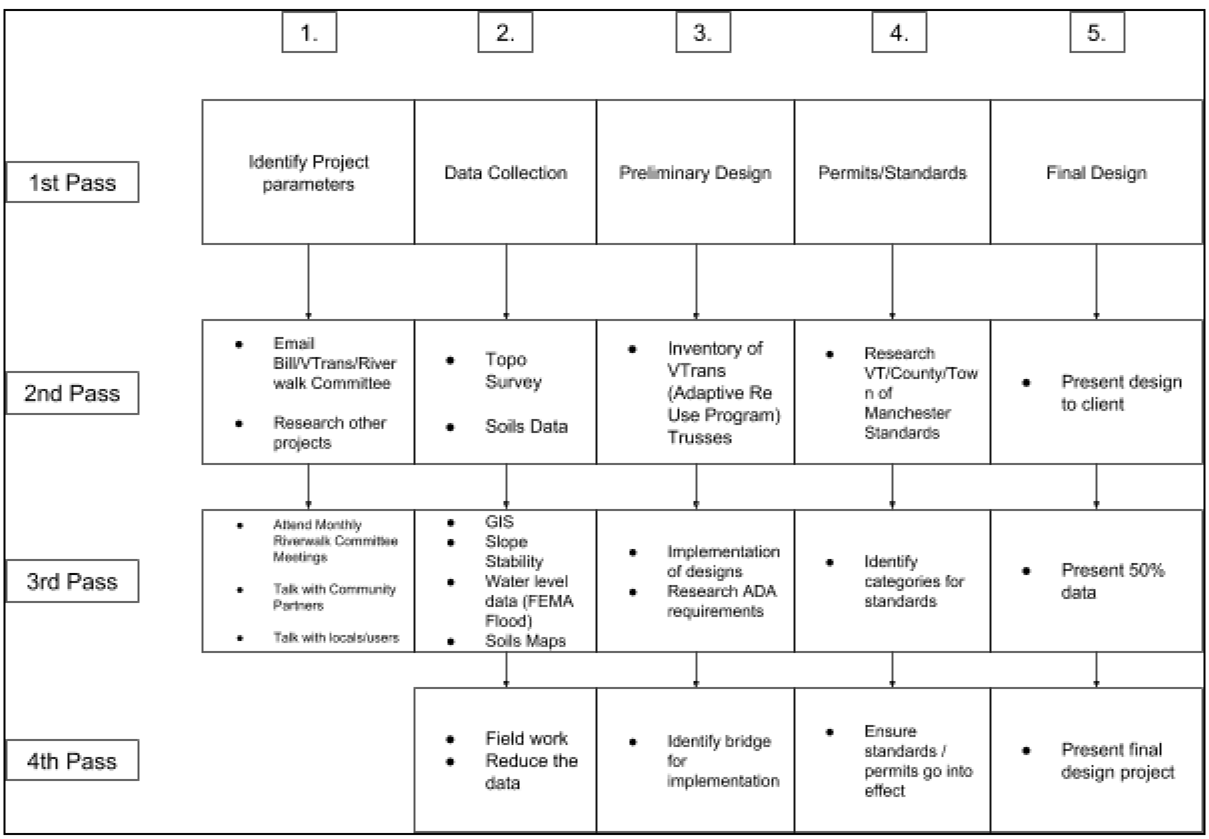

Figure 2. Work Plan Iterations

Project Task List

We've delegated each assignment due this semester to a team leader. This will help divide up the responsibilities. Table 2 shows the delegation of assignments to team members.

Table 2. Delegation of Member to Assignment

Team Member Heading	Assignment
-	Project Choice
-	Applicable Standards, Resources, Example Reports
Andrea	Project Meeting and Preliminary Work Scope Report and Video
Augie	Project Task List / Work Breakdown Structure
Shaun	Project Scope and Deliverables Report
Kate	50% Data Collection and Presentation Report
Andrea	Project Precedents and State of Practice Report
Augie	100% Complete Data Report
Shaun	Preliminary Design Report
Kate	Preliminary Design Report to Client

We have also decided to change our project managers regularly so that everyone can have a chance to experience leading the team. Table 3 shows the dividing of project managers for the entire year. Note, these are subject to change throughout the year.

Table 3. Member and Term for PM

Member	Term
Andrea	September - November
Augie	November - January
Shaun	January - March
Kate	March - May

Appendix IV – Cost Analysis
Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

April 18, 2018

Stage One: Site Maintenance	Item	Amount	Cost $ (2014)	Present Cost $ (2018)	5-year Future Cost $ (2023)
Survey	Topographic Survey, Minimum	1	610.00	896.09	1218.68
	Borings, Stake and Elevation Det.	1	1200.00	1762.80	2397.41
	Drawings Showing Boring Details	1	425.00	624.33	849.08
	Cased Boring Samples, 2-1/2" sample	4	282.00	414.26	563.39
Site Cleansing	Brush Removal, hand	2	7550.00	11090.95	15083.69
	Selective Tree Removal 14"-24"	3	1425.00	2093.33	2846.92
	Selective Tree Removal 26"-36"	2	1180.00	1733.42	2357.45
	Common Earth Excavation, 2 Cy Bucket	17	457.30	671.77	913.61
	Soil Hauling, 8 Cy Truck	2	812.80	1194.00	1623.84
	Backfill, Structural	2	113.28	166.41	226.32
Machinery	Auger, for borings	1	786.40	1155.22	1571.10
	Log Chipper, 22"	1	898.60	1320.04	1795.26
	Dump Truck	1	140.80	206.84	281.30
		Total	15881.18	23329.45	31728.06

Stage Two: Construction	Item	Amount	Cost $ (2014)	Present Cost $ (2018)	5-year Future Cost $ (2023)
Foundation	4000 psi Structural Concrete, CF	140	1232.00	1809.81	2461.34
	Load Bearing Metal Stud Framing	6	690.00	1013.61	1378.51
	Steel Decking, 1-1/2" thick	2	56.85	83.51	113.58
	Connection Bolts	16	80.00	117.52	159.83
	Rip Rap, Slope Protection, SY	10	625.00	918.13	1248.65
	Erosion, Sediment Control, Biodegrade Mesh	12	7.92	11.63	15.82
Bridge Frame	Glulam Southern Pine 5"x22"x66'	3	6150.00	9034.35	12286.72
	Cross Braces, White Pine 6"x12"x8'	8	1440.00	2115.36	2876.89
	18-Gauge Strong Tie	8	180.00	264.42	359.61
	Bracing, Studs @ 24" O.C.	6	20.04	29.44	40.04
Bridge Railing	Posts, White Pine 4"x4"x4'	34	4896.00	7192.22	9781.42
	Side Rails, White Pine 2"x4"x5.5'	24	3120.00	4583.28	6233.26
	Top Rails, White Pine 2"x4'x5.5'	24	3120.00	4583.28	6233.26
	Post Connectors	34	207.40	304.67	414.35
Decking	White Pine Structural Decking, SF	480	4608.00	6769.15	9206.05
	Subfloor, Plywood 1/2" thick, SF	480	604.80	888.45	1208.29
Labor	Manual Worker, 12 Day, 8 hr. day	3	7032.00	10330.01	14048.81
	Foreman, 12 Day, 8 hr. day	1	7329.60	10767.18	14643.37
Machinery	Work Bench	1	915.00	1344.14	1828.02
	Table Saw	1	3225.00	4737.53	6443.03
	Drill	2	110.00	161.59	219.76
	Nail Gun	2	44.70	65.66	89.30
	Jointer	1	1775.00	2607.48	3546.17
Soil Rehabilitation	Backfill Planting pit, by hand, CY	6	225.00	330.53	449.51
		Total	47694.31	70062.94	95285.60

Stage Three: Finishes	Item	Amount	Cost $ (2014)	Present Cost $ (2018)	5-year Future Cost $ (2023)
Bridge	Refinish Wood floor, sand, 2 coats poly, was, hard wood, max, SF	480	2380.8	3497.40	4756.46
Railing	Sanding and Finishing, 2 Coats Polyurethane, SF	496	1240	1821.56	2477.32
		Total	3620.8	5318.96	7233.78

Stage Four: Maintenance	Item	Amount	Cost $ (2014)	Present Cost $ (2018)	5-year Future Cost $ (2023)	15-year Future Cost $ (2033)
Bridge	Refinish Wood floor, sand, 2 coats poly, was, hard wood, max, SF	480	2380.8	3497.40	4756.46	11093.75
Railing	Sanding and Finishing, 2 Coats Polyurethane,SF	496	1240	1821.56	2477.32	5777.99
Soil Rehabilitation	Backfill Planting pit, by hand, CY	6	225	330.53	449.51	1033.55
Labor	Manual Worker, 2 Day, 8 hr. day	3	1172.00	1721.67	2341.00	5461.14
		Total	5017.80	7371.16	10024.29	22366.43

Project Cost	**2014**	**2018**	**2023**
Site Maintenance	15881.18	23329.45	31728.06
Construction	47694.31	70062.94	95285.60
Finishing	3620.80	5318.96	7233.78
Maintenance	5017.80	7371.16	10024.29
Total Cost	72213.09	106082.51	144271.73
Total Cost	$73,000.00	$106,100.00	$144,300.00

The cost analysis for our project was completed using a 2014 RSMeans Construction Data Unit Cost book. The cost was broken up into four main stages, stage one being site maintenance, including clearing trees, scrubbing, and preparing the soil for building the foundation. The cost for the site maintenance includes labor, tools, and operation costs. Stage two is the construction costs, this included pouring the concrete for the foundation, the cost of the wood for the bridge and labor for the whole construction process. Some of the costs for construction included labor, however there were some that did not so we also included a standard labor cost of 4 workers for 12 days. Stage three was the cost for finishing the bridge, this included preparing the bridge for weather, i.e. sanding it down and putting a waterproof layer to prevent rotting in the wood. We added the predicted maintenance of the bridge as part of the cost analysis for up to five years, however we anticipate that more maintenance will be needed in about 15 years.

Since we used a book from 2014 we used an interest of 8% and a multiplication factor of 1.469 to bring those costs to present worth, 2018, and since we anticipate the project not being built until 2023 multiplied the costs again by 1.469 to bring to a future cost in 2023.

The final cost of our project was **$106,100.00**, and we anticipate there being a maintenance cost of **$22,400** in 15 years.

Appendix V - Project Precedents and State of Practice Report Vol. II

Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

October 27, 2017

Table of Contents

1.0 OBJECTIVES

To provide the research conducted for this project and how it relates to the ecological impacts, hydraulics, geotechnical, and structural design and analysis needed. The priority of this project is the hydraulic research and data, because the geotechnical (foundations) and structural (bridge) aspects rely directly on the hydraulic analysis conducted to ensure this river is able to accommodate a bridge placed across it.

Figure 1. Existing Site Conditions Upstream of Proposed Bridge Location
(Fallen Tree Acting as an Interim Bridge)

2.0 RELEVANT RESULTS

2.1 Ecology

2.1.1 Summary of Research

A major part of research that we have dedicated to this bridge project has been the conservation of the stream itself and the surrounding ecology. Standards set in place by the Vermont Agency of Natural Resources (ANR) and the Department of Environmental Conservation will be closely referenced throughout the design and build process. Most of the statutes and standards of practice that are in place are from the Vermont State government and ANR. While researching, two main sources, the Vermont Statutes on the Vermont General Assembly website and the Environmental Protection Rules, explained in detail the modern standards that are set place in conservation of the ecology.

The Vermont Statutes, Title 10: Conservation and Development explains the acts that ensure every and all projects are met with some standard on how to conserve the environment that the project may be affecting, either directly or indirectly. The standard that will be of focus is in Chapter 111: Fish § 4607. Obstructing Streams. This section states that in order for a project to be signed off by the Commissioner, one cannot prevent the passing of fish life or any other aquatic life in the stream, or inlet and outlet of a natural or artificial pond. This is pertinent to our project because we must consider the natural habitat of the fish and aquatic life in this section of the river and ensure we will not be cutting any part of the river off in the design of the Manchester Riverwalk pedestrian bridge.

The second source that we are using, the Environmental Protection Rules, has two relevant parts. The most useful part is that it sets the standards and statutes that must be obeyed when designing a bridge that crosses water. Also, it features a stream alteration general permit that must be followed when designing a structure that spans the length of a stream or river, which in our case we are.

The Environmental Protection Rules, by the ANR, dedicates three chapters for the protection and conservation of riverways, watersheds, and wetlands. Chapter 27: Vermont Stream Alteration Rule implements rules and standards to "promote and protect the natural maintenance and natural restoration of dynamic equilibrium." Chapter 27 states that a person cannot change the physical characteristics of the stream, e.g. the channel width, channel depth, meander pattern or the slope of the river; any changes that occur to that are not natural will have adverse effects on the stream. These changes become a huge potential hazard to public safety due to the erosion and scouring that may occur.

Chapter 27 also explains that no alterations can occur to the stream that affects the course, current, or cross section of the river by excavating, moving, or adding fill of ten or more cubic yards. The DEC explains that additions or excavations to the stream bed and bank can lead to a concern for public safety due to increasing the flood potential and affecting wildlife and fish that use the river. Although, there are times when the Secretary or Commissioner can issue a general, or specific permit that allows for the alteration of the stream, but that will be unnecessary for this project.

2.1.1 Reason for Stopping

The standards related to ecological conservation of the site mostly revolve around the river itself and the irreversible damage that would occur if these standards weren't not followed. All sources found had similar comments regarding the protection of wildlife and the preservation of the shape of the river. Due to the repetitive research results, it was evident that a sufficient research level was achieved.

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2.2 Hydraulics / Hydrology

2.2.1 Summary of Research

Information relating to our project in Manchester was gathered through extensive research; Government manuals that contained standards that should be taken into consideration when designing the bridge. One concept that kept reappearing in the research is that hydraulics should be a primary consideration in determining the bridge design. The hydrological data that is taken from a site will determine the minimum length a bridge should be, as well as the height the bridge should be above the water's surface. As far as designing the height the bridge must be above the water, there are different standards that can be chosen. An appropriate frequency that will be the basis of design can range from a 2-year event all the way up to a 100-year event. For a small pedestrian bridge, the standard is that the conditions, such as backwater, after the bridge is installed must be the same as if there was no bridge there.

The Stream Alteration General Permit cites two main standards that are evaluated when considered for a general permit. These standards are the Equilibrium Standard and the Connectivity Standard. Both of these standards deal with evaluation of the river for risks; mentioned in the previous section such as scour, flood and wildlife accessibility. The Equilibrium Standard states that any alteration cannot change the physical shape of the stream so that it departs from, further departs from, or changes the ability for the stream to meet normal channel width, depth, and slope associated with normal equilibrium. Tests can be done for this, once all the alterations are done, by showing that the water flow and any debris that will be transported by the stream channel in a way that the stream maintains the dimension and slope with no unnatural raising or lowering of the channel bed.

Figure 2 below shows the cross section of the stream that the bridge will likely span. It is important to note that at this location has a change in elevation. This results in a larger flow-rate which creates a higher possibility for scour and incising. These physical changes to the characteristics of the river will have detrimental effects. A river that is incised refers to the eroding of the river bed due to a constriction point that prevents the river from expanding in the horizontal direction; which causes the the turbulence of the river to eat away at the river bed.

Figure 2. Downstream Cross Section of Stream at Potential Bridge Location

The second standard is the Connectivity Standard. This standard explains that an activity shall not change the physical stream forms and activity shall not alter the channel hydraulics, bank stability, or floodplain connectivity where it affects the horizontal alignment of the streambanks or the vertical profile of the stream (through erosion or depositions).

The final resource used, the Vermont Flood Hazard Area and River Corridor Rule. This resource presents the basic standards for building a structure in a floodplain. Although, most of the standards apply to building-like structures, it is important to recognize them as they are in place to avoid the loss of life and property damage.

Since there will be excavation of the existing ground and the addition of fill, the No Adverse Impact Standard (NAIS) will be an important reference. This standard states that development shall not decrease flood fringe storage capacity; meaning that if you fill in part of the flood plain, you need to add compensatory storage to offset the impacts of the proposal.

Standards pertaining to flood plains will play a major role into in the reevaluation of the site and bridge design. The existing site has a major floodplain on the river left bank where the bridge would connect to the land. Due to the location of a nearby parking lot, we cannot move the bridge any further downstream because that would create a dam that may cause flooding of that parking lot. The next step, currently, is to conduct a hydraulic analysis with our collected data and make a model in HY-8. This model is crucial to the reconstruction and design of the Manchester Riverwalk.

Federal regulations govern how a bridge is designed if it crosses a waterway in the United States. These regulations for floodplains were derived in 1977 from Executive Order (EO) 11988. This order says that a bridge must not impact a floodplain, both short-term and long-term. Included in this order is an eight-step, which are described below, process that agencies should carry out as part of the decision-making process.

1.) Determine if a proposed action is in the base floodplain (that area which has a one percent or greater chance of flooding in any given year).
2.) Conduct early public review, including public notice.
3.) Identify and evaluate practicable alternatives to locating in the base floodplain, including alternative sites outside of the floodplain.
4.) Identify impacts of the proposed action.
5.) If impacts cannot be avoided, develop measures to minimize the impacts and restore and preserve the floodplain, as appropriate.
6.) Reevaluate alternatives.
7.) Present the findings and a public explanation.
8.) Implement the action.

2.2.2 Reason for Stopping

A professional source mentioned regulations as to how long the bridge span must be as well as how high above the water the bridge is to try and avoid backwater from happening. These standards come from designing for a certain type of flood event. A flood event is the probability that a certain rain event could happen in one year. A 2-year storm has a 50% chance that it will happen in a year, where as a 100-year storm has a 1% chance of happening in a year. Each of these flood events will cause a river to flow at different levels, which means that a bridge would need to be a certain height above the river depending on what flood event is used. Figure 3 shows the upstream rapids of the proposed bridge location.

Figure 3. Rapid Upstream of Proposed Bridge Location

After doing extensive research, the results started to get repetitive. This is when the realization hit that it would be a good time to stop researching and start putting all of the research together. Some key points that were taken away were the ideas of scour, backwater, and design flood event. Scour is the erosion of soil, or other material, that surrounds a foundation by water. This erosion can impact the stability of the structure, which could eventually cause the structure to fail. Backwater is caused when water is not allowed to flow like it previously could and starts to back up. The water hits a feature, such as bridge abutments, the flow is constricted which causes water levels to rise upstream. This type of action can cause the floodplains upstream to increase in size and allow it to flood with a more probable storm event.

2.3 Geotechnical

2.3.1 Summary of Research

Helpful information in regards to geotechnical data is best acquired from professionals that are familiar with the area and the scope of the project. For example, Cassidy Cote, with Vermont Agency of Transportation, visited the site with us to give his expertise. From what he could see, there is work that needs to be done related to the geotechnics of this project. For starters, the abutments are sliding into the river and have about 4 inches of scour (seen in Figure 4); they will have to be completely taken out, the foundation re-dug and re-poured, and then backfilled with gravel material, in order to provide a reliable and safe foundation for the pedestrian bridge.

Figure 4. Current Scour on Existing Abutments

The existing conditions of the site are not up to par with the expected outcome of the project. There are steep banks on either side of the river, one of which on the left side of the river has undergone a landslide already, seen in Figure 5. Cassidy observed the site and said to expect another landslide within the next year, because the fill put into place to stabilize the bank is too small of stones. A volunteer committee organizes this project, where all funds are donated so the budget for this project is minimal, while the work needed is at a maximum.

Figure 5. Site of Predicted Landslide

By observing the site, it is apparent that the river is eating away at the banks, rather than out and flooding the surrounding land. This is not ideal because once it starts eating down vertically it is hard to prevent it from continuing to do so because the exposed soils become more sensitive with rainfall and river flow. According to the Pedestrian Bridge Design article, to prevent scouring, it is best to put in a deep foundation, which should be done in this case to prevent further eroding and scouring of the abutments. Figure 6 shows the eroding of the riverbank.

Figure 6. Eroding of the Riverbank.

In designing the abutments, according to the next generation library article "Abutments in Bridges", a factor of safety against failure should be at least 2, and a factor of safety against overturn should be at least 1.5. To ensure optimum stability and safety, the backfill should be as granular as possible with optimum moisture content between 7 and 10 percent. This will be considered in the design of the foundation to ensure maximum safety for the users. The design will start with considering the borehole logs gathered.

The FHWA standards will provide step-by-step help in designing a foundation that meets the requirements of the site. For bridge foundation design, AASHTO LRFD Section 10 is suggested for optimum design.

2.3.2 Reason for Stopping

The research was stopped after gathering standards and suggestions of how to design a pedestrian bridge foundation. There is no need to go into strenuous detail for this because it is not a unique situation for building a foundation, it will just require more data gathering and analysis to match standards than other site locations.

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2.4 Structural

2.4.1 Summary of Research

After some initial research with Google, applicable information was found from Washington State Department of Transportation LRFD guide specifications for the design of pedestrian bridges as well as the VTrans Structure Design Manual. To broaden and get more reliable sources, online databases through the UVM Library were explored. These proved to be extremely less useful than Google because all of the information found there pertained solely to research into innovative types of structures and new materials. This is not applicable to our project because we are looking for basic design standards to implement on a small-scale, simple pedestrian bridge. Google also proved useful to finding similar, or like-minded, projects and will be of great use as our team steps through the design process for the first time.

From the VTrans Structures Design Manual, clear specifications are given for pedestrian bridges specifically located on trails. These guidelines will be followed first and foremost. The live loads from maintenance vehicles need not be applied for trail bridges because they will not be plowed. The snow load on bridge decks, according to the VTrans Bridge Design Manual (which references LRFD section 3.9.6), do not need to be considered in designs (for an uncovered bridge) unless an avalanche causes the snow load or if the snowfall accumulation creates a load of 70 psf or more. Manchester, VT is safely out of the Green Mountain Range and for extreme snow loading cases 50 psf may be used.

From the Washington State Department of Transportation LRFD GUIDE SPECIFICATIONS FOR THE DESIGN OF PEDESTRIAN BRIDGES, many important requirements were noted. The uniform pedestrian loading was found to be 90 psf. According to this manual, wind loading is considered for the possible flexible nature of pedestrian bridges (as well as any traffic signs that may be mounted from it). Because our bridge is on a trail, is within an enclosed valley and will be relatively short in height from river surface, the additional loading due to heavy wind and traffic signs as a live load may be neglected. Wind will be considered as a fatigue live load for the pedestrian bridge.

A similar project was found (via Google) of the design of a pedestrian bridge. This was completed by engineering students at the University of Toledo in Ohio. ADA accessibility is a requirement for any state or federally funded structures. While state and federal funds have not played a role thus far in the Manchester Riverwalk, these will be inevitable for the successful completion of this project. The ADA requirements implemented by the University of Toledo students include:

- 1 to 12 slope of the deck
- 60” by 60” landing

The sources that will be heavily used in consideration of our project and the design of the structure are the AASHTO Bridge Specifications and the ASCE Minimum Design Loads for Buildings and Other Structures. The VTrans Structure Design Manual does a great but brief overview of the pedestrian walkway standards for the state. AASHTO and ASCE will be great resources to further examine the applicable standards and design cases to consider for the Manchester Riverwalk bridge.

Concerns regarding the implementation of the structure range from economic, practicality, and aesthetic viewpoints. Looking briefly at some of the photos of the trusses from VTrans Adaptive Reuse program, the 60 foot span trusses in consideration were not in acceptable condition for the use of pedestrian traffic. Figure 7 below shows a truss in Burke, VT that is in the Adaptive Reuse program. There is section loss and pitting at the end connections and along the bottom chord of the truss (left below). Also, there are diagonals members that are bent (right below).

Figure 7. Burke No. 25, 66.5 ft-span

The superstructure stands at around 7.5 feet and would not be considered in the reuse of the truss for the Riverwalk site. Furthermore, the structural fitness of the bottom chord alone does not appear to be sufficient. Other trusses around the state are being considered but based on this initial assessment other design options must also be considered.

Figure 8, below, is the proposed site location for the pedestrian bridge. The fallen tree on the left is the current bridge in use for trail visitors. The marble abutments remain standing on the north side of the river from the previous bridge that was built in the 1970s but was then torn down in the late 1980s. On the north side of the river (far side in Figure 8) the marble abutments could be repurposed aesthetically but cannot be used at the future abutments for the bridge due to erosion problems (scour) and the close proximity of the marble to the steep embankment. On the south side of the river, there are no abutments present and the only sort of stable material are the few large boulders next to riverbank.

Figure 8. Proposed Bridge Location

2.4.2 Reason for Stopping

Research was concluded for the structural portion of the Manchester Riverwalk because the online database searches proved futile in delivering anything applicable to this bridge. In addition, the Google searches, which proved to be the most useful, became futile as well as the same standards and resources kept reoccurring in searches (applicable for different states). Once Federal standards, Vermont standards, and ample examples were located, research was completed.

3.0 NOVELTY OF PROJECT / EXPECTED SOLUTION

This project does not include any unique or innovative designs; it was presented with hopes that the existing conditions of the Battenkill River and riverwalk path would be sufficient for a bridge crossing. Through research and site visits, it was determined this site would need to undergo preliminary construction before a bridge could be placed across the river. In order to begin the process of designing a bridge, both sides of the riverwalk trail would have to be elevated in order to meet standards associated with ANR, and new foundations would have to be poured for the existing abutments; making a longer construction phase than expected for the state of practice.

We expect to develop a preliminary design to our client for a bridge to connect the existing riverwalk. If a VTrans truss is not the ideal choice for the crossing, we will design a pedestrian bridge that will fit the aesthetic and safety needs of the community. From the articles researched, we know the standards that need to be followed in order to ensure the FHWA, ANR, and AASHTO requirements for the state of Vermont, which can be directly followed because of the low novelty of this project.

In order to deliver to our client what is expected, we will need a higher budget. The site will need to be reworked to accommodate a pedestrian bridge. It is important to note that another pedestrian bridge is to be put 300 feet upstream from our bridge location, also at the expense of the MRC. The bridge we have been asked to design is at a gentle decline in the riverbed (but still with some intense velocity from the dam upstream) which causes frequent flooding of the level area.

The construction of this bridge has the potential floodplain of the adjacent business' parking lot. With modifications made to the riverwalk trail, it is possible to implement a bridge that will safely allow pedestrians to pass from one side of the riverwalk trail to the other. The completion of this work is essential in order to extend the lifespan of any pedestrian bridge at this location, prevent any further erosion, and maintain the homeostasis of the surrounding residential/business owners as well as the ecological/hydraulic state of the Battenkill River.

We will have to bring forth a solution for this problem to our client. There is currently no federal grants or other funds being used or pursued for this project. The client is hesitant to apply for such funds due to the stricter standards the Manchester Riverwalk will be subjected to. However, finding alternative sources of funding is inevitable due to the larger scope of work (more construction hours) that must be completed in order to fill the initial state of practice (putting a pedestrian bridge across the Battenkill.)

4.0 PROJECT SCOPE REVISION

4.1 Initial Project Scope

The stakeholders for the Manchester Riverwalk are the Manchester Riverwalk Committee (MRC), the companies donating, the community of Manchester, the environment and ecological community of the Battenkill River, and the University of Vermont (us).

This is a privately funded venture, so cash reserve comes specifically and sporadically. The project has already received specific donations for certain aspects of the project (signage, ecological restoration, etc.). Based on the most current meeting minutes (2/7/17) there is $19,000 available this year; if this income was to stop or decrease, the project would, over time, cease operations.

The "high level" risks associated with the Manchester Riverwalk include the technical feasibility, budget and funding sources, community acceptance, and adequate resources. In terms of technical feasibility, a difficult task will be the bridge design due to the site complications. Manchester, Vermont has a certain aesthetic and the Riverwalk Committee's goal for design fits within this. It is important for us as a Capstone team to fit our design within the community's appearance. In addition to all of the aforementioned "high" level risks, we must remember that we are a Capstone team and only have so many hours to work on this project. If the Riverwalk Committee has higher expectations than we can allow, the project's success may be at stake.

The deadline for the Manchester Riverwalk is tentative and dependent on the flux of funds and the minimal increments of work that be done at a time. The goal for our team is to have a design in place for the pedestrian bridge by the time funding becomes available, so construction can commence.

4.2 Revised Project Scope

After our first meeting with the Manchester Riverwalk Committee (MRC), it was evident they had high expectations of us. It was requested they receive a preliminary design and construction phase model. After the preliminary site visit, it was clear that the bridge design was not going to be as easy as initially thought. The revised scope consists of conducting a hydraulic analysis, subsurface soil classification, and ecological consideration of the site. Also, preliminary designs the pedestrian crossing is to be drafted.

Due to the lack of funding of the MRC, there will be several different design options presented so the Riverwalk Committee can choose which fits their needs and budget best. The deadline is still tentative but the preliminary design will be done early December. By the end of the project (March/April), the goal is to have all preliminary designs and budgets for each option and alternative completed. While construction may not be able to take place immediately after design (dependent on weather, funding, and site accessibility), the goal for our team is to still produce a generic, however useable, design that the MRC can use, develop, and eventually implement at the Manchester Riverwalk.

5.0 RESEARCH SUMMARY

Table 1 below provides the keywords and search engines used to conduct the research for this project; the most helpful research came from meeting with professionals and reading standards. Only the relevant information used in this report is included in the log.

Table 1. Research Log

Name	Date Searched	Source Used	Key Words	Results	Notes
MRC Team	9/27/17	John Lens	-	-	landslide has occurred in past
MRC Team	10/18/17	MRC	-	-	abutments from boy scout bridge
Kate	10/19/17	Google	"Geotechnical Standards" / "Pedestrian Bridges"	PermaTrak Boardwalk Company	use deep foundations to prevent scouring
Kate	10/19/17	Google	"Pedestrian Bridge Foundations"	FHWA Manual	section on formulas to use to then lead into design of bridge
Kate	10/20/17	Google	"Raft Foundation"	Abutments in Bridges	different types of abutments for bridges
Kate	10/25/17	Cassidy Cote	-	-	landslide will occur within next year, used incorrect fill on slope
Kate	10/25/17	Cassidy Cote	-	-	may want to consider stope stabilization
Kate	10/25/17	Cassidy Cote	-	-	dig out existing abutments and start over
Kate	10/25/17	Cassidy Cote	-	-	will have to raise riverwalk and abutments
Andrea	10/17/17	James McCarthy	-	-	locations and contacts for bridges around the state
Andrea	10/19/17	Google	"Pedestrian Bridge" / "Design Standards"	LRFD Specifications Pedestrian Bridges (Washington State DOT)	loading considerations, from Washington State DOT, would be better if from VT or N.E.
Andrea	10/19/17	Google	"Pedestrian" / "Vermont Standards"	VTrans Structures Design Manual	Useful for Vermont standards but not as detailed or complete as previous source
Andrea	10/25/17	Cassidy Cote	-	-	Asked about the reuse of VTrans stored truss, he replied, "...Not sure..."
Andrea	10/25/17	Cassidy Cote	-	-	Second pedestrian bridge by VHB is unnecessary

Andrea	10/26/17	Senior Design Room	-	"Minimum Design Loads for Buildings and Other Structures"	Basic Load Combinations, Lateral Soil Loads, Live Loads,
Augie	10/25/17	VTrans Website	"Environmental Conservation"	Fish & Stream Obstruction Statute	Cannot block fish from moving up or down stream
Augie	10/25/17	Google	"Hydraulic Standards in Bridges"	Hydraulic Design of Safe Bridges	Take into account flow changes, height and width bridge when designing
Augie	10/25/17	Cassidy Cote	-	Site Visit	Further understanding of what standards we need to take into account for our bridge
Augie	10/25/17	Cassidy Cote	-	Site Visit	bed of trail raised to account for the 1' comfort zone for a bridge height w.r.t. Max flow
Augie	10/25/17	Cassidy Cote	-	Site Visit	designing for hydraulic flow, take into account the % grade change and the flow velocity
Augie	10/26/17	Google	"Vermont standards for hydraulic bridge crossings"	"Vermont Stream Alteration General Permit"	Permit that correlates to the Vermont Stream Alteration Rule
Augie	10/26/17	Google	"Vermont Stream Alteration Rule"	"Vermont Stream Alteration Rule"	
Augie	10/26/17	Google	"Vermont Environmental Protection Rule"	Vermont Flood Hazard Area And River Corridor Rule	
Shaun	10/23/17	Google	“Hydraulic Standards”	“Hydraulic Design of Safe Bridges” U.S Department of Transportation	Standards for what hydraulic data needs to be considered for bridge design
Shaun	10/24/17	VTrans	“Hydraulics”	“Hydraulics Manual”	
Shaun	10/24/17	Compendex	“Hydraulics standards for bridges”	“Review of Bridge Scour Practice in the U.S.”	
Shaun	10/25/17	Cassidy Cote		Site Visit	requirements for bridge span and height
Shaun	10/25/17	Compendex	“Hydraulics standards for bridges”	“Estimation of Backwater effects at Bridge Crossings”	The idea of backwater is described in detail

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Appendix VI - Manchester Riverwalk Pedestrian Bridge

Community Partner: Bill Laberge, Manchester Riverwalk Committee

Submitted by: Andrea Ameden, August Arles, Kate Fuller, Shaun Roberts
December 8, 2017

UVM Project Team Manchester Riverwalk
213 Votey Hall
33 Colchester Avenue
Burlington, VT 05405

December 8, 2017

Mr. Bill Laberge
Manchester Riverwalk Committee
5046 Main St.
Manchester Center, VT 05255

Re: *Manchester Riverwalk* with UVM CEE Senior Capstone Design Students Preliminary Design Report

Dear Mr. Laberge:

We are pleased to provide you this preliminary design report. This report describes our recommended design based on your input and our analyses.

Please review this report and provide your comments to us by early January 2018. We would be glad to review your comments with you upon our return to classes in mid-January. We will provide a final submittal on April 28, 2018.

Thank you for providing this opportunity for us to serve your community.

Sincerely,

UVM CEE Project Team Manchester Riverwalk.

August Arles
Team Project Manager
aarles@uvm.edu
(619)777-9129

Andrea Ameden
Kaitlyn Fuller
Shaun Roberts

Attachment: Preliminary Design Report dated December 8, 2017

Table of Contents

EXECUTIVE SUMMARY

The Manchester Riverwalk (MRC) project consists of designing a pedestrian bridge to cross the Battenkill River to connect two portions of the riverwalk trail. This report provides a detailed evaluation of the current site conditions which have evoked concerns with the proposed pedestrian bridge. These consist of the regular flooding of the current trail and slope instability of the banks upstream.

Hydraulic and subsurface soil data was collected on site. It was initially proposed to utilize the VTrans Truss Re-Use Program for the stream crossing. After photo investigation of bridges in storage around the state, it was concluded that reusing a truss would prove least effective for the MRC's project.

The project scope was redefined to incorporate more rehabilitation of the riverwalk and improving the current conditions. Other stream crossings were evaluated, such as implementing formal stepping stones. This is a more cost-effective option but limits trail accessibility and denies trail use during high-water events (i.e. spring snowmelt). This option would also allow for a fun, unique alternative to a bridge design and would allow the riverwalk to expand its features to be more dynamic and interactive at a starting cost of around $4,000.

To save further on costs, our other alternative was considered which include only riverwalk maintenance or "doing nothing". The riverwalk maintenance portion allows MRC's funds to be directed solely on fixing the trail and preventing future flooding or washouts and preparing the site for future bridge designs. The limitation of this alternative is that it will cost at a minimum $7,400 to only rehabilitate the full site and it will not produce any sort of stream crossing to connect the riverwalk trails. While this "do nothing" option is cost-effective, it is the unfavorable option because it is unsafe for users to leave the riverwalk in its current state with a failing slope and fallen tree as the bridge.

Although more expensive, an arched bridge is the most reasonable to the client's needs at this time. This allows for water, sediment, debris, and wildlife to safely pass without damming. Depending on the client's wishes, the bridge could also extend to the higher elevated portion of the trail which would remove the need to raise the trail, since the proposed location is in the floodplain. The current limitations of this alternative are its cost, at $60,000, the concerns of getting equipment to the side, and possibly having to build from only one side of the river.

1.0 BACKGROUND INFORMATION

1.1 The Site

Manchester riverwalk is located in Manchester, VT. The site where the bridge is to be implemented is located at approximately 43.176707, -73.055199. The main goal of the project is to implement a pedestrian bridge across this site location, seen in Figure 1.

Figure 1: Site Location from Google Maps

Below, Figure 2 shows the upstream view from the site location, note the narrowness of the river at this location, the river meanders while widening and narrowing downstream. Figures 3 and 4 show the river looking downstream and the width of the river with the existing abutments. This information is important to understanding the hydrology of the river and the flows. Once those are established they will be used to determine the reinforcement at the footings of the bridge. It is also pertinent to mention that upstream about 300-ft, VHB is designing and building a pedestrian bridge to cross from the Factory Point Town Green (seen in Figure 1) to the backside of the Mountain Goat building. Our bridge considerations need to incorporate the thought of another bridge being upstream in order to prevent any flood hazards.

Figure 2: Upstream View from Site Location

Figure 3: Downstream View from the Site.

Figure 4: Site Width and Original Abutments

1.2 Applicable Design Standards

Table 1 lists the applicable design standards that we found. The categories of standards are ecology, hydraulic, structural, and geotechnical. The standards range from State to Federal, but are mostly related to state because this project is not federally funded and the State regulations are more strict to follow. The research conducted on these standards is presented in attached Appendix II.

Table 1. Applicable Design Standards

Ecology	Hydraulic	Structural	Geotechnical
Vermont Statutes Title 10	Stream Alteration General Permit	VTrans Structures Design Manual	FHWA
Chapter 111: Fish 4607 Obstructing Streams	Equilibrium Standard	LRFD Specifications	AASHTO LRFD
Environmental Protection Rules	Connectivity Standard	AASHTO Bridge Specifications	VTrans Structures Design Manual
Chapter 27: Vermont Stream Alteration Rule	Vermont Flood Hazard Area and River Corridor Rule	ASCE Minimum Design Loads for Buildings	VTrans Hydraulics Manual
	No Adverse Impact Standard (NAIS)		
	Federal Regulations: Executive Order 11988		

1.3 Data

1.3.1 Provided Data

Figure 5, shown below, is the lidar survey (zoomed in to show our site) given to us by VTrans representative, Carolyn Carlson. The survey was completed by Mance Engineering Partners, P.C. out of Manchester, VT. The pink highlighted leader is the location of the proposed stream crossing.

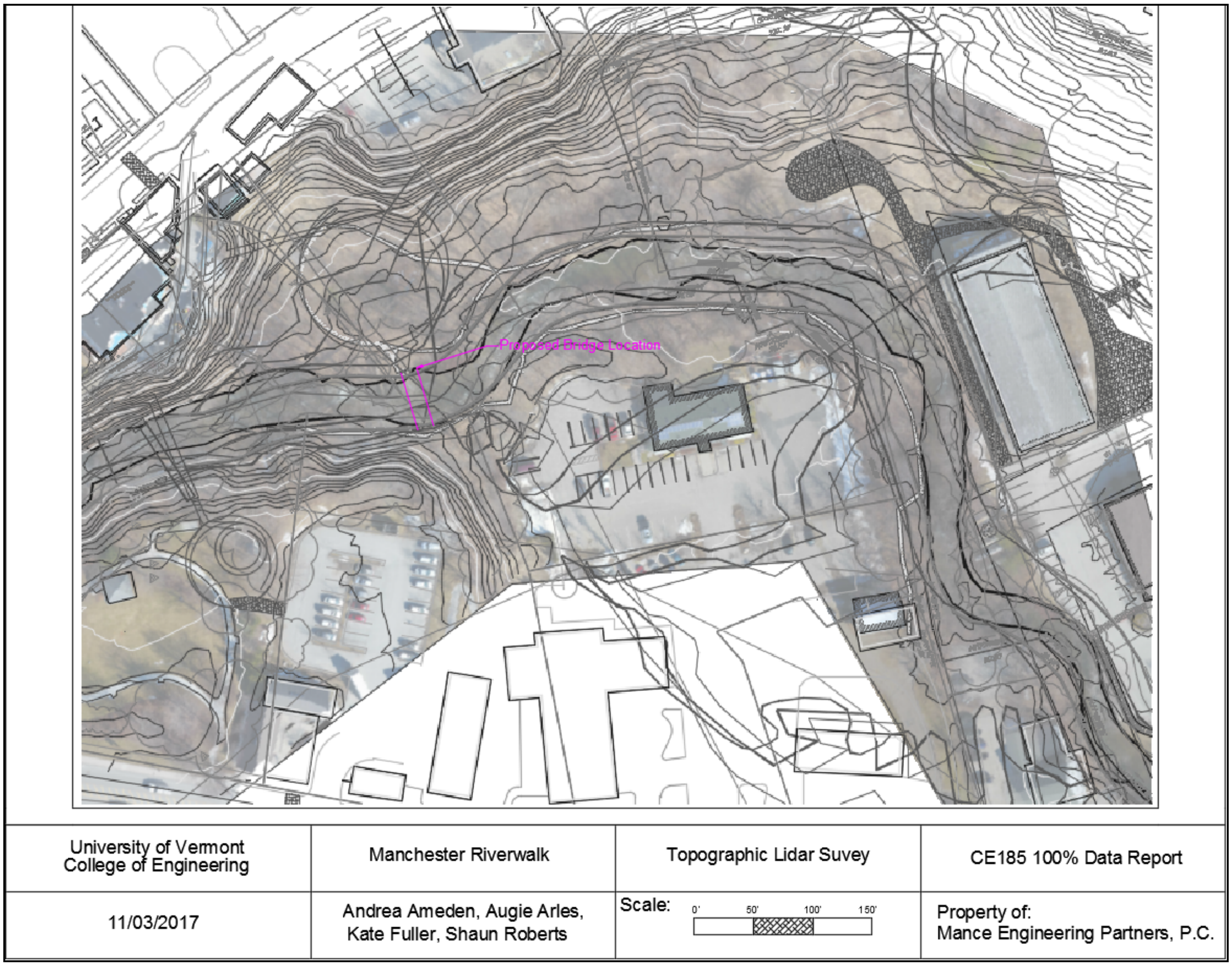

Figure 5: Topographic Lidar Survey

Figure 6, below, shows an overview of the floodplain for different storm severities. The blue and red colored diagonal covered area is the normal floodplain of this location, meaning this has the possibility to flood during a normal storm or snowmelt. However the area covered in a light blue is the one percent annual flood area, this means that a storm which would flood this area has a one percent chance of happening every year. The primary bridge location for the MRC is designated with the orange line, we have added a secondary location for the bridge, seen by the pink line in the Figure below. This location would allow for a bridge with a shorter span, which could lead to a lower cost, however it has a higher risk of being affected by flooding.

The existing wood chip path is also highlighted in yellow in this picture. Notice how on the South (bottom) side of the river, the floodplain goes right up to the wood chip path. This is an issue that is seen for the Riverwalk during the spring snowmelt, which leaves the path unusable. Ideally, the path would be raised so it could still be used during these wet times, but standards keep maintenance from raising the level of the walkway due to it being in the floodplain. We have thought of the idea to design a raised, pier like walkway that would allow the water to go underneath in the event of a flood to keep accessibility and minimize damage costs.

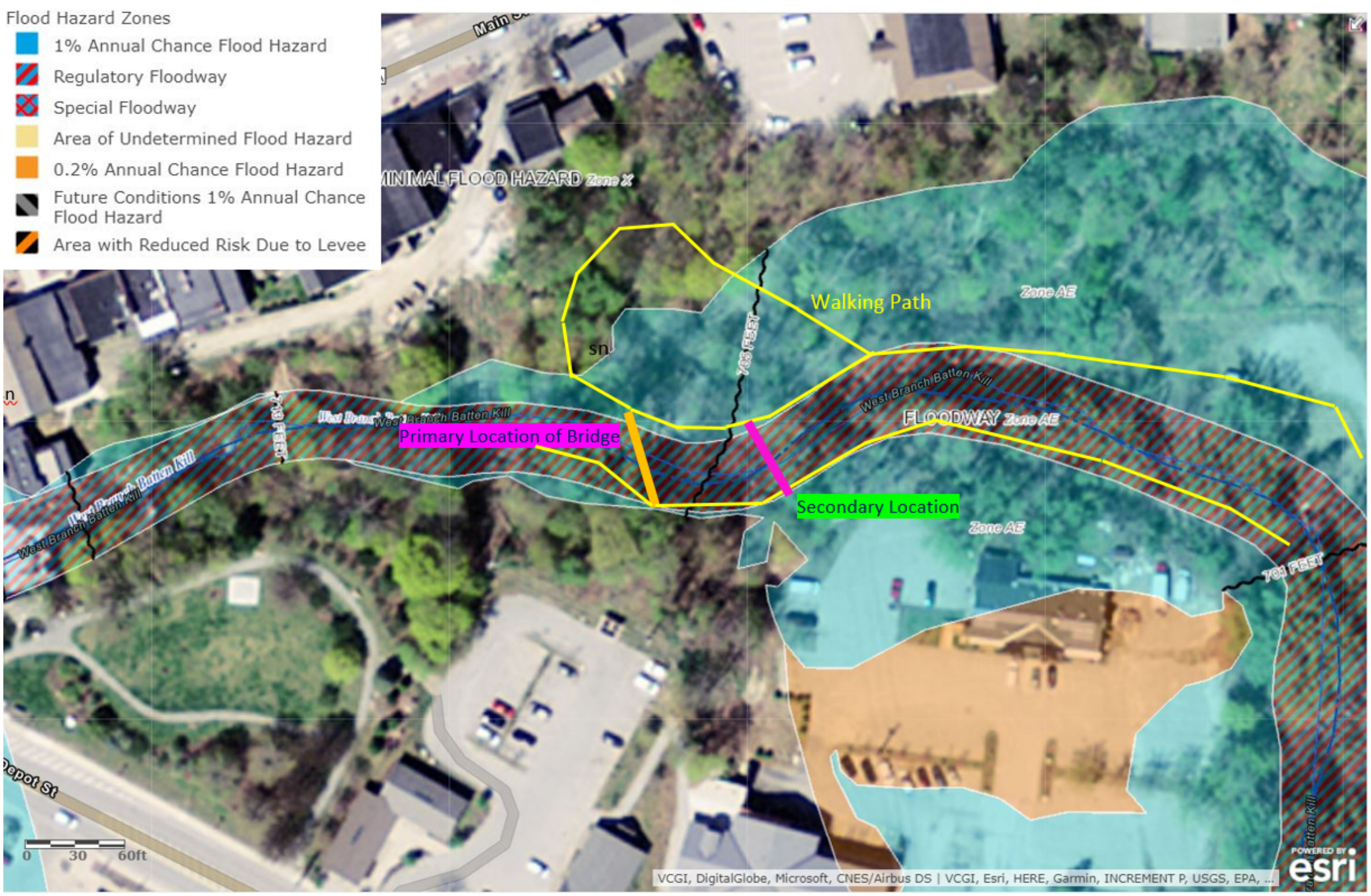

Figure 6: Plan View of Site with Floodplain

1.3.2 Hydraulics + Hydrology

Referencing Appendix II, we gathered a sufficient amount of data in order to run a full hydraulic analysis; i.e. the bankfull widths, bankfull depths, and the span with depths for developing a cross section. Figure 7 is the cross section of the riverbed at the proposed location 1 for the bridge. A survey rod and a pocket sight level were used to get the depth of the riverbed, from eyesight, at 3 foot increments. The orange dashed line shows the elevation of the water during a ten year storm.

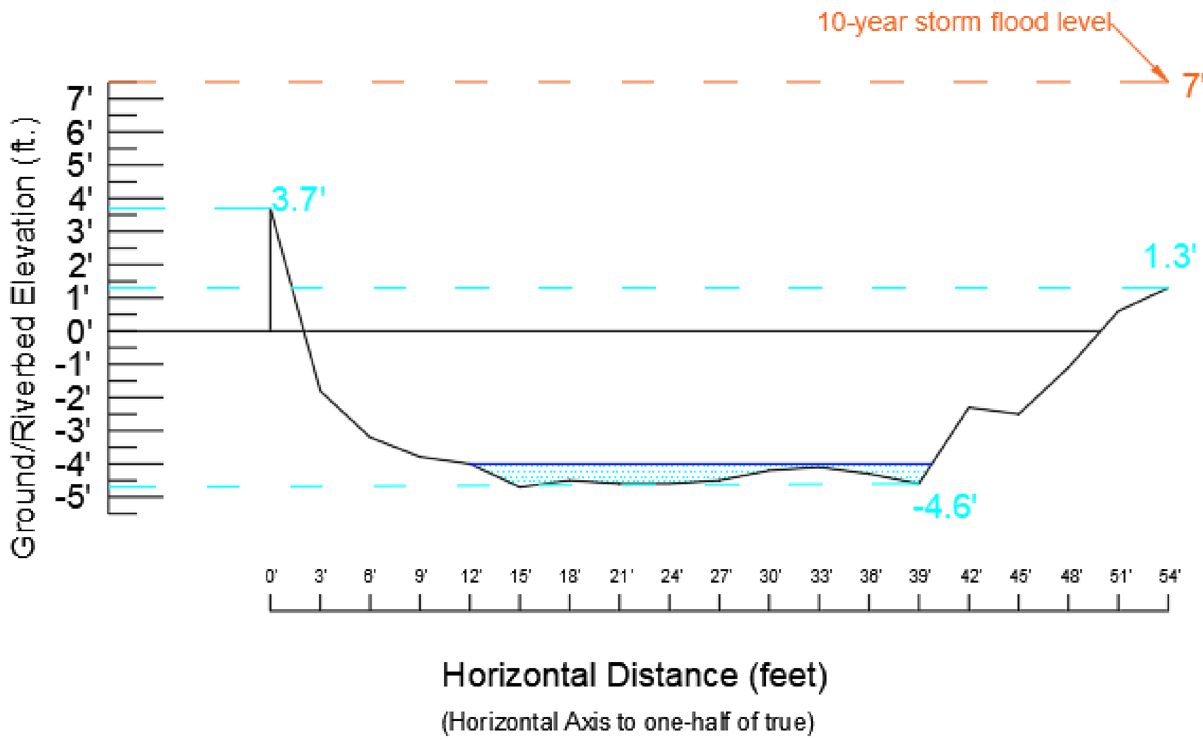

Figure 7: Cross-Section of the Battenkill Riverbed at the site of the project bridge. NTS

A cross-sectional survey was also performed a few hundred feet downstream from the site. This section was not done with set increments, but at the drastic changes in riverbed elevation. Instead of just getting data of the riverbank, this survey went into the parking lot on the right side of the river so we could have a better idea of the floodplain. A drawing of this cross-section is shown in Figure 8.

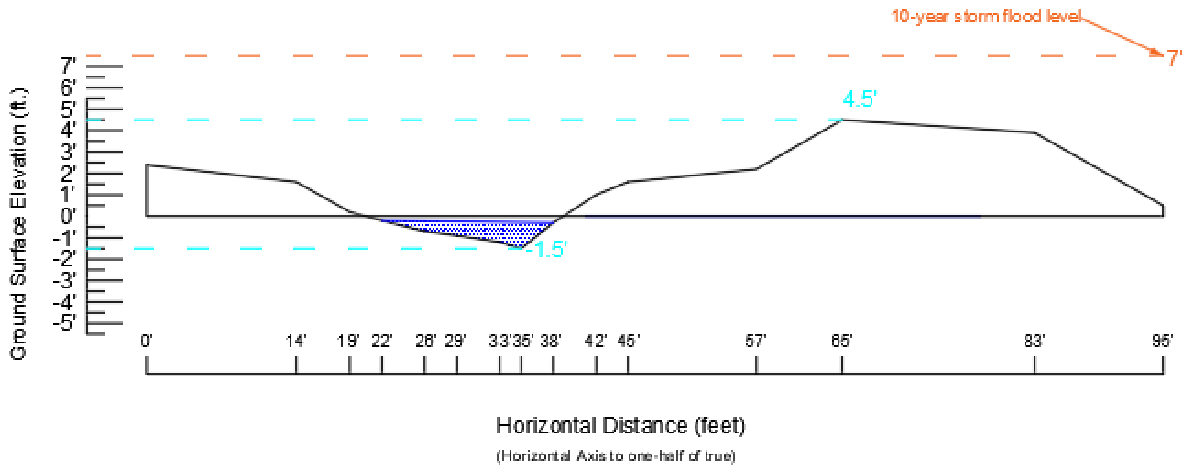

Figure 8: Cross-section of the Battenkill riverbed downstream from the project site. NTS

All of the collected hydraulic data was input to the program HY-8, which models the river and shows the elevation of water after the design storm event, which is a 10-year storm. The program also shows the water elevation in relation to the low-beam elevation of the bridge and will describe if the structure tops out or not. In Appendix III, the charts and figures created by HY-8 are shown; which designate the design of our bridge to have a low beam elevation of at least 8-ft. Due to how high the low beam will have to be located, an arched bridge would be an ideal design for this location. An arched bridge would also be beneficial when it floods during snowmelt season because it would allocate more height for debris to flow under the bridge and not cause a damming effect that would lead to more flooding.

1.4.2 Geotechnical

Table 5 in Appendix II shows the data gathered from the hand auger exploration at the site. Boring 1 was dug on the top of the foundation where the existing abutments are, Boring 2 was dug to the left of the foundation, and Boring 3 was dug on the right side of the river at the top of the riverbank. The auger went further down than was recorded at the end, this is due to the soil being loose and collapsing in on the hole when the sampler was taken out of the whole to gather the soil data. Figure 9 shows the cross section of this subsurface exploration.

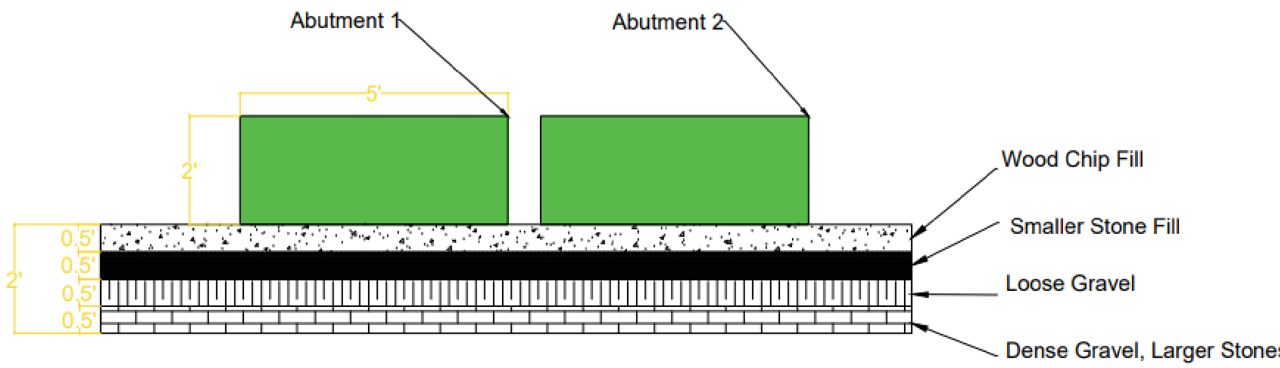

Figure 9: Subsurface Cross Section of Existing Abutments; NTS

The upstream conditions of the river were observed as:

- Erosion currently about 3-ft high
- Roughly 30-degrees from channel to top of riverbed
- Landslide occurring on left side of river
    - Need some sort of slope stabilization
        - Possible retaining wall

We observed about 4-inches of scour on each abutment. This must be fixed and redesigned in order to provide a more sustainable and safe landing for the bridge. Currently, if these abutments were to be used, they could potentially continue to scour to an unsafe depth and eventually fail, and fall into the river.

1.5 Final Scope

The initial client agreement is attached as Appendix I for reference. It provides a brief overview of what we believe the clients wants and objectives to be.

1.5.1 Initial Project Scope

The stakeholders for the Manchester Riverwalk are the Manchester Riverwalk Committee (MRC), the companies donating, the community of Manchester, the environment and ecological community of the Battenkill River, and the University of Vermont (us).

This is a privately funded venture, so cash reserve comes specifically and sporadically. The project has already received specific donations for certain aspects of the project (signage, ecological restoration, etc.). Based on the most current meeting minutes (02/07/17) there is $19,000 available this year; if this income was to stop or decrease, the project would, over time, cease operations.

The "high level" risks associated with the Manchester Riverwalk include the technical feasibility, budget and funding sources, community acceptance, and adequate resources. In terms of technical feasibility, it will be a difficult task to design this bridge due to the site complications. Manchester, Vermont has a certain aesthetic and the Riverwalk Committee's goal for design fits within this. It is important for us as a Capstone team to fit our design within the community's appearance. In addition to all of the aforementioned "high" level risks, we must remember that we are a Capstone team and only have so many hours to work on this project. If the Riverwalk Committee has higher expectations than we can allow, the project's success may be at stake.

The deadline for the Manchester Riverwalk is tentative and dependent on the flux of funds and the minimal increments of work that be done at a time. The goal for our team is to have a design in place for the pedestrian bridge by the time funding becomes available, so construction can commence.

1.5.2 Revised Project Scope

After our first meeting with the MRC, it was evident they had high expectations of us. It was requested they receive a preliminary design of the pedestrian bridge and construction phase model. After the preliminary site visit, it was clear that the bridge design was not going to be as easy as initially thought. The revised scope consists of conducting a hydraulic analysis, subsurface soil classification, and ecological consideration of the site.

Due to MRC's lack of funding, there will be several different design options presented so the Riverwalk Committee can choose which fits their needs and budget best. By the end of the project (March/April), the goal is to have all preliminary designs and budgets for each option and alternative completed. While construction may not be able to take place immediately after design (dependent on weather, funding, and site accessibility), the goal for our team is to still produce a generic, however useable, design that the MRC can use, develop, and eventually implement at the Manchester Riverwalk.

1.6 Brief Overview of Project Motivation

The point of this project is to help the community of Manchester, VT enhance their natural beauty surrounding the town, while providing a safe, alternative path for pedestrians and bicyclists to travel without the rush of cars in the downtown area. The design that we hope to carry out will not only provide a way to cross the river, but will hopefully be a unique, fun design that will attract more people to the riverwalk. The committee organizing this project hopes to expand the riverwalk from its current location and length, to connect to other existing trails throughout the town of Manchester.

The motivating factor of this project is the diverse committee, made up of volunteers ranging from teachers and artists to solar power installers, and putting their dream into a reality. This is a low budget project so we hope to provide the most affordable, unique design that fulfills all the MRC's expectations. Having two team members from the area in which this project is located is also high motivation to provide a useable and respected product.

2.0 EXISTING CONDITIONS, CONSTRAINTS, and IDENTIFIED NEEDS

Currently, the location of the proposed bridge is in need of major reconstruction. There are existing abutments on the north side of the river; however, they will require maintenance in order to become usable again due to the apparent scour (seen in Figure 10). The existing structures are currently in the floodplain of the design storm event. For them to be used in the design of a new bridge, they must be elevated so that they clear the flood levels, or moved farther back from the river, which would require a longer spanning bridge. Elevation is not a reasonable option because we will not be able to bring fill into the floodplain. We will have to come up with a reasonable suggestion and location of the potential bridge that satisfies all permitting and committee requirements.

Figure 10: Scour on the Current Abutment

The south side of the river has no existing abutments. The elevation of the south side is higher than the elevation of the north side, so that will need to be addressed in order for a level bridge to be built. An abutment at the south side will also need to be designed so that it can minimize the amount of scour and allow a long-lasting structure.

Another concern is the feasibility of getting heavy machinery into the site for construction. On either side of the site, there are steep slopes that lead almost all the way to the bridge site. Looking at the current condition, there is only one way into the site with equipment, and that is on the south side. With this issue, some innovative construction is required so that heavy machinery would not be needed. Figure 11 shows the slope that leads up to the bridge location on the south side of the river.

Figure 11: The slope of the land leading up to the site on the south side

There are also a series of wooden boardwalk-style pathways that lead to and from the bridge location. There has been previous issues of these walkways flooding after storms and in the spring after snow melt. The elevation of these paths relative to the water's surface is all but a few inches. In order for these walkways to be effective, they need to be raised so that they will be out of the floodplain of the design storm event. The walkways are also very unstable in their current condition, and flex under the weight of a single pedestrian on it. Their structural integrity is a concern that should be addressed along with elevating them above the flood level.

Permitting is a large constraint that must be kept in mind when designing the dimensions of the bridge. Table 1 above shows the standards that must be met for each category of design. There are different standards for the ecology, hydraulic, geotechnical, and structural portions of the design. These permits and standards are set by the town, the state, and the federal government. Reference Appendix II for detailing on specific permits.

3.0 ALTERNATIVES EVALUATED

A fallen tree is the current bridge in use for trail visitors. The marble abutments could be repurposed aesthetically but cannot be used for a future bridge. Looking briefly at some of the photos of the trusses from VTrans Adaptive Reuse program, there are concerns for reuse. The trusses in consideration were not in acceptable condition for the use of pedestrian traffic due to severe section loss and pitting at the end connections as well as some bent diagonal members.

3.1 Alternative 1 - Design a New, Arched Bridge

This design alternative will be pricey for the MRC but meets their desire for a bridge. Our site is sensitive due to the risk of heavy floods and the requirement to not impede river sediment or water. An arched bridge is the only feasible option for a footbridge at this location. Having a high low beam will allow for ANR regulations to be followed, and there will be less of a chance for debris, ice, etc. to be caught and cause a potential dam. Figure 12 shows the potential design in cross-section view for the arched bridge.

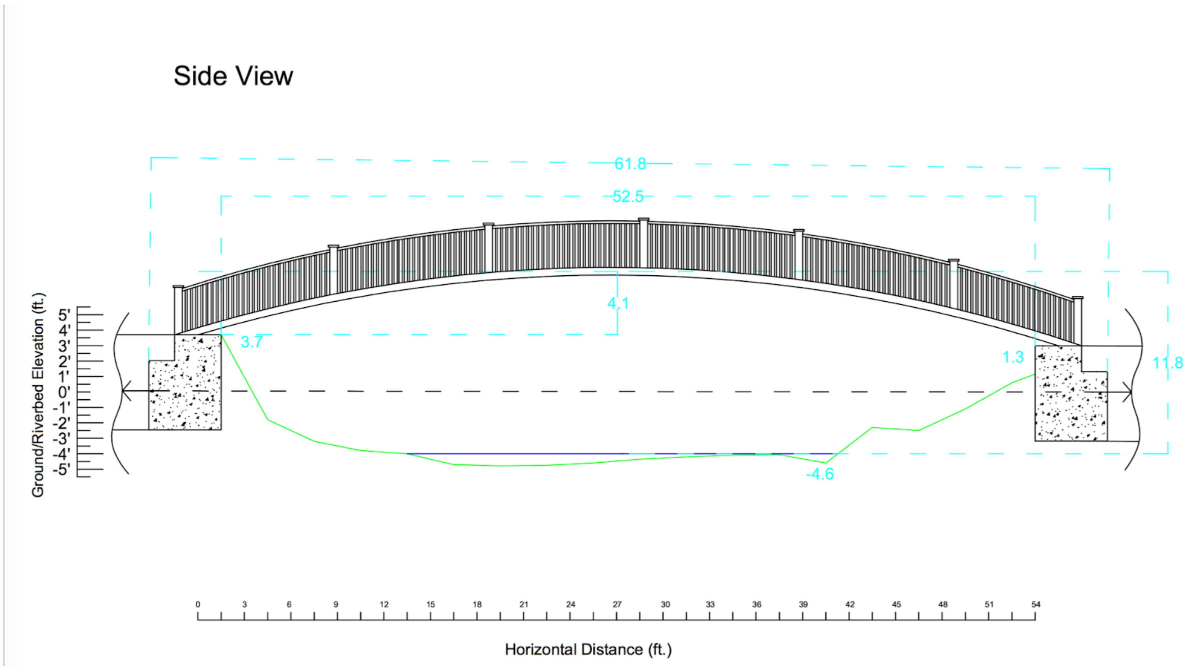

Figure 12: Potential Design for Arched Bridge; NTS

The constructability of an arched bridge is still in question for our site. It is possible to get smaller equipment there, e.g. an ATV, small truck and trailer, mini-excavator, skid steer, but the problem would be that the bridge will have to be constructed from only the South side of the river. Innovation will have to come into play in how to construct this arch bridge from one side of the river, whether there is a temporary pier used or finding a way to plow through the North side of the trail.

3.2 Alternative 2 - Floating Bridge

This design alternative will be the most expensive for the MRC but meets their desire for a bridge. As said before, this site is very susceptible to flooding. A floatable bridge is a feasible option for a footbridge at this location because the pile sleeves allow for a sturdy support for the structure while allowing the bridge to translate vertically in the event of severe flooding. The piles (similar to Hapgood Pond, in Figure 13) are expected to be driven outside of the channel but within the floodplain.

Figure 13: Hapgood Pond "floating" bridge structure (left) and adjustable sleeve piles supporting the structure (right) (Photo property of Ken Allard)

3.3 Alternative 3 - Stream Crossing

The stream crossing involves creating a unique stepping stone design for trail-users to cross the Battenkill. This alternative would only allow access to cross the stream in warm seasons where high-water and ice conditions will not pose a danger to visitors. In the event of flooding, the stone path would stay in place while the water would rise over it. This would also only allow for able pedestrians to cross the river, bicyclists would be detoured around to the upper level bridge.

The biggest design challenge posed with the stepping stone path is damming of sediment, flow, and any aquatic wildlife. The stepping stone crossing adds a dynamic feeling to the riverwalk and allows a greater capacity for this trail to become a park that feels alive. A full analysis of the stepping stone design implemented in the Manchester Riverwalk will be evaluated in hydraulic software to ensure any structure is capable of passing sediment and debris. The stream crossing structure would be similar to Figure 14 below located at Mad River Path River Crossing.

Figure 14: Mad River Path River Crossing (Source: http://www.wvnh.com/mad-river-stepping-stones/)

Figure 15 below shows the plan view of the stepping stones in the proposed bridge location. It is unsure at this time how stepping stones would alter the hydraulics of the river. This is not what the MRC is looking for, we propose this as a fun alternative to keep in mind.

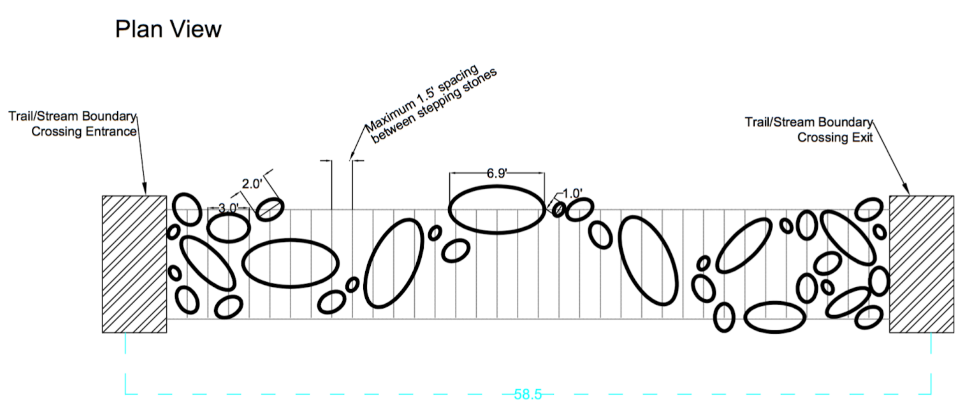

Figure 15: Plan View Stepping Stones Design; NTS

3.4 Alternative 4 - "Do Nothing" Riverwalk Maintenance

Regardless of a river crossing being implemented at the designated location, there is some serious maintenance that needs to occur at the Manchester Riverwalk. There is excessive debris on and around the trails that needs to be cleaned up, and there are some concerning slope stability issues upstream (between our proposed stream crossing site and the future VHB bridge) that should be addressed. The biggest component to this alternative is modifying the trails on either side of the stream by raising them and adding support so the trail is out of the floodplain. This alternative would only consist of the maintenance required to bring the trail up to a safer standard, with no implementation of a river crossing. In Figure 16 below, all of the current walkways are in danger of flooding again and need to be raised above water level.

Figure 16: Exposed Trail with Floodplain outlined (blue)

This is being considered as an alternative because this work alone will cost a fair amount, taking up a majority of MRC's time. Should either of the stream crossing alternatives not satisfy our client, this alternative provides the work that is highly recommended for the continued use of the Manchester Riverwalk today without a stream crossing at the proposed location.

4.0 ALTERNATIVE FINDINGS

4.1 Arched Bridge

Although a unique alternative that may be difficult to implement, we believe that this is our best option. The committee came to us at the beginning of Fall 2017 and asked us to present them with a bridge, and after many other considerations, this is what we find best fit. This design does have considerable drawback. Because of the current site conditions this will be the option that needs the most cosmetic and foundational work done before we consider building.

This type of bridge will bring the natural aesthetic feel to the Manchester area that the committee is looking for. We need to look at the permits that we will need to build. The most significant one is the Stream Alteration Permit, because we may need to put piles closer to the stream bed itself.

The Table below outlines the total funds that this option will need. It is important to note that our client has confirmed there is no real budget “constraint” on this project, due to the predictability of being able to raise funds seeing the bridge meets aesthetic needs of the town of Manchester, VT.

Table. 2 Cost Analysis of Implementing Arched Bridge

OPTION	ITEM	AMOUNT	COST PER ITEM	TOTAL COST
ARCHED BRIDGE	Clearing and Grubbing	1 (Lump Sum)	$20,518.66	$20,518.66
	Common Excavation	5 (CY)	$9.86	$49.30
	Gravel Backfill for Slope Stabilization	2 (CY)	$36.38	$72.76
	Subbase of Crushed Gravel, Course Graded	1 (CY)	$36.49	$36.49
	Concrete, High Performance Class A	2 (CY)	$857.16	$1,714.32
	Controlled Density (Flowable Fill)	2 (CY)	$214.75	$429.50
	Pre-Fab Arched Bridge (50' span)	1	$30,000	$30,000.00
	Construction Laborers	60 hrs	$15.40/hr	924
	Resident Engineer	60 hrs	$50/hr	3000
			Total	$56,745.03

4.2 Floating Bridge

Although a unique alternative that may be difficult to implement, we believe that this is our best option. The committee came to us at the beginning of Fall 2017 and asked us to present them with a bridge, and after many other considerations, this is what we find best fit. This design does have considerable drawback. Because of the current site conditions this will be the option that needs the most cosmetic and foundational work done before we consider building.

This type of bridge is rare for the area which will pose a challenge to us as, the design team, to find any comparable examples to work off of as well as the construction as a whole which will be a problem. The committee has said before that they are under budget constraints because they want this to be privately funded, and this options poses a threat to those funds. As well as the build and cost constraints, we need to look at the permits that we will need to build.

The most significant one is the Stream Alteration Permit, because we may need to put piles closer to the stream bed itself.

The table below outlines the total funds that this option will need. For all three cost estimations we used the VTrans 5 year summary of past projects as a base point for our pricing. Although, this figure is nowhere near what the total cost that will need to be allocated (does not include cost of hiring a PE Engineer), it is a good starting point to be able to estimate the cost to present to our client.

Table. 3 Cost Analysis of Implementing Floating Bridge

OPTION	ITEM	AMOUNT	COST PER ITEM	TOTAL COST
FLOATABLE BRIDGE	Common Excavation	10 CY	$9.86/CY	$98.60
	Large Tree Removal	2 (min.)	$1,500.00	$3,000.00
	Steel Piling, HP 10 x 57	4	$40.69/LF	$162.76
	Steel Piling, HP 12 x 63	4 x 5 LF	$59.16/LF	$1,183.20
	Concrete, Class D	2 CY	$275.45/CY	$550.90
	Structural Lumber trd.	0.150 MFBM	$5,686.77/MFBM	$852.90
	Nonstructural Lumber	0.150 MFBM	$6,436.84/MFBM	$965.53
	Carpenters	2 (200 hrs.)	$21.65/hr.	$4,330.00
	Construction Laborers	3 (200 hrs.)	$15.40/hr.	$4,620.00
	Construction Inspectors	1 (25 hrs.)	$23.03/hr.	$575.75
	Future Maintenance (est.)	1	$1,000	$1,000.00
			Total	$17,339.64

4.3 Stream Crossing

The rock stream crossing along the river bed is the least technically challenging option out of the possible designs we have come up with, besides the 'Do Nothing' approach. However, a stream crossing poses threats to the surrounding ecosystem that we will have to take into consideration. Large rocks that are being placed directly into the stream bed derive problems to change of flow to the river, and pose a threat to native species that may navigate this river. When looking further into the possibility of this design we need to take into consideration the adverse effects it will have on the surrounding environment.

The stream crossing is one of the less fund consuming options (see Table 4 below). However, we do expect that the cost will be higher because, as stated above, these figures are just estimates to try and begin to evaluate the possibility of the design.

Table 4 Cost Analysis of Implementing Stepping Stones

OPTION	ITEM	AMOUNT	COST PER ITEM	TOTAL COST
STEPPING STONES	Construction Laborers	3 (48 hrs)	$15.40/hr.	$2,217.60
	Excavator	1	$250.00	$250.00
	Steeping Stones	12	$125.00	$1,500.00
			Total	$3,967.60

4.4 Riverwalk Maintenance

Having been to the site twice, we are all under the agreement that before any bridge goes in, there needs to be major maintenance on the trail. The current riverwalk is in an area that is in one of the main floodplains. We believe, for this to be a complete project in ten years time, there will need to be some major structural, geotechnical, and cosmetic work done to the area so that it will meet the expectations of the committee.

This option calls for elevating the trail above the floodplain so there is no damage to it when there are massive storms. We believe the best way to go about this is to add fill so that we can raise the whole pathway. However, this will inevitably affect the channel hydraulics because we will be destroying some area of the floodplain. There are a couple different ways we can approach this option. If this is our client's final choice as an alternative, we will need to pay special attention to the permits that are in place so we do not violate any laws that govern chances to stream channels and floodplain areas.

Even though this project option may seem like less work out of the above two that were presented, it does not come with a lower cost (see below in Table 5).

Table. 5 Cost Analysis of Riverwalk Maintenance

OPTION	ITEM	AMOUNT	COST PER ITEM	TOTAL COST
RIVERWALK MAINTENANCE	Granular Backfill	18 CY	$40.30/CY	$725.40
	Subbase, Fine Graded	6 CY	$40.03/CY	$240.18
	Nonstructural Lumber	0.12	$6,436.84/MFMB	$772.42
	Construction Laborers	3 (100 hrs.)	$15.40/hr.	$4,620
	Future Maintenance	1	$1,000	$1,000
			Total	$7,358.00

5.0 CONCLUSIONS and RECOMMENDATIONS

5.1 Project Objectives

We understand the overall project objectives to be:

1. Provide design recommendations for a
    a. lower level bridge crossing
    b. associated pathway designs
2. Preserve the Battenkill river ecology
3. Produce an opportunity to reuse a VTrans truss
    a. This objective has been determined as unattainable

5.2 Design Alternatives Considered

The following are the alternatives that are being considered for this project. They are listed below in order of highest to lowest performance.

1. <u>Design an Arched Bridge</u>

This alternative is ranked as number 1 because, as seen in Table 5, it has advantages that outweigh the disadvantages, as well as more advantages than the other alternatives. It also meets the clients expectations, which is important in our choosing of a design.

Table 5. Advantages and Disadvantages of Arched Bridge

Advantages	Disadvantages
Fulfills clients expectations	Expensive
Low probability of damming with sediment or debris	Constructability may be difficult
Would not necessarily have to perform trail maintenance	

The arched bridge will meet the above objectives 1 and 2. Objective 1 of providing a design recommendation for a lower level bridge crossing is what the design for an arched bridge will be. Although, it will no longer incorporate the associated pathway design, as our team has decided to focus solely on providing a bridge design instead of improving the surrounding area.

There is some uncertainty associated with this design, such as ground conditions and altering stream heights. It is hard to judge how much a river will flood in a given year, and this bridge will have to be designed to its optimum level, which in some ways could be either way over or under designed. The risks involved include the proposed bridge damming during a flooding event. In order to avoid this, we will try to design a bridge which is hinged at the center to open as a floodgate for once the maximum river flow is reached. The cost of this bridge is going to initially be steep, but over time will be the most efficient, because there will be minimal yearly maintenance involved for the bridge, as long as all standards and permits are met.

2. Floating Bridge

This alternative has been chosen as our second bridge design. Although expensive and hard to construct, we believe it is the second best to giving the MRC an arched bridge. The committee has confirmed the arch bridge as their design and want, but if it turns out that this will be unachievable, we want to still provide them with a pedestrian bridge to cross the river.

Table 6. Advantages and Disadvantages of Floating Bridge

Advantages	Disadvantages
Fulfills clients expectations	Expensive
Can alter with rising stream conditions during peak flood season	May take away from the natural aesthetic of the area
Would not necessarily have to perform trail maintenance	Possible damming

The floatable bridge will meet the above objectives 1 and 2. Objective 1 of providing a design recommendation for a lower level bridge crossing is what the design for a floatable bridge will be. There is some uncertainty associated with this design, such as ground conditions, altering stream heights, and the idea of the bridge alone. We are not completely sure this design will be feasible in this area, due to the piles that will need to be driven. However, driving piles will not be placing any fill into the floodplain, like the potential of the arched bridge. This is our secondary option for a pedestrian crossing if there are any issues with permitting an arched bridge.

3. Stepping Stone Crossing

The stepping stone crossing is ranked second, because of the uncertainty of its implementation in our stream. There are more disadvantages to this than advantages, Table 7, but VHB will be implementing a pedestrian bridge upstream regardless of what we do downstream, so this would provide a fun, unique alternative.

Table 7. Advantages and Disadvantages of Stepping Stones

Advantages	Disadvantages
Fun, unique, attractive alternative	Only abled bodied pedestrians can cross
Cost-effective	Only able to use when river is low
	Possible injuries from slipping on rocks
	Possible damming

This alternative meets the objectives by providing a way to cross the stream. We are unsure of how this will affect the ecology of the stream, and whether or not it will be disruptive to flow or not. If so, this alternative can not be used because we must follow all ecology standards in not altering the river in any way, or disrupting its natural ecosystem. This is the uncertainty and risk involved with this alternative; the idea that the river may or may not be altered or disrupted by a stepping stone path.

This alternative has the best life cycle cost, because it simply consists of purchasing large boulders to cross the stream. Unless, of course, the trail is to be maintained and brought out of the floodplain, which will cost more (see alternative 3 below). There are no maintenance costs associated with the stepping stones alternative.

4. <u>Riverwalk Maintenance</u>

The third alternative is to update the riverwalk to get the walkway out of the floodplain. This alternative is going to be costly and won't even provide a stream crossing. Table 8 shows the advantages and disadvantages to this alternative.

Table 8. Advantages and Disadvantages of Floating Bridge

Advantages	Disadvantages
Fixes trail from washing out	Expensive
Prevents future flood problems for future bridge design / VHB's bridge	Won't necessarily allow for future bridge

This alternative meets the objective of this project by providing a design for an associated pathway to the bridge. This alternative does not include a design for a bridge, however, it just focuses on the maintenance of the riverwalk itself.

There is little uncertainty or risk involved with this alternative because it would be purely updating the surrounding area to be more sustainable and user friendly. Currently the riverwalk has a large flooding issue, so by updating it, it would be out of the floodplain and allow use during all times of the year. The life cycle cost of this would be higher than the other alternatives, however. Even with updating the area, there will be a risk of future erosion during high flood and rain seasons, and this may cause for monthly or yearly maintenance.

5.3 Preferred Alternative

Our team has chosen to move forward with design for an arched pedestrian bridge. The advantages outweigh the disadvantages, and this alternative is more productive than the other alternatives. We believe it is what best meets our client's needs and objectives of this project, while providing a unique enhancement to the surrounding area.

In order to implement this bridge, we will need to look at getting equipment to the site. The equipment for this will include, but is not limited to, a mini-excavator, pile driver, and a cement mixer. The mini-ex will be used to strip excavate the area to clear for the pile driver to come in and drive the necessary amount of piles. The amount of piles will be dependent on the pile drivers estimate for the location and capacity of the bridge.

In order to mitigate any risk, we will keep careful watch over all construction processes that take place at the site, to ensure everything is by the books. It is important that all materials used are approved by the local standards, and more importantly, the ecological standards we will be following. The outcome of this project solely reflects our reputations to this committee so we are committed and determined to delivering a product that meets all their criteria. We will work closely with local contractors to ensure all rules and regulations be followed, and that this design is even feasible at all.

5.4 Project Operations and Maintenance Recommendations

Below, Figure 16 shows the preliminary order of operations suggested for this project. This Figure includes both alternatives 1 and 2, and the steps needed to carry out both. These are both mentioned here, because there is a possibility the funds will not be available for the floating bridge, so we need to have a backup plan in place.

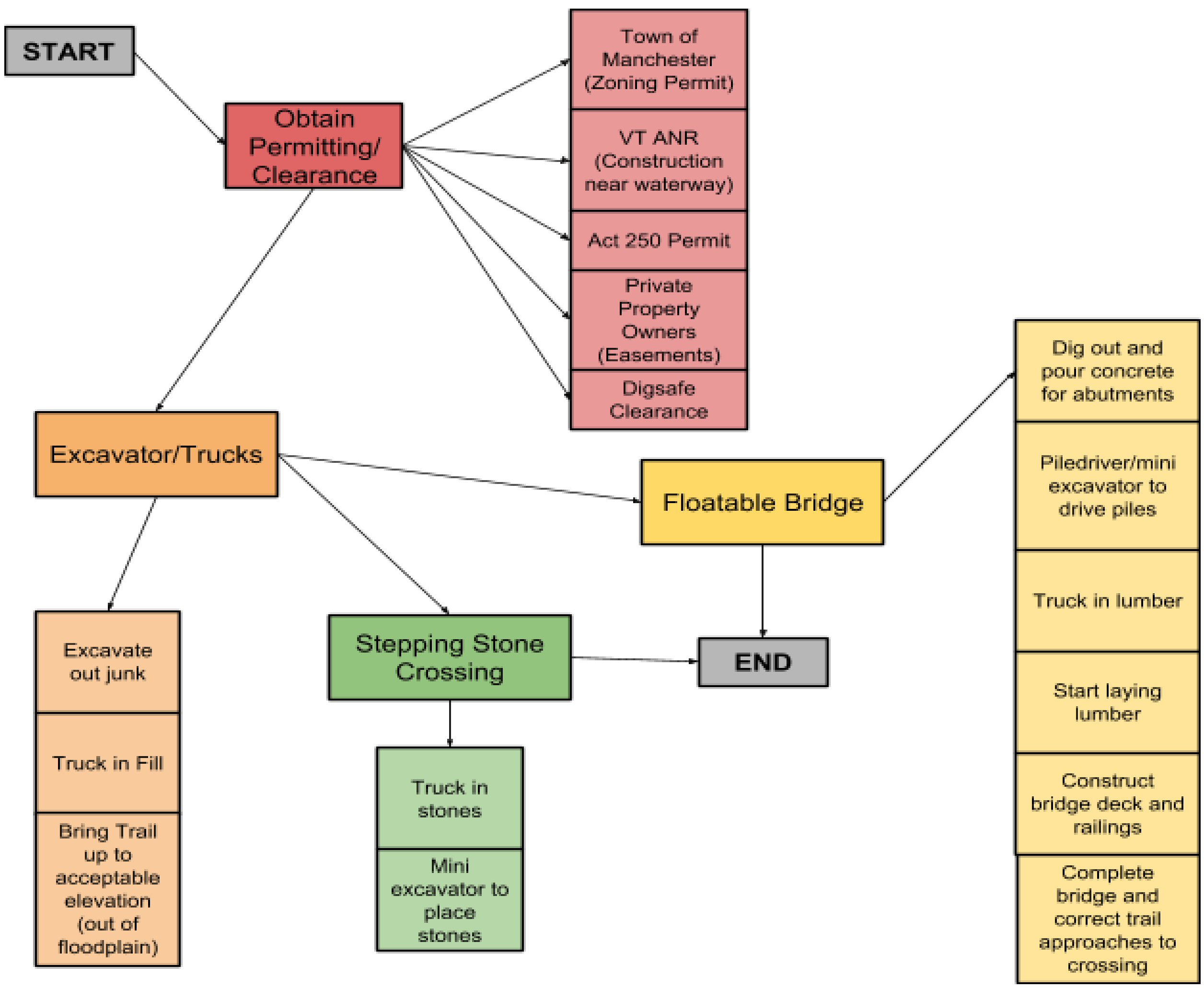

Figure 16: Potential Project Operations

ACKNOWLEDGMENTS

We’d like to give special thanks to Cassidy Cote, with Vermont Transportation Agency Hydraulics Department, for his dedication to helping us with our data collection and analysis for this project.

Also, thank you to the Manchester Riverwalk Committee for giving us the opportunity to work with them on this project to enhance the beauty of Manchester, Vermont.

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FIGURES

TABLES

Appendix VII - Project Risks, Mitigations, Uncertainties
Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

March 26, 2018

Summary:

The following report will provide information on the risks and uncertainties associated with this project, and the mitigation tactics we have implemented in order to avoid a failure of our project. Failure for our project would be not meeting our clients needs, or providing the committee with an unusable design. We have, hopefully, successfully found a way to avoid major risks in our project in order to provide the client with a detailed design.

Discussion:

Project Risks

The uncertainties that we have identified associated with the pedestrian bridge crossing are listed below in Table 1. We are taking steps to mitigate these risks, such as ensuring all design aspects are meeting requirement and permitting needs. A risk was determined by multiplying the probability (0-1, 1 being very likely) with a cost factor (0-1, 1 being higher pricing). From this table, we were able to focus on the higher risks, as these would be the ones we want to ensure are avoided at all costs. As seen in the Table, the highest risk is not getting community acceptance. This is because if the community does not approve the design, they will not help with donating the funds to cover the cost of the bridge, therefore, this has been a highly looked at aspect of our design and we have made sure to include the community on every aspect thus far.

Table 1. Risk Cost Analysis

ASSOCIATED RISKS	PROBABILITY	COST	RISK (PxC)
Technical Feasibility of Implementation	0.25	1	0.25
Not Meeting Permitting Needs	0.1	0.1	0.01
Lack of Funding	0.1	1	0.1
Not Getting Community Acceptance	0.5	1	0.5

Project Uncertainties

Subsurface Conditions

The soil conditions in this area have not been explored heavily. Based on the exposed bedrock in the river bed, a boring done about 1,000 feet upstream, and from a preliminary hand auger exploration (down to ~3 feet), this is not a major concern. However, there is always some uncertainty in the materials that could be found under the ground surface. The design of the bridge will have to incorporate a unique build and installation process, possibly being built only from the accessible side of the river. The foundations were designed as shallow spread footings, in order to help with easement of construction, and not having to worry about exploring deeper into the subsurface. We believe if checked by an engineer who is familiar with the area, this design will be sufficient.

Severe Weather

As in most projects, the unpredictable weather of Vermont can pose a uncertain hazard to our project. If there is an excessive amount of snowfall/ice build up prior to the spring melt, this could raise flood levels significantly. If we were to get large storm (Tropical Storm Irene Part II possibly, or worse), the Manchester Riverwalk site could need serious restorations to bring it back to a useable condition. Our bridge design is for a 10-year storm, per Manchester specs, so this is an uncertainty to us whether or not a severe storm happens, because our bridge was not designed for this impact.

Approval of Design

Specific design restraints and foundation issues are a major uncertainty in this project as well as the approval of the design from the committee, community and ANR. We have contacted representatives from ANR and VTrans to talk us through the permit process, and have even met with a representative from both agencies at our site. ANR has graciously offered improvements to AutoCAD drawings and has ensured all HEC-RAS models run are accurate. We feel this is no longer an uncertainty for our project and we have checked it off of our list.

Conclusion:

The risks and uncertainties associated in the above document have been considered in all aspects of design for this project. Our mitigation tactic was to, from the beginning of the project, address these and apply them where they would cause a failure of our design. Since addressing these from the beginning, we were able to eliminate some uncertainties and risks, by being vocal with our community partner and assuring our design was meeting all requirements per ANR and VTrans at every step of the way. We feel our project has sufficiently met our clients expectations and is able to be handed off to a professional engineer in order to follow through with design.

Appendix VIII - Project Sustainability Report
Manchester Riverwalk

Andrea Ameden, Augie Arles, Kate Fuller, Shaun Roberts

March 26, 2018

Summary:

To provide information on the sustainability aspects of the Manchester Riverwalk Pedestrian Bridge. The implementation of a pedestrian bridge over the Battenkill River will socially, environmentally, and economically sustain the surrounding area of the project site. Although, we are not engineers heavily versed in sustainability, this report will provide a preliminary analysis, which would be followed through and confirmed by an engineer with this specialty.

The town of Manchester, Vermont is the geographic sphere of interest for this project. The town already experiences high tourist visitation, and we believe by the implementation of this pedestrian bridge, the town will thrive with having more opportunities to adventure around. This location was chosen for the pedestrian bridge because there is opportunity for outside development here. There is talk about building an amphitheatre and possibly a ropes course around the river to gain attraction to this natural aesthetically pleasing site in the middle of a busy town. With these expansions will come positive and negative impacts to the social, environmental, and economical sustainability of this area.

The time frame of interest associated with this project isn't set. With the implementation of this pedestrian bridge, this will attract more people to the area surrounding the river. With the growth of attraction, there is talk to also build an amphitheater to encourage more visits. If this project is successful, there is potential it will continue to grow for many years to come, and bring in enough tourism and attraction that it will be well maintained and replaced if need be.

Discussion:

Design Alternatives Ranking

Table 1 below shows the ranking of each alternative for our designs. The rankings are based on impacts to the social, environmental, and economical sustainability of our project and surrounding site. These ranking were based off of a 1-4 scale, where 4 was denoted to the alternative ranking best in each specific category mentioned. That ranking was then multiplied with a value of 0.25 (social), 0.5 (environmental), and 0.25 (economical) , by how important we believed that aspect to be in choosing which alternative to move forward with. An alternative would ideally be chosen at the end with the highest score.

Table 1. Alternatives Ranking

Alternative	Social	Environmental	Economical	Total Score
Do Nothing	3	4	4	1.25
Stepping Stones	2	3	2	2.5
Floating Bridge	1	1	1	1
Arched Bridge	4	2	3	2.75

Comparison of Sustainability

Table 2 below shows the comparison and weightings of the social, environmental, and economical sustainability aspects of this project. The weights were given as +1 for positive impacts, 0 for neutral, and -1 for negative impacts. The points for each aspect were tallied and divided by the number of aspects, giving a final score between 0 and 1, with 1 being the most sustainable aspect. As seen in Table 2, the economical sustainability ranks highest, then environmental, and then social. The social aspects rank lowest because there are more uncertainties (as seen in the table) associated with this aspect than the others.

Table 2. Comparison of Sustainability Aspects

Social			
Item	**Score**	**Justification**	**Total**
Increase in outdoor activities	1	less air pollution from driving around town where walking is applicable	0
Opportunity to build off of in future	1	more jobs (to build it), more outside friendly area, encourages healthy outdoor activities	
Provides a safe place during the day to hang out	1	encourages kids and teens to go outside instead of go home and sit inside after school	
Tourist attraction	0	can lead to more foot traffic and more pollution, but also could help local economy	
Unlit area at night	-1	potential for crimes	
Property still owned privately	-1	property owners being unhappy with foot traffic or littering with no one responsible to clean it up	
More people to pollute river	-1	more foot traffic and people hanging out usually leads to more trash which can pollute river and kill off species of fish and other aquatic animals there	

Table 2 Cont'd. Comparison of Sustainability Aspects

Environmental			
Item	**Score**	**Justification**	**Total**
Air	1	initial affect from construction equipment, but over time would ideally improve air quality by encouraging more people to walk / bike	0.4
Surface Water	1	no impact because of all ANR regulations we are following, construction could cause some preliminary pollution	
Soil	1	no impacts because of all ANR regulations	
Groundwater	-1	no impacts foreseen at this time, but there is an uncertainty involved once excavation begins	
Stream Alteration	0	ANR regulations to avoid this, but could be potential damming or flooding that is unforeseen and unavoidable	
Economic			
Item	**Score**	**Justification**	**Total**
Bridge	1	fundraise from locals to be able to buy and build	0.75
Future plans	1	encourages others to build similar structures around area, put money back into local economy	
Tourist attraction	1	more people coming into the center of town and walking, possibility to eat and shop locally	
Unknown use of bridge	0	could be a waste of money if not built correctly or used for the intended uses	

The total overall score for our projects sustainability is an average of about 60% sustainable. This number is sufficient for our project, because of how low-scaled it actually is, the sustainability will actually be much higher. We took into account risks that are very unlikely to occur, but scored them as a -1 just incase they were to occur. We are prepared to move forward with our project and emphasize the sustainability aspects it entails.

Conclusion:

We believe that the above social, environmental, and economic sustainability attributes are addressing the goals of our community partner. The major goal for our community partner is to provide a safe way to cross the river while enhancing the natural beauty of the surrounding site. Us, as soon to be Professional Engineers, have a responsibility that our structure and site are safe and serviceable. We do not want to set others up for failure on a structure that will not hold up, possibly causing injuries. We want to provide a structure that can be maintained and easily replaced if needed. Those are two key things we have learned in our undergrad career at UVM, all structures need to be safe and serviceable. We as a team did strive for these as we finalized the design of our bridge.

View Appendix 7 - Cost Analysis for details on our life cycle cost analysis, created in rsmeans. Please also view Attachment 1 of this document, as it states the applicable standards per Vermont Act 250 that we will be following for our project, to ensure the highest quality of sustainability is reached.

Attachment 1 - Act 250 Guidelines

Social Sustainability - Applicable Act 250 Guidelines

Per 10 V.S.A. § 6086 Section 5, our project should not cause "unreasonable congestion or unsafe conditions with respect to use of highways" and must incorporate "transportation demand management strategies" in order to provide safe access and connections to adjacent properties. This area of Downtown Manchester is frequently busy during the year as is. The adjacent park where concerts are held and shopping outlets surrounding that receive much of the pedestrian and vehicular traffic during the summers. The expected growth of the Manchester Riverwalk will not cause congestion for vehicles due to the available parking near the Factory Point Town Green as well as the other available parking across and down Main Street near the outlets. There is an expected increase in pedestrian traffic on and around the Manchester Riverwalk trails which could cause unsafe conditions for pedestrians on either end of the trail (i.e. Factory Town Point Green entrance - close proximity to Route 30 and Price Chopper Plaza parking lot entrance.) To mitigate these hazards, another crosswalk should be placed at the Route 30 intersection with the park and proper signage for drivers should be place to make them aware of the increased pedestrian traffic. In addition, more signs for the Riverwalk should be added to encourage users to park in the Price Chopper Plaza parking lot to avoid the dangerous crossing at Route 30.

Per 10 V.S.A. § 6086 Section 6 and 7, our project should not cause an unreasonable burden on the ability of a municipality or local government to provide educational or municipal services respectively. The Manchester Riverwalk is a low-maintenance site (once constructed) and should not put any burden on the Town of Manchester government officials.

Per 10 V.S.A. § 6086 Section 9A, our project should not significantly affect the growth of the population experienced by the town and region or affect the potential financial capacity to reasonably accommodate the total growth and rate of growth. Since this is not a town project or of a large scale, the increase in rate of population growth is not expected to change in the Manchester Center area. Similarly, the town's funds have no stake in this project so the financial capacity to reasonably accommodate growth will not be compromised by this development.

Per 10 V.S.A. § 6086 Section 9G, our project, being currently privately owned, must show some sort of capital program or plan regarding the municipality involved should the municipality be required to assume the responsibility of the services and facilities. The current maintenance plan for the Manchester Riverwalk is low, with an assumed annual spring clean up.

Per 10 V.S.A. § 6086 Section 9L, our project is not to contribute to a pattern of strip development in accordance with Vermont's historic settlement pattern of compact village and urban centers separated by rural countryside. The Manchester Riverwalk project promotes and encourages the natural beauty of Vermont by placing walking trails along the tranquil stream with a natural, wooden pedestrian crossing to help visitors and locals alike escape the busy downtown area of Manchester.

Environmental Sustainability - Applicable Act 250 Guidelines

Act 250 states that any development in the river corridor cannot restrict or diver any flow of the floodwaters, or increase the discharge of the river or stream. This standard is mainly in place for safety of the public during high flow events. However, when there are high flow events and a structure impacts the flow it will have definite effects on the surrounding environment. The main issue during high flow events and bridges or structures near the stream is that the high velocity flow causes scouring and damage to the surrounding soils. When soil is eroded, roots of plants are then damages causing further damage to plants. This is an add on to the fact, that causing change in flood water level will have the potential to drown plants that are not meant to be underwater causing further damage to the ecosystem.

Act 250 considerations also extend to explain that there shall be no "undue adverse effect on the scenic or natural beauty of the area, aesthetics, historic sites or rare and irreplaceable natural areas." Although this seems like an easy problem to keep under control, we do not know what type of crowds this new project will attract and may have a negative impact on the environment. One of the biggest issues that we will face is the introduction of manmade trash into the stream with the attraction of more and more humans. On each trip we noticed that there was trash that littered the stream banks and the surrounding ground. If this is an issue before there is structure to draw people to the location then you can infer that it will be a much larger issue when the structure is build. Not only will the increase in potential trash be an issue but because this project will draw more attention to the area the amount of damage due to foot traffic alone is a major issue. It is hard at this point to determine the overall damage that will be caused by foot traffic but it is something to keep an eye out for as the years pass.

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