DEDICATION

"THE PRESENT GENERATION OF MEN, AND WE KNOW NOT HOW MANY GENERATIONS AFTER, WILL TRUDGE ALONG NEARLY IN A PATH TRODDEN BY THEIR FATHERS, PERHAPS STRAIGHTENING A BEND HERE, AND AVOIDING A HILL OR SLOUGH THERE, BY SLOW DEGREES MAKING THE ROAD OF LIFE SMOOTHER AND STRAIGHTER; AND WHAT THE FINAL RESULT WILL BE, IT IS ONLY IN OUR POWER AT THE PRESENT TIME, TO CONJECTURE. BUT IT IS ALWAYS WELL TO HOPE AND STRIVE." (*The Way to Happiness,* S. WHIPPLE., P.201.)

CONTENTS

EXECUTIVE SUMMARY

Union College's involvement in the preservation of Whipple Iron Canal Bridges began in 1980, when a restored bridge was reconstructed on the College grounds. The students in Civil Engineering continue this effort with the 1996 Senior Design Project.

An 1869 Whipple Bowstring Truss, currently in located in Fonda, New York, was donated by its owners with the stipulation that a replacement span must be provided. This made a multifaceted project more complex. The project includes dismantling, restoring, and reconstructing the bridge. Several options were explored for the replacement span, but the final design was guided by the donations of local benefactors. Steel beams, and their required fabrication were generously donated by Barry, Bette & Led Duke, Inc., and Schenectady Steel Corp., respectively.

Perhaps the most challenging aspect of the project was finding an historically appropriate site for the restored bridge. This call was answered by the Vischers Ferry Nature and Historic Preserve, in Clifton Park, New York. The preserve is the home of the abandoned Erie Canal; authentic abutments are present on the site. The project's preliminary timeline will have the Whipple bridge dismantled at the Fonda site and the replacement span erected in the fall of 1996. Restoration of the bridge will proceed through the winter months at Union College, and the restored bridge will be erected at Vischers Ferry in the spring of 1997.

I OBJECTIVES

The overall goal of the Whipple Truss Restoration Senior Design Group was to dismantle, restore and reconstruct an original Whipple Iron Erie Canal Bridge. The first step taken in achieving this goal was to locate and obtain an original Whipple Bridge. A bridge was located in Fonda, New York, and it was "donated" by its owners with one stipulation; a new bridge must be built in its place.

The group then outlined the remaining tasks which needed to be accomplished and organized itself into three teams which would be responsible for completing these tasks. The three teams were the new bridge design group, the hydrology/survey group and the existing bridge restoration group. The new bridge design team was responsible for designing a new structure to replace the Whipple Bridge. Several criteria were considered when designing the new bridge structure. The bridge would have to require a minimal amount of maintenance and carry vehicular traffic, including farm equipment, on a regular basis.

The hydrology/survey team had two major responsibilities. The first of these was to perform topographic surveys and other fieldwork necessary to establish the existing conditions at both the existing site and the proposed site. The team was also responsible for performing hydrologic analyses of both sites to determine proper bridge placement and abutment configurations. A subset of this team was the abutment design group. It was the responsibility of this group to assess the condition of the existing abutments and recommend any necessary renovations. In addition, they were responsible for the design of abutments at the new site.

The existing bridge restoration team had the responsibility to design a dismantling plan, a new deck design and perform a structural analysis of the existing and proposed bridge loading. In order to complete these tasks, the team broke up into three sub-groups. The dismantling plan team had to design the method to be used in dismantling the bridge at the existing site and reconstruct it at the proposed site. The deck design team was responsible for designing a new decking system to withstand the loading requirements at the proposed site. The structural analysis team performed analyses on the bridge as it exists now, and after restoration. The second analysis was used to determine the loading which the bridge could withstand once reconstructed at its new site.

II HISTORY & BACKGROUND

1. Squire Whipple

He has been called "the father of iron bridges", but Squire Whipple's contributions to the field of bridge design extend far beyond that title. His book, printed in 1847, was the first work that correctly computed stresses in bridge trusses. It was still in print (with minor revisions and additions) over fifty years later. Its content is still relevant. In his book, almost 150 years ago, he introduced what we now call the *method of joints* taught in mechanics classes today. It was also the first work to describe the functional design and economic proportioning of truss members and introduced the idea for a factor of safety in truss design. The work includes his own tests on the strength of materials. Before Squire Whipple, bridges were built based on only past experience or trial and error ("If it stood, it was good"). Squire Whipple brought science to the art of bridge building.

Squire Whipple

Squire (not a title, this was his given name) Whipple was born in 1804 in Hardwick, Massachusetts. At age thirteen, his family moved to a farm in New York. Having a passion for knowledge, he studied two terms at Hartwick Academy and three terms at Fairfield Academy. On his own, he studied Latin, Greek, French, Math, Astronomy and Chemistry for three years while saving money to further his education. Whipple entered Union College with advanced standing in 1829. At that time, the science courses offered at Union were the best preparation of any school in the country for an engineering career. He graduated with a perfect honor record with the class of 1830.

After he graduated, he worked for the Baltimore & Ohio Railroad for two years. Then he worked on the enlarged Erie Canal for four years. In 1841 he patented his Iron Truss Bridge. It was to become a standard design for iron bridges built in the second half of the nineteenth century. In 1854, New York State adopted this "Whipple's Patent Iron Arch Truss Bridge" (also called the bow-string truss) as the standard Erie Canal bridge. There were hundreds of them over the canal in the mid to late 1800's. The following table from the Canal Comissioners Annual Report of 1880 (see next page) illustrates how many bridges of that time could be attributed to Whipple. There is only one entry on the table which does not include his name. However, it is very likely that this was also his design, since his iron trapezoidal truss was widely used at this time.

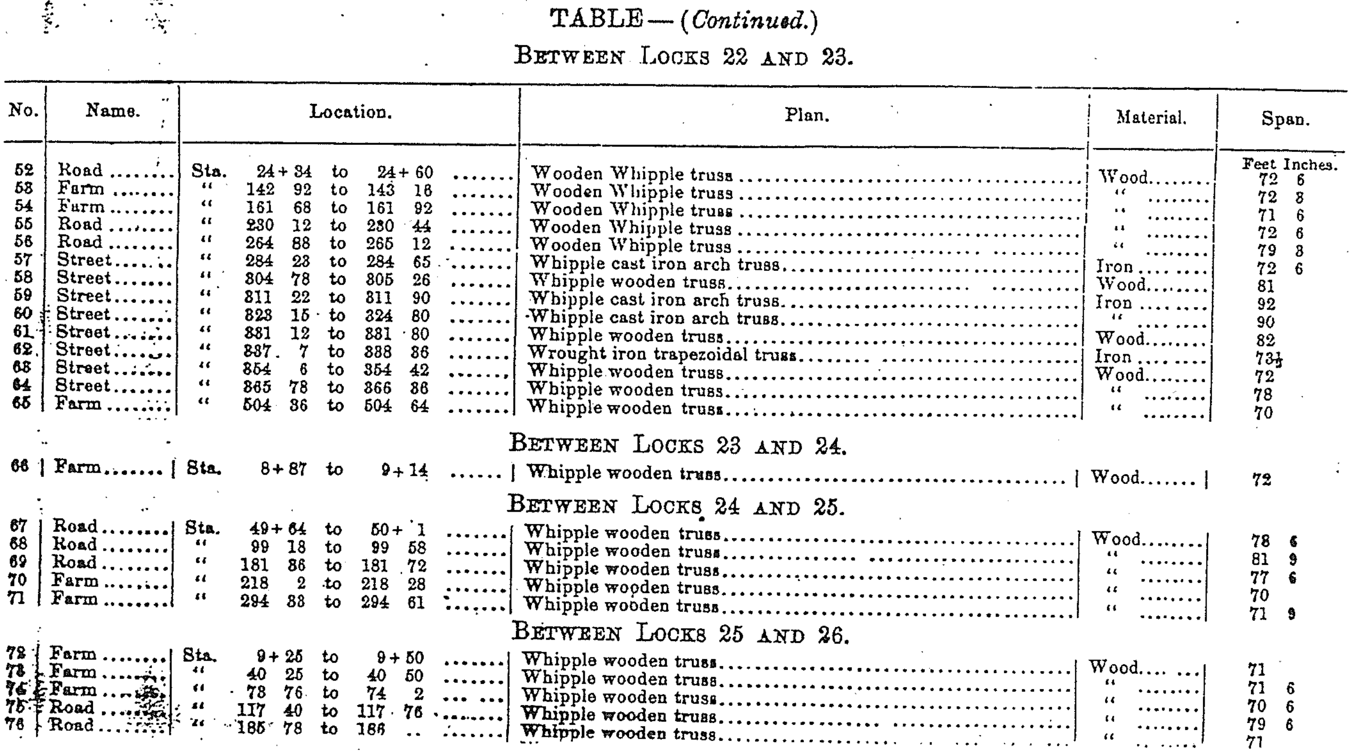


TABLE — (*Continued.*)

BETWEEN LOCKS 22 AND 23.

No.	Name.	Location.	Plan.	Material.	Span.	
					Feet	Inches.
52	Road	Sta. 24+34 to 24+60	Wooden Whipple truss	Wood	72	6
53	Farm	" 142 92 to 143 18	Wooden Whipple truss	"	72	8
54	Farm	" 161 68 to 161 92	Wooden Whipple truss	"	71	6
55	Road	" 230 12 to 230 44	Wooden Whipple truss	"	72	6
56	Road	" 264 88 to 265 12	Wooden Whipple truss	"	79	8
57	Street	" 284 23 to 284 65	Whipple cast iron arch truss	Iron	72	6
58	Street	" 304 78 to 305 26	Whipple wooden truss	Wood	81	
59	Street	" 311 22 to 311 90	Whipple cast iron arch truss	Iron	92	
60	Street	" 323 15 to 324 80	Whipple cast iron arch truss	"	90	
61	Street	" 331 12 to 331 80	Whipple wooden truss	Wood	82	
62	Street	" 337 7 to 338 36	Wrought iron trapezoidal truss	Iron	73½	
63	Street	" 354 6 to 354 42	Whipple wooden truss	Wood	72	
64	Street	" 365 78 to 366 36	Whipple wooden truss	"	78	
65	Farm	" 504 36 to 504 64	Whipple wooden truss	"	70	
BETWEEN LOCKS 23 AND 24.						
66	Farm	Sta. 8+87 to 9+14	Whipple wooden truss	Wood	72	
BETWEEN LOCKS 24 AND 25.						
67	Road	Sta. 49+64 to 50+1	Whipple wooden truss	Wood	78	6
68	Road	" 99 18 to 99 58	Whipple wooden truss	"	81	9
69	Road	" 181 36 to 181 72	Whipple wooden truss	"	77	6
70	Farm	" 218 2 to 218 28	Whipple wooden truss	"	70	
71	Farm	" 294 33 to 294 61	Whipple wooden truss	"	71	9
BETWEEN LOCKS 25 AND 26.						
72	Farm	Sta. 9+25 to 9+50	Whipple wooden truss	Wood	71	
73	Farm	" 40 25 to 40 50	Whipple wooden truss	"	71	6
74	Farm	" 73 76 to 74 2	Whipple wooden truss	"	70	6
75	Road	" 117 40 to 117 76	Whipple wooden truss	"	79	6
76	Road	" 185 78 to 186 ..	Whipple wooden truss	"	71	

A few of Whipple's other accomplishments:

- The long-span railroad bridge he built in Troy in 1853 was a trapezoidal truss design. It became the model for long-span railroad bridges for the next thirty years.
- His wooden farm bridge design was widely used.
- In 1874 he built and was issued a patent for the first iron lift bridge in the United States. This successful bridge over the canal was in use for over forty years.
- Whipple designed and built the first weigh lock scale for the enlarged Erie Canal. It was the largest weigh lock scale ever built at that time.
- He built and sold his own survey equipment.
- He wrote a book on his philosophy of life entitled "The Way to Happiness".

By the 1860's, Whipple had gone into semi-retirement. This bridge in Fonda is likely one of the last that he built. Squire Whipple lived to the age of 83, which was remarkable for the nineteenth century. In 1868, the American Society of Civil Engineers elected Whipple as an honorary member. The following is an extract from the annual address to the A.S.C.E., 1880.

> "HIS BOOK, PRINTED IN 1847, CONTAINS NEARLY ALL THAT IS VITALLY IMPORTANT CONNECTED WITH THE THEORY OF FIXED SPANS, AND HIS BRIDGES

> STAND TO-DAY AS MONUMENTS TO HIS SKILL AND AS REMINDERS TO US OF THE DEBT WE OWE TO THAT DISTINGUISHED ENGINEER."

2. The Fonda Bridge

The bridge in Fonda is was built in 1869, and was originally over the enlarged canal most likely in Fultonville. It was moved to its present location over the Cayadutta Creek sometime after the canal was filled in 1918. This is now a private road owned jointly by Roger Gray and Anthony Kikkis. It is used for access to farmland and to a home off of route 334.

This site was "the White Bridge Stop" for the Fonda, Johnstown & Gloversville trolley line which ran along Cayadutta Street. The trolley was in operation between 1870 and 1932. The White Bridge was a Whipple farm bridge.

There are six known remaining Whipple truss design bridges: One has been restored in Tokyo, Japan; one is the restored bridge on the Union College campus; three others are on private roads in New York State. Last, there is this bridge in Fonda, New York. Of the remaining structures, only the Fonda bridge is an original Whipple, built by the master. (Griggs, 1996)

III SURVEY OF THE FONDA SITE

1. Photographic Documentation

The documentation process normally consists of photos, measured drawings and a history of the site and the structure. The Historic American Engineering Record (HAER), a division of the National Parks Service, uses this type of analysis. The HAER was organized in 1969 to identify and record historic American engineering structures. When this renovation is completed, it is our hope that the site will become a National Historic monument. For this to happen the documentation process needs to be complete.

A complete set of photographs were taken of the bridge at its current site. Shots were taken of the approaches, abutments and substructure. Joints were labeled and photographed individually to provide a record of their condition.

2. Measurements of Truss

Precise measurements of each member of the truss were obtained. These measurements were necessary because of the variability of 19th century casting methods and visible corrosion. The wrought iron members making up the lower chord, web bracing, and cross bracing were carefully examined. In some locations corrosion had drastically reduced the cross sectional area of the members. In addition, the average web thickness and cross sectional area were determined on each cast iron member of the top chord. This information was then used to perform a complete structural analysis of the truss.

3. Structural Analysis of Existing Bridge

The structural analysis of the truss was done using the Structural Analysis and Design Program (STAAD - III). This program uses matrix methods to analyze the trusses. The program requires joint coordinates (obtained from field survey) , member properties, and loads as inputs.

The Whipple bridge is made out of cast and wrought iron. To analyze the trusses, the modulus of elasticity of steel (29,000 ksi) was used. Each junction block is connected by twin wrought iron loops. Their area was summed, and this one value was used for the analysis (see appendix A, p.10). The same assumption was made in twin vertical members (member 4-12 and 5-11; see appendix A, p.10). The measured smallest diameter of the diagonal and vertical web members was used. For the analysis of the existing bridge, the smallest diameter was near the lower joints where some necking has occurred. For the analysis of the bridge after restoration, the bar diameters are larger because the necked down sections will be removed. The average moment of inertia in the x axis was used in top compression members. There will be no buckling in y direction, therefore, moment of inertia in the y axis was not used.

Seven cases of loading are analyzed. Case 1 is for pedestrian loading only. Case 2 to Case 7 are for a vehicular moving load. The moving load is placed on various joints to simulate a vehicle moving across the bridge. A 15 lb./ft^2 dead load was assumed for the weight of the existing wood deck and a 10 ton vehicle for the moving load.

Results: (see appendix A, p. 4 & 5, for stresses on all members)
The maximum tensile stress occurs in one of the moving load cases. It occurs on cross diagonal member 6-9 in the North truss. The value of the stress is 36.3 ksi, which is well in excess of an allowable stress of 20-22 ksi. Some other diagonal members have large stress values as well.

Conclusion:
With large stresses apparent on the bridge as it stands, the restoration of this historical bridge is critical. If it were not repaired, this bridge would eventually fail. By rehabilitating the diagonal members, the stresses on the members will be reduced, and this bridge will be able to stand for generations to come.

4. Existing Abutment Analysis

The two existing abutments in Fonda, which are supporting the Whipple Truss bridge, need to be repaired before they can be used for the new bridge. The east abutment is in good condition. It has some minor surface cracking and needs some added protection against undercutting. The west abutment has significantly more problems. There is a large amount of undercutting along the face and sides. The biggest problem is a vertical crack which extends to its full height on the north side of the west abutment.

The east abutment's (Appendix A, Fig. 1) condition will require very minor repairs. The surface cracking can be fixed by an epoxy patch. The cracks will have to be cleaned prior to patching. This will ensure a strong, and long lasting patch. The second problem is to prevent any undercutting of the abutment. The river has not yet compromised the soil beneath the foundation; there is still some existing soil above the water line along the face. In order to protect the face from potential undercutting, rip-rap will be placed along the base.

The west abutment (Appendix A, Fig. 1) requires some major repairs. The first problem is the undercutting at the base along the river. The underlying soil at the abutment face has eroded. In order to repair the undercutting, the river needs to be sandbagged to divert it away from the damaged area. The soil then needs to be removed from underneath the abutment. A dry pack concrete will replace the removed soil. This will give a long lasting replacement and reinforce the abutment. Rip-rap will then be placed along the base as an additional prevention against erosion.

There is also undercutting along the sides of the abutment where pieces of concrete have fallen away from the foundation. These areas require patching and rip-rap placed along the affected area to prevent further erosion.

The vertical crack along the north side is a major concern. The best option to prevent the crack from increasing further is to use tie-backs (Appendix A, pg. 1-2). The tie-backs would be attached to a concrete block located at the base of the back side of the abutment (Appendix A, pg. 2). Excavation along the approach of the abutment will be required so the block can be poured. The holes for the tie-backs will be drilled from the top of the concrete face (Appendix A, Fig. 1).

The preceding solutions are all based on the most economical way of repairing the problems. There will be many factors that will have to be addressed in the field. Transportation of material to the west side of the bridge will most likely be done by hand. The bridge cannot hold heavily loaded construction equipment. Concrete can be brought to the site by a mixer. It is feasible to channel the concrete to the west side without having the truck cross the bridge.

IV HYDROLOGIC ANALYSIS

1. Methods

A hydrologic analysis of the Cayadutta Creek in Fonda, NY, over which the Whipple Bridge is to be removed, was carried out to determine the flow rates for various flood events. This study was performed to ensure that our replacement bridge would not be washed out. Even though the bridge's abutments are sitting much higher than the flood plain, this study was completed in the event of an ice jam occurring near the bridge site, preventing the spillway of the flood waters into the flood plain.

First, a study was done on the current conditions of the Cayadutta Creek watershed. The current flow velocities of the stream were obtained by use of a flow meter and ranged from 3.8 to 4.2 ft/sec which translates to a flow of approximately 240 cfs.

Next, the watershed area was determined for our point of interest. The approximate watershed area is 62.5 square miles. This watershed consists of about 65% woods, 30% pastures and meadows, and about 5% developed areas (villages). The northern most portion of the watershed extends into the southern section of the Adirondack Park.

The flood flows could be established from the watershed and the type of soil use within the area. The two methods of determining these flows were the TR-55 method and the Federal Highway Administration (FHWA) method. The two methods produced comparable results, but the TR-55 method was adopted since its use is more applicable to our design.

The TR-55 method is less conservative than the FHWA method and, hence, results in lower flood flows. See Appendix B-1 for the steps involved in this method. The unknowns involved are the watershed area, the curve number, the time of concentration of the water, the Manning's *n* value, the pond and swamp area, and the rainfall for each event considered. The curve number (CN) pertains to the soil use of the watershed. With the land use percentages, an average CN of 79 for the whole area, was obtained (see Appendix B-8). The time of concentration (T_C) of the flood waters is the time it takes for a drop of water to travel from the boundary of the watershed to the point of interest. This time assumes a channel width throughout the open channel flow portion of the stream. The flow will be a bit conservative since we assumed a rather large width (see Appendix B-3&4). The Manning's n value was obtained from a book titled *Roughness Characteristics of Natural Channels*. We used the n value of 0.06 which pertains to a stream that most closely resembles the Cayadutta Creek. The pond and swamp area for the watershed were estimated as 3% of the total area. The rainfall data for each flood event, on a 24 hour basis, was interpolated using the TP-40 maps of the United States. See Appendix C-6&7 for the determination of the flood flows using this method.

The FHWA method is a generally accepted method of determining flood flows for culverts. It is a very good way to obtain an approximate flood flow. See Appendix C-15 for the steps involved in this method. The unknowns in this method are the watershed area, the isoerodent number, and the change in elevation of the stream. The isoerodent number is obtained from a State of New York isoerodent map (see Appendix C-19). The change in elevation of the stream is the change in elevation of the furthest point of the stream to the point of interest. Using the formula pertaining to the Cayadutta Creek zone, the flood flows for the 10, 50, and 100 year events were obtained. See Appendix C-16 for flood flows using the FHWA method.

2. Conclusion

With the flood flows determined for various flood events, the depth of water at the bridge site could be determined for each of these flood flows. Using a TK! Solver software model prepared by Professor Thomas K. Jewell, the critical depths were determined. In a worst case scenario, such as an ice jam at the bridge site, there would be no flood plain. For this case, it was assumed that the channel had vertical banks, infinite in height. See Appendix C-13 &14 for critical heights of the flood flows for the 50-yr and 100-yr flood events. Also, local residents told us the water level for the worst flood event was approximately 1-2 feet below the top of the abutments. With the combination of our hydrologic analysis and the word of local residents, we consider a bridge placed at the elevation of the current abutments to be safe against a wash out.

V DISASSEMBLY, MOVING, & REHABILITATION

The removal process has been broken into 15 steps (Appendix D). A list of required equipment and tools for removal include: scaffolding, three 6 foot step ladders, two acytlene torches, large size wrenches, oil, pry bar, and tags. The bridge will be removed and tagged according to figures in Appendix D. It will then be transported to the Union College Campus on a college vehicle. Once on campus, the dismantled bridge will be restored in Potter Lab or another building suitable for the task. At the Fonda site, all construction debris will be carted to the appropriate landfill.

A majority of the original members will be incorporated in the restored bridge. Once the bridge is on campus the restoration will begin. This includes cleaning all usable parts, replacing any broken or non-usable pieces, and straightening members. The scrap metal and steel not suitable for the new bridge will be donated to the Arts Department at Union College. Once the restoration is complete, the reconstruction and erection will begin in the spring of 1997.

VI REPLACEMENT BRIDGE FOR THE FONDA SITE

1. Options Considered

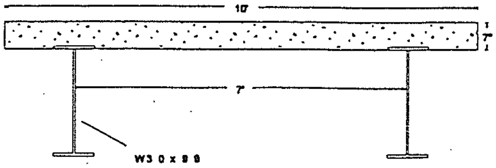
There are five major concerns for the design of the replacement bridge. They are as follows: cost, ease of placement, load on existing abutments, future maintenance requirements and aesthetics. Several different designs have been considered for the replacement bridge with the above concerns in mind. Each design needed to allow for a maximum live load of 6 tons (tractor weight) and snow load of 30 psf. The stream flow at flood levels, was also a design consideration for each case. The span is 72 ft 6 inches and the road width is 10 ft.

A. **Wood Options:**

The wood options considered included: wood beams, laminated beams, wooden roof trusses and a wooden truss of our own design. The wood beams required a 12 inch wide 24 inch deep section for the 72 ft 6 inch span (see Appendix E, page 1). The laminated wood beams required a 12 inch wide 22 inch deep section (see Appendix E, page 1). Wooden roof truss distributors were contacted and the results were very unfavorable. The same results were encountered in the preliminary design phase of our own truss. The loads were far too large for the wood to support. The size of the members needed to cross the 72 ft 6 inch span were unreasonable due to the relative strength of wood. In addition, the high maintenance and short life expectancy of the options were undesirable. A cost analysis of the wood options was not performed, since the designs were so unfeasible.

B. **Inverset bridge:**

Composite structure of 2 steel beams and a concrete slab
Precast, precompressed



Inverset Bridge
Front View

Cost: (($45/sq. ft.)(730 sq. ft.) = $32,850

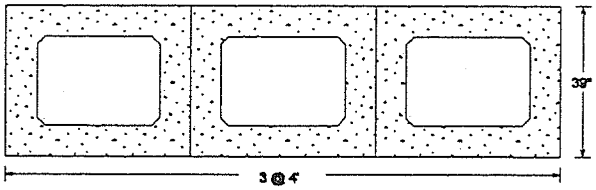
also add: cost of guide rail, crane to lift 38 tons,
fill to grade (bridge would sit 2.5' higher than existing bridge)
Approximate weight: 76 tons

Advantages of the Inverset System include: speed of placement (concrete is cured at the factory, so the bridge is ready to use upon erection); durability (deck lasts longer than conventional cast-in-place concrete decks).

Disadvantages include: high cost; weight of structure on existing abutments (approximately 4 X weight of Whipple truss).

C. **Spancrete bridge beams**

Precast rectangular beams, prestressed

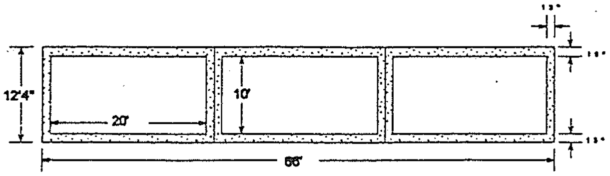


Spancrete Bridge
Front View

Cost: ($8000 per beam)(3 beams) = $24,000
also add: cost of guide rail, crane, fill.
Approximate weight: 83 tons

Advantages and disadvantage are similar to those for Inverset System bridge.

D. **Concrete box culverts**



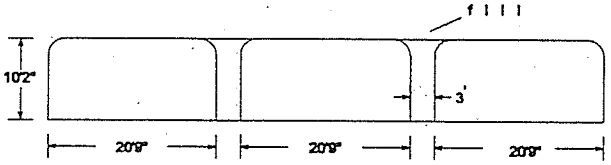
Concrete Box Culverts
Front View

Cost: ($1800/linear ft.)(12 ft.)(3 units) = $64,000
also add: cost of head wall, guide rail, crane to lift 34 tons, fill.

Disadvantages include: very costly, reduction of area for stream, time consideration for construction of head walls.

E. **Corrugated steel culverts**

galvanized, low profile box, full invert, square ends
to and invert of 7 gage steel, sides of 8 gage steel.

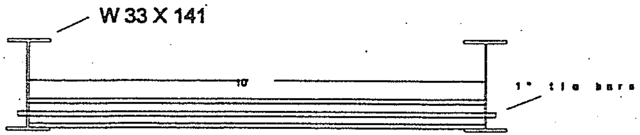


Corrugated Steel Culverts
Front View

Cost: ($862.75/ft.)(12 ft.)(3 units) = $31,059 delivered to job site
also add: cost of head wall, guide rail, crane fill.

Disadvantages are similar to those for concrete culverts.

F. **Wide-flange beams with concrete deck**

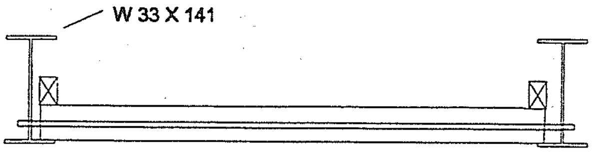


Steel Bridge w/ Concrete Deck
Front View

Cost: 2 W 33x141 beams = $6135
18, 3 ft. concrete sections = $6000
also add: tie bars, grout, crane, guide rail.

Advantages include: low maintenance, high durability, relatively low cost

G. Wide-flange beams with wood deck



Steel Bridge w/ Wood Deck
Front View

Cost: 2 W 33x141 beams = $6135
C 7x14.75 ($5.20 per ft.)(70 ft.) = $364
wood decking (1080 ft.)($2.20 per ft.) = $2400
also add: tie bars, crane, guide rail

This design is less expensive than the steel and concrete bridge, but more maintenance is required.

There are five major concerns for the design of the replacement bridge. They are as follows:
cost; ease of placement, load on existing abutments, future maintenance requirements, aesthetics.

Several different designs have been considered for the replacement bridge with the above concerns in mind. Each design needed to allow for a maximum live load of 10 tons (tractor weight) and snow load of 30 psf. The stream flow was also a design consideration for each case. The span is 73 feet and the road width is 10 feet.

2. Preferred Design

The removal of the Whipple Truss Bridge from the Fonda site has created the need for a replacement bridge. The replacement bridge must be a durable, low maintenance structure, capable of carrying moderate loads such as a 6 kip tractor. Initially, wood, concrete, and steel were investigated as possible building materials. The designs were compared based on cost, maintenance, and feasibility.

The design for the replacement bridge at Fonda essentially chose itself thanks to very generous donations from Barry, Bette and Led Duke, Inc. and Schenectady Steel Corporation. The Barry, Bette and Led Duke, Inc. of Albany, donated three, 56 ft W33x118 girders along with about 90 to 100, 10 ft 12 in x 12 in timbers, for decking and curbing (see Appendix E, pages 3 and 4). Two of the girders will be cut into 50 ft sections and the third will be cut into two 22 ft 6 inch sections, so that when welded they will cover the 72 ft 6 inch span (see beam splice detail, Sheet 3 of 8). Schenectady Steel has offered to fabricate the beams free of charge. The two beams will be pulled together by tie bars placed every 24 ft (see Sheet 3 of 8). The wood timbers located at these points will have to be routed to accommodate for the tie bars. The deck will be 10 ft wide with a foot of curbing on each side providing an 8 ft road width (see Sheet 3 of 8).

The beams will be loaded by crane onto a flat-bed eighteen wheel truck and transported from Barry, Bette and Led Duke, Inc. to Schenectady Steel. The cost for transporting the beams will be about $750. The beams will then be welded to the appropriate 72 ft 6 inch span as previously described. Since the girders are covered with lead paint, they will have to be treated using AGP-Protecta Poxy (see Appendix E, pages 5 and 6). Before cutting the girders, a 6 inch surface on each side of the cut must be cleared of all paint using Dumond Chemicals Peel Away I (see Appendix E, page 8). The chemical is applied to the 6 inch areas on each side of the cut, bonds with the paint, and pulls it from the girder. The beams are then cut to the appropriate lengths and welded together using a complete penetration double v-groove weld (3) butt joint (B) (see Appendix E, page 7). Peel Away I must also be applied to channel sections attached to various portions of the web. After these sections are removed, they must be ground down flush to the web. A neutralizer is then applied to cleaned sections to deactivate the Peel Away chemicals (see Appendix E, page 9). Protecta Poxy can now be applied to the entire beam to seal in the lead paint. The Whipple Farm Bridge that originally spanned the Fonda sight was known as the "White Bridge". Accordingly, we will be using white protecta poxy to paint the bridge.

The beams will be too long to put on a normal flat bed truck so it will be necessary to use a stretch trailer. Stretch trailers are capable of providing up to 65 ft of trailer length plus 10 ft of overhang. This will cost approximately $1,000. The beams will be lifted by crane and placed on 1 inch Neoprene Bearing Pads, which will be resting on the abutments (see abutment detail on Sheet 3 of 81). One 10 inch long, 1 inch diameter, anchor bolt will be driven through the flange and pad, into the abutments on each side of the web (see abutment detail on Sheet 3 of 8). The flanges will have 3 inch slotted holes to provide for room for expansion during temperature change (see abutment detail on Sheet 3 of 8).

The decking will be placed in one of two ways. The timbers may be able to slide in from the top at an angle and pushed into place. Alternately, the flanges could be greased and the timbers pushed in from the front and back of the beams.

The cross-bracing on the replacement bridge will provide sufficient reinforcement against lateral forces (see Appendix E, page 10). The cross-bracing consists of 10, 9/16 inch diameter bars with 90° angled brackets at each end (see cross-bracing detail on Sheet 3 of 8). The angled brackets will be welded to the bottom of the beams and the bars will be inserted and bolted. Turnbuckles are used to tension each bar.

The final design for the replacement bridge is ideal for the Fonda sight. The bridge will be far more than adequate for the expected loads. The wood options investigated were unfeasible due to the span, and the maintenance involved. The concrete structures were found to be too large and expensive for our specific needs. It was apparent early that steel was the material of choice and thanks to Barry, Bette and Led Duke, Inc. and Schenectady Steel the materials took care of themselves. The "White Bridge" will be a strong, durable structure that will provide service well into the 21st century.

VII NEW SITE FOR THE WHIPPLE BRIDGE

Four criteria were established for the new site of the Whipple Bridge:

1. The new owner must maintain it.
2. It must be highly visible and open to the public.
3. The restored structure should not be subjected to undue service loads.
4. If at all possible, the bridge should be relocated in a setting that is historically accurate.

In the brief time allotted to investigate suitable new sites, it was the attempt of the group to search as wide an area as possible. We became aware of a bridge, in Five Rivers State Park in Bethlehem, that was washed out in a storm this spring. The washed out bridge formerly spanned a marshy area, linking a nature trail. A draw back to the site is that it is located centrally and is only visible from within the park. Also, the flooding conditions here would require that the finished grade of the replacement span be elevated several feet. The group determined that prominently placing a man-made structure in an otherwise undisturbed, natural setting was inappropriate, and was the primary factor in rejecting this site.

Our search introduced us to the Washington County Committee on Covered Bridges. The Committee oversees the maintenance and preservation of single lane wooden covered bridges on county highways. They expressed interest in possibly locating the bridge on a rural road. The projected service loads of this alternative were a concern. While the design group concurred that the bridge would have the structural capacity, in the interest of its continued longevity, pursuing this alternative was abandoned.

We were investigating a potential site on the bike path at Lock 9 of the New York State Barge Canal, when we were directed to the Vischers Ferry Nature & Historic Preserve in the Town of Clifton Park. The preserve encompasses over 400 acres of historically and ecologically significant land adjacent to the Mohawk River. In 1907, the river was dammed to create the barge canal. Increased water levels in the river, coupled with annual spring flooding, created a wetland in what was once a prime agricultural area. When the New York State Barge Canal officially opened in 1917, the old Erie Canal was abandoned.

Highly visible and open to the public, spanning the original Erie Canal on authentic stone abutments, the Vischers Ferry Nature & Historical Preserve is the ideal site for the restored Whipple Bowstring Truss Bridge. The support that the preserve receives from the Town of Clifton Park, and the town's interest in its continued development, makes this site even more desirable.

VIII THE WHIPPLE BRIDGE AT VISCHERS FERRY NATURE & HISTORIC PRESERVE

1. Site Survey

Once the new home for the Whipple Bridge was established, a topographic survey of the existing conditions at the site had to be performed. Knowing that the overall change in elevation was not too large, a 100 foot benchmark elevation was assumed at a nail on a nearby telephone pole engraved with the symbols FS5. Using contemporary methods of surveying, including the use of Electronic Distance Measurement devices (EDM's) and prism poles, the survey was completed. A site plan was drawn with the field notes obtained at the site. To make the site plan reflect actual conditions, the elevations calculated from the field notes were converted into elevations corresponding to USGS mean sea level elevations (See sheet 4 *of* 8). The most important aspects of the site plan are the locations of Riverview Road, the tow path, and the existing, authentic Erie Canal stone abutments. With this site plan and the completion of a hydrologic analysis, the new bridge height could be established.

2. Hydrologic Analysis

A hydrologic analysis for the new site of the Whipple Bridge was performed to ensure the bridge would be above the flood waters of, at least, the 100 year event. This hydrologic study was much different than that of the Cayadutta Creek because here the Mohawk River's flood plane is our main concern. The bridge will sit over the Erie Canal, which has little to no flow, and the water is only a couple of feet deep. Hence, the only time the bridge could be flooded is when the nearby Mohawk River stretches into its flood plain.

With the use of the Flood Insurance Study for Saratoga County (performed by the Federal Emergency Management Agency, effective on August 16, 1995), the elevation of water above mean sea level was determined. Using Map number 36091C0670 E (Appendix C-21), containing the new site, the elevation for the 100 year flood event was determined to be 200 feet above mean sea level.

Using the 200 foot flood elevation, the Niskayuna, NY USGS quadrangle, and the site plan, the height the abutments must be raised could be established. Coordinating the information from our site survey with the NY USGS quadrangle, the abutments must be raised at least 10 feet. We recommend raising them 11 feet for an additional factor of safety. The final elevation of the abutments will be 201 feet above mean sea level.

The hydrologic study was also checked with the help of a local resident. This resident showed us the water level for the last major flood event at a nearby site. A level run was completed and resulted in a flood elevation of 200 feet, which is exactly the same as that obtained through the hydrologic study.

3. Abutments & Approaches

Two options were considered to raise the height of the abutments at Vishers Ferry (Appendix B, Fig. 2). Existing abutments could be removed and a new concrete abutment constructed, or suitable stone could be procured to extend the existing abutments to the required elevation. The first option would be more expensive, and would not be appropriate from an historical perspective (Appendix B, pg. 3). Fortunately, within the preserve there are several abutments, in various states of repair, that once supported wooden 'farm bridges' designed by Whipple. An abundance of stone suitable for rebuilding the abutments exists in the preserve. However, the abandoned abutments, as they currently exist, do have historical and archeological significance, and our proposal to salvage stone from these locations is being considered by the Town of Clifton Park, and the town historian.

4. New Loading Requirements

The same methods, using STAAD - III, were used in analyzing the rehabilitated bridge, as for in existing bridge. The inputs needed were joint coordinates, member properties, and loads.

Member Properties:
Same assumptions used existing bridge were applied on rehabilitated bridge. The diameter of the bars was expanded, to accommodate the removing of necked down section.

Loading:
Seven cases load cases are analyzed for both options. Case 1 is for pedestrian loading only. Case 2 to Case 7 are for moving load. Moving load is placed on various joints to simulate a vehicle moving across the bridge.

Option I - with sidewalks:
The dead load for new decking was 2358.5 lb./joint; a 100 lb./ft pedestrian load was used. This pedestrian load is very conservative for safety. A 7.5 ton moving load was used to accommodate the town's backhoe. Snow load of 45 lb./ft^2 was used. This was obtained by using snow map of New York State. A large side surface does not exist, therefore the wind load was not considered.

Option II: without sidewalks:
The load on this option is the same as "Option I", except for the decking weight of 1792.9 lb./joint.

Results: (see Appendix A, p. 6-9, for stresses on all members)

Option I: with sidewalk
The maximum tensile stress occurs in load Case 1. It occurs on the bottom tension member 7-8 in the North truss. The value of the stress is 23.5 ksi with a maximum compressive stress of 1.6 ksi. Table 1 shows maximum tension and compression for each load case.

Table 1

Load Cases	Maximum Tension(ksi)	Maximum Compression(ksi)
Load Case 1	23.5	1.6
Load Case 2	18.5	1.3
Load Case 3	18	1.3
Load Case 4	18.1	1.2
Load Case 5	18	1.2
Load Case 6	18.6	1.3
Load Case 7	19.1	1.3

Option II: without sidewalk
The maximum tension stress occurs at the same place and loading case as "Option I". The value of this stress is 20.5 ksi. The maximum compression stress was 2.1 ksi. Table 2 shows maximum tension and compression for each load case.

Table 2

Load Cases	Maximum Tension(ksi)	Maximum Compression(ksi)
Load Case 1	20.1	1.6
Load Case 2	8.9	1.3
Load Case 3	8.4	1.3

Load Case 4	8.5	1.2
Load Case 5	8.4	1.2
Load Case 6	8.6	1.3
Load Case 7	9.2	1.3

Conclusion:
The maximum stress allowed on cast iron is 25 ksi. Therefore, trusses are sufficient to take the loads for both options.

5. New Deck Structure

Three options were considered for the bridge deck. The first option was for a 6 foot wide pedestrian bridge. The second option was for a 9.5 foot wide traffic lane designed to accommodate a live load of 7.5 tons, as requested by the town of Clifton Park. The last option included the previous traffic lane with two 4 foot wide sidewalks.

While Whipple bridges often included sidewalks on one or both sides, research has determined that a single traffic lane without sidewalks previously spanned the canal at the Visher Ferry site. Subsequent excavation at the site uncovered existing abutments 19 feet wide, confirming this research.

A. Pedestrian Bridge

The lane width of this bridge is 6 feet, while the overall width is 11 feet. Two 4x5.4 steel channels are placed back to back at each of the eight panel points of the truss. Placed on top are the 4x4 stringers, which run parallel to traffic. The last layer is the 2x8 planking which rests on top of the stringers. Detailed calculations can be found in Appendix F, pages 1-2.

Cost: $3,096.32
This cost includes the following: Timber sections, steel sections, and railings.
For detailed calculations see Appendix F, pages 24-29.

B. One Traffic Lane

The option chosen by the design team is a 14.5 feet deck with a vehicle clearance of 9.5 feet. This deck was designed in two parts and for a capacity of 7.5 tons. The first element designed was the timber. Beginning with the top of the deck it contains 2x8 planking, and then 4x6 planking. This rests on top of the 4x12 stringers which run parallel with traffic. The purpose of the 2x8 planking is to provide a wearing course. This will give the town an inexpensive method of maintaining the bridge deck. The second element of the design is the two 9x13.4 steel channels placed at each of the eight panel points.

Detailed calculations of the design can be found in Appendix F, pages 3-8.

Cost: $9,678.48
This cost includes the following: Timber sections, steel sections, and railings.
For detailed calculations see Appendix F, pages 24-29.

C. One Traffic Lane and Two Sidewalks

For the last option, a 9.5 feet traffic lane with two 4 feet sidewalks was considered. This design is identical to the previous option with only two differences. The steel channels will be 22.5 feet long and cantilever outward to support the sidewalks. Also, the timber in the sidewalks is lighter weight than the traffic lane. The sidewalks consist of two parts, the 2x8 planking and 4x4 stringers. Detailed calculations can be found in Appendix F, pages 7-19.

Cost: $13,532.99
This cost includes the following: Timber sections, Steel sections, and railings.
For detailed calculations see Appendix F, pages 24-29.

5. Falsework Layout

The bridge will be reassembled in late spring, 1997, on site in Vischers Ferry. All members will be marked appropriately according to figures in Appendix G.

The first step is the false work or scaffolding layout. This will be placed on the existing earth bridge between the abutments. The average height of the scaffolding at the south end is 10 feet, gradually increasing to 12 feet in the center and north end. The exact layout of the scaffolding and all the required pieces are stated in Appendix G. The fabricated U-blocks used in the disassembly from Fonda will be reused in the reconstruction. These U-blocks will ease the tension from the members for easier placement.

6. Erection Plan

The erection of the bridge at Vischers Ferry is very similar to the dismantling in Fonda in reverse order. In Appendix G, there are 16 steps to a successful erection of the bridge. It is important to refer to the figures and understand the procedure well before completing each step. Each truss is constructed independently at various stages.

The estimated time of erection includes placing falsework and the actual building of the bridge. This does not include the construction of the abutments or the excavation of the earth bridge. The final placement and completion of the bridge will resemble a scene from the 1860's.

IX ACKNOWLEDGEMENTS

There are many people and organizations that have provided valuable assistance to this project. We would like to give special thanks to the following organizations: Barry, Bette & Led Duke, Inc. for the donation of steel beams and decking for the replacement bridge; Schenectady Steel Co., Inc. for beam welding and fabrication; Spancrete Northeast, Inc.; and, The Canal Corporation of the New York State Thruway Authority.

Several individuals deserve special thanks. Without the donation of the bridge by Roger Gray and Anthony Kikkis, this project would not have been able to get off the ground. For help with historical research we would like to thank the following people: Craig Williams, John Scherer, Volkert Veeder and Jacqueline Murphy. We appreciate Professor George Shaw, Chair of Civil Engineering and Geology at Union College, for initiating this endeavor. Professor Frank Griggs, through his guidance and undying enthusiasm, has helped to make the planning stage of this effort successful.

For us as seniors, this project has helped to bring together analysis, planning and design techniques with an appreciation for some of the great history of the engineering profession. Although some of us will be moving on to jobs in other parts of the country, there are several members of the team who live in the area and intend to see the project through to completion. It is our hope that more people will become involved with this historic effort. We would like to offer our gratitude in advance to those organizations and individuals who may help to take this project out of the planning stage and into reality.