NEW LIFE FOR AN OLD SPAN

A first-ever approach to pin-and-link replacement breathes new life into a veteran Mississippi River span.

At 75 years old, the original U.S. 84 Mississippi River Bridge, also known as the Natchez-Vidalia Bridge, was showing its age. The vital connector between Natchez, Mississippi, and Vidalia, Louisiana, was designed by HNTB when it was built in 1940. After decades of use, a routine, in-depth inspection found that a truss pin had begun to shift. A later inspection showed a second pin was shifting.

It became apparent that age was taking its toll. Two of its eight links and four corresponding pins needed replacing. The cost of doing nothing meant its potential loss. Replacing the bridge was cost-prohibitive.

After considering all options on the table, the job soon became an endeavor to repair the bridge for $3.8 million rather than replacing it with a new $250 million structure.

ASSESSING THE SITUATION

While the condition of the bridge posed no immediate risk, there was no way to create a warning system to alert officials if things deteriorated further. HNTB worked with MDOT and LADOTD to determine how to temporarily support the bridge to facilitate replacing the pins and links. While both states share the responsibility for the project, MDOT served as the lead and contracting agency.

The U.S. 84 bridge is a vital connector between the towns of Natchez, Mississippi, and Vidalia, Louisiana.

"One of the unique approaches we took with this project was that we sat down with officials and developed a risk matrix," said James Gregg, HNTB project manager. "There are a lot of unknowns when you take apart an old bridge. This matrix helped us understand what we were up against."

HNTB arrived at four options, which included:

- restrain and monitor: a low-cost, less-intrusive approach
- reset pins: a repeat of an earlier approach that was not successful
- replace pins: replace the pins, but not the links
- replace lower and upper pins and links: remove and replace existing pins with new pins and hexagonal recessed nuts

"This led us to agree as a team that we needed to replace the pins and the links that hold up the bridge," Gregg added. "Working with bridge experts from HNTB offices in Baton Rouge, Chicago, Kansas City and New Jersey, we developed a concept that would lock down the bridge and create a true bypass for any of the load that's on it."

Creating a bypass that locked the bridge down in all directions was a challenge. The piers are fixed, so that the pins and links on the truss accommodate expansion and rotation. The truss expands and contracts throughout the day. Fortunately, an analysis showed that the piers were flexible enough to take the force once the joints were restrained.

SURGICAL PRECISION

HNTB and MDOT collaborated to develop multiple bypasses and contingency plans to ensure redundancy. The bypasses needed to act as a failsafe, because the teams were embarking on a quest not unlike open-heart surgery.

"We were essentially going to open up the bridge, remove its old heart that was keeping it operational, then put in something new," Gregg said. "We had to make sure that there was nothing that could go awry. We spent a lot of time putting ourselves in the contractor's shoes, developed plans that were highly detailed and suggested a sequence of construction and methods on how to remove the pins and links.

"We wanted to demonstrate to the contractor an exact route that we believed would make this project successful. The contractor for this project, CEC, Inc., is very sophisticated and nearly always suggests ways to create more constructability within a project. In this case, CEC commented that we had gotten down to the actual nuts and bolts of the project and there was little to modify."

The reality was that this project was simple in concept, yet complicated in detail. This plan included instructions from the big picture down to how to remove every rivet.

"These plans took away any chance that we might have installed something wrong," said David Huval, Jr., president of CEC, Inc. "The backups to critical parts of the plans guided us with alternative ways to get things done, when needed."

FIRST TIME EVER

Unlike cardiac surgeons, designers and engineers working on the Natchez-Vidalia Bridge didn't have more than a century of proven procedures on which they could rely. In fact, they had no road map as this process had never been attempted before. Railroads have completed successful pin replacements on bridges, but they typically don't have as much dead load to temporarily support as long-span highway bridges do. The importance of this detail was reinforced during pre-bid meetings in that HNTB and MDOT wanted a partner, not just a contractor, to supplement and follow the plan.

"HNTB and MDOT determined that replacing pins of this size had never been done on vehicular bridges," said Justin Walker, MDOT director of structures. "We did find examples where sections of trusses had been removed, but those projects contained expensive

QUICK FACTS

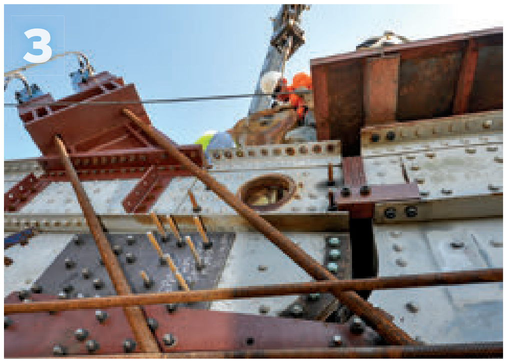
NAME
U.S. 84 Mississippi River Bridge
Works Progress Administration Project #1126

CONSTRUCTED IN
1940

BUILT FOR
City of Natchez, Mississippi

ORIGINAL CONSTRUCTION COST
$3.56 million

DESIGNED BY
Ash-Howard-Needles & Tammen (HNTB)



View a video of the U.S. 84 Natchez-Vidalia Bridge pin-and-link replacement. www.youtube.com/watch?v=3pPF1CL4J3c

Video available for iPhone and iPad on the HNTB Publications App.

shoring systems, adding new structures to the bridge or shoring off certain parts of it.

"This was different. We left everything in place and bypassed the joint to replace links and pins in place. HNTB found several small jobs where this had been done, but not on this scale. One of the bigger challenges with this project is that we didn't have the opportunities to talk with peers and use their projects as historical examples. This is one reason why the many contingency plans were needed. We had to predict issues that might be detrimental to the project and design around them."

Another challenge the team faced was the loading situation. Thermal movement in a bridge this large can escalate the loading or shift it to unfamiliar positions. To alleviate thermal variations as much as possible, work took place in the middle of summer when temperatures are relatively constant.

KEEP THE REGION MOVING

The U.S. 84 Mississippi River Bridge is critical to the economies of the Vidalia and Natchez communities. From agricultural and industrial products to daily commuters going to work on both sides of the river, a complete closure would create a detour of 60 to 70 miles roundtrip for those on both sides. Fortunately, a newer, parallel bridge was kept open and the original bridge closed during the pin-and-link replacement.

"One of the easiest contingencies we executed was to take traffic off the bridge," Walker said. "That way, if we did have issues, we wouldn't subject travelers to it. Plus, it made for greater contractor and driver safety, which gave us all peace of mind that we didn't put the traveling public at risk."

COOPERATION, COMMUNICATIONS SUPPORT GOAL

Despite all of the risks and unknowns of the replacement process, the team of HNTB, MDOT, LADOTD and CEC, Inc., attributes preparation and communications as the key to a well-run, successful project. Collectively, team members worked to add more years of service life to the bridge. Though coordinating activities between two state agencies is often a challenge, this job turned out to be the opposite.

"The process went smoothly," Walker said. "The project team gave us a lot of feedback. We considered many of the contractor's suggestions and applied a lot of them, particularly on issues such as thermal movement or monitoring.

"This is probably one of the better jobs we've had when it comes to communication. With all team members, and even the subcontractors, it was a very open atmosphere. Everybody listened to each other. We had to. None of us had any experience in doing work like this. Because we didn't have the luxury of doing the job before now, we had to talk and listen."

Listening paid off. Replacement of the upper and lower pins and links was a success and the bridge has a new lease on life.

"This project means a lot," Gregg said. "HNTB was part of this bridge in the beginning and here we are, 75 years later, still making sure it's serving the needs of the community. The bridge is at an age when we'd typically consider replacing it, but with current funding, there's no way to do that. The pin and link replacement was successful and will allow the structure to provide another 40 years of good service. It's an example of what cooperation, communication and technical excellence can achieve." ■

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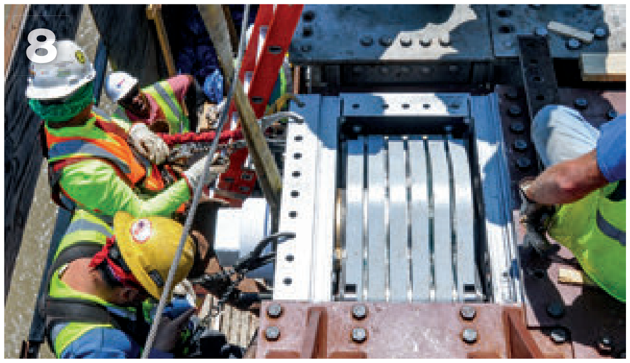


A CLOSER LOOK AT THE REPLACEMENT PROCESS

The photos above show the steps that took place during the pin-and-link replacement process, which extended the life of the U.S. 84 Mississippi River Bridge another 40 years.

1—Employees from CEC, Inc., the contractor partner for the project, removed splice plate templates that were welded together so that holes could be drilled in the temporary splice plate, which was one inch thick. Fill plates were installed to ensure the splice plate was flush between the two gussets. More than 400 A490 bolts measuring 7/8 of an inch in diameter were used to fasten the temporary splice plate to the gussets. Horizontal post-tensioning bars were used to prevent the joint from moving.

2—The project team removed the 4,500-pound forged link from the bridge by cutting the upper and lower pins with a wire saw.

3—During removal of the U29 link, a diagonal bypass was used to temporarily support the bridge. A one-inch splice plate was used to lock the upper joint, as well as act as a secondary load path if the diagonal bypass failed.

4—To facilitate removal of the forged link from inside the truss, the upper diagonal bypass was positioned on the cantilever span side of the truss to support the suspended span side at the adjacent lower joint (L28-U29 and L48-U49).

5—A subcontractor, In-Place Machine Company from Milwaukee, Wisconsin, worked around the clock during the replacement to measure and line bore upper and lower pins simultaneously over a three-day period. The team spent 24 hours setting up and measuring before work began to ensure upper and lower pins were plumb and in line with each other.

6—A new hole was line bored for the existing gusset and new eyebars. Because the existing lower pin hole was oblong from wear and the upper pin was not plumb, the diameter of the new pins was increased up to 3/4 of an inch to ensure proper fit and provide a clean bearing surface.

7—The contractor team installed new upper pins, which were packed in dry ice and transported from the machine shop to the job site, where ice was removed. Grease was applied prior to installation, allowing the new pins to slide into the newly bored holes with ease.

8—The team worked to install new upper pins through the existing gusset and six new eyebars. Both upper and lower pins were turned down in the machine shop just hours prior to installation to ensure a correct fit.

9—The newly installed eyebars are shown in place and secured with a retainer plate to provide a more robust method to prevent the pins from rotating or moving transversely.

10—The completed U49 with new eyebars and retainer plates provides the structural support needed to extend the life of bridge.

US 84 MISSISSIPPI RIVER BRIDGE – TRUSS PIN AND LINK REPLACEMENT

JAMES GREGG

JUSTIN WALKER

MICHAEL XIN

BIOGRAPHY

James Gregg is the bridge department manager for HNTB Baton Rouge, LA office. He served as the project manager for US 84 Mississippi River Bridge Rehabilitation project as well as assisted with several NBIS inspections of the bridge. Mr. Gregg has over 10 years' experience with design and rehabilitation of complex structures, design-builds, and bridge construction inspections.

Justin Walker is the current state bridge engineer for Mississippi Department of Transportation with over 15 years of experience in bridge design. He currently serves as a member of AASHTO T17 Welding Subcommittee on Bridge structures and is a member of the Mississippi Engineering Society and the Structural Engineering Association of Mississippi.

Michael Xin is a principal bridge engineer in HNTB Chicago, IL office with more than 20 years' experience on complex bridges. Michael served as one of the lead designers of the for the US 84 Mississippi River Bridge Rehabilitation project.

SUMMARY

The US 84 Mississippi River Bridge is a 5 span cantilever truss bridge crossing the Mississippi River in Natchez, Mississippi. Two lower truss pins on the bridge shifted transversely and were flush with the outside gusset. The existing truss pins and links were removed and replaced. Temporary restraints were used to bypass the load in the truss pins and link and instrumentation used to evaluate stresses in the truss during removal.

US 84 MISSISSIPPI RIVER BRIDGE – TRUSS PIN AND LINK REPLACEMENT

Introduction

The westbound US 84 Mississippi River Bridge is a 5 span cantilever truss with a 7 span approach that carries US 84 over the Mississippi River between Natchez, Mississippi and Vidalia, Louisiana (Figure 1). The Westbound Bridge was designed by HNTB in 1939 and opened to traffic in September 1940. The bridge was the third Mississippi River Bridge built south of Memphis, Tennessee and the first highway only Mississippi River Bridge south of St. Louis, Missouri. The bridge has one suspended span located between Piers 1 and 2 and eyebar links on Spans 2, 3, and 4. The Louisiana approaches, Spans 6 through 11, are plate girders. A twin structure located downstream was completed in July 1988 and the older bridge was restriped to two westbound lanes.

Figure 1 – Bridge Location Map

The westbound bridge has a 24’-0” clear roadway width, 2’-0¼” wide steel curb and rail, and a 7¼” thick deck (Figure 3). The deck is supported by crossbeams which are supported on 3 stringers. The stringers are framed into the floor beams that are spaced at either 39’-10½“or 43’-9”. Eyebar links (2’-0” x 10” x 7’-6½” long) are located at truss Joints U19, U29, U49, and U69. The westbound bridge was originally designed for a H15 vehicle (truck or lane).

A general elevation view is shown in Figure 2 and a section view is shown in Figure 3.

Figure 2 –General Elevation View

Figure 3 – Section View

As a border bridge between Louisiana and Mississippi, the bridge is maintained by Mississippi Department of Transportation (MDOT) but cost equally shared between MDOT and Louisiana Department of Transportation and Development (DOTD).

Pin and Link Details

Unlike other cantilever truss bridges in which eyebars supporting a suspended span are full length truss member, the pins and links on the US 84 Mississippi River Bridge are confined to the upper joint. The suspended span and quasi-suspended span loads pass through the suspended span or quasi-suspended span upper gusset and into the 7'-6½" long links via $10^{1}/_{16}$" diameter lower pins (Figure 4). The load is then transferred from the link into the cantilever span upper gusset via $10^{1}/_{16}$" upper pins. The pins and link also function as expansion joints for the bridge and were designed for up to 9" of movement between the two gussets.

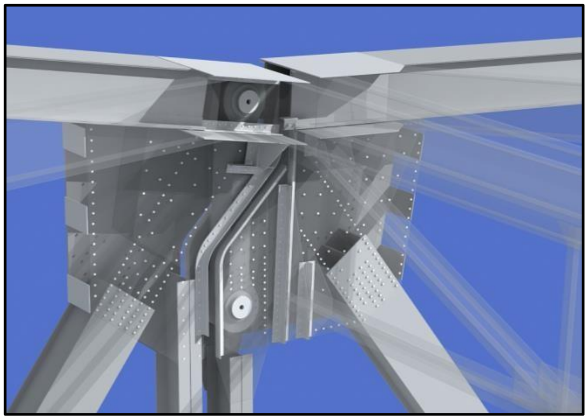


Figure 4 – Upper Joint

Pin Movement

U29 Pin Movement

In 1995, MDOT observed the tie rod that holds and restraints the pin from lateral movement was fractured and cover plates missing on the lower pin at U29 downstream truss. The weld that prevents the lower pin from rotating about the gusset was broken and the pin had rotated 2¾" from its installed position. The lower pin was also flush with the inside face exterior gusset on one side and extended 1" on the outside face exterior gusset (Figure 5 & 6).

MDOT contracted with HNTB which advised the outside ½" gusset supported the hanger and if the pin continued to move past the outside gusset, there would be an adverse effect to the factor of safety for the bridge, potentially resulting in closure of the bridge.

Figure 5 – U29 Lower Pin Downstream Truss Inside Face

Figure 6 – U29 Lower Pin Downstream Truss Outside Face

Pin Rehabilitation

In 1996, MDOT awarded a contract to temporarily remove the load off the pin and link via temporary restraints and push the lower pin back into place. Beneath one lane of traffic, HNTB proposed a vertical jacking assembly that would bypass the load on the link and pins via 4 post-tensioning bars (Figure 7).

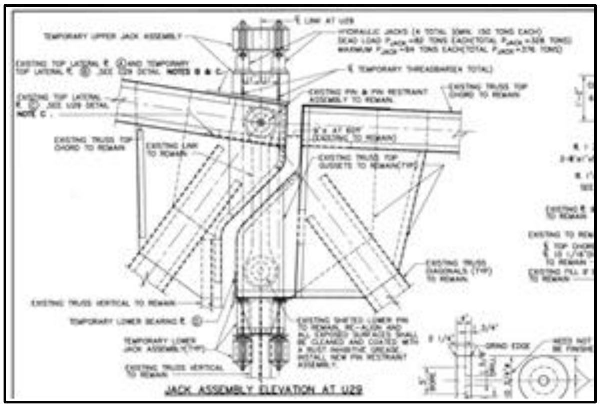


Figure 7 – Vertical Jacking Assembly

Prior to installing the vertical jacking assembly, the contractor attempted to reset the pin without removing the vertical load. The first attempt the contractor applied 675 kips of horizontal load in which his post-tensioning system failed resulting in post-tensioning bars passing traffic and into the river. The second attempt (Figure 8) the contractor redesigned the horizontal jacks and increased the horizontal load to 884 kips. The third attempt the contractor redesigned the horizontal jacks and increased the load to 1,325 kips, at which point no movement in the lower pin was recorded.

Figure 8 – Horizontal Jacks

The fourth attempt, the contractor redesigned the temporary restraints to include a vertical jacking assembly in which he applied 800 kips of vertical load to remove the theoretical dead load in the pin and link and then applied 727 kips of horizontal load to the pin, at which point no movement in the lower pin was recorded. Ultimately, MDOT and HNTB agreed any additional attempts would be futile, potentially cause damage to the bridge, and agreed to regularly monitor the pin for additional movement.

2010 In-Depth Inspection

In 2010 HNTB was contracted by MDOT to complete an in-depth inspection of the westbound US 84 Mississippi River Bridge in which non-destructive testing was completed on 8 of the 16 pins. The non-destructive testing revealed inter-component acoustic coupling (ICAC) between the lower pin at U29 downstream truss and the link which indicated the pin may have fused with the link. ICAC typically occurs when the ultrasonic wave from an ultrasonic examination is reflected from the transverse surface of an adjacent component, typically under high local bearing stress. The lower pin was still flush with the exterior gusset but an oblong hole in the gussets with a 3/8” gap between the bottom of the lower pin and the gusset was observed. The oblong hole was consistent with the assumption the lower pin was rotating about the gusset vs. the pin. It was the intention of the original designer that the pin would not rotate about the gusset and the bearing stress on the gusset from the pin be 0.56 F_y. (AASHTO allows 0.4 F_y for pins subject to rotation and 0.8 F_y for pins not subject to rotation)

The in-depth inspection also revealed the lower pin tie rod on U49 upstream truss had fractured, the cover plates missing, the pin was flush with the exterior gusset, and there was roughly ½” gap between the bottom of the lower pin (Figure 9).

Figure 9 – U49 Lower Pin

Pin and Link Replacement

Investigation

After the 2010 in-depth inspection, MDOT contracted with HNTB to investigate and make recommendations to address the lower pins at U29 downstream truss and U49 upstream truss. HNTB investigated four options:

1. Restrain and monitor
2. Rest pins
3. Replace lower pin
4. Replace lower and upper pins and link

Option 1 – Restrain and Monitor – This option is similar to the "no build" option in an environmental assessment and entails reinstalling the cover plates on the lower pins and continuing to monitor.

Option 2 – Reset Pins – This option would entail reusing the concept from 1996 and attempting to reset the lower pins

Option 3 – Replace Lower Pins – This option would entail using the vertical jacking assembly similar to figure 7, however, using destructive measures to remove the lower pin, boring a new hole in the gusset and link, and installing a new lower pin.

Option 4 – Replace Lower and Upper Pins and Link – This option would entail installing temporary restraints so that the upper and lower pins and link could be removed and replaced.

Risk Matrix

In order to review all four options, HNTB prepared a risk matrix for all four options listing the pros and cons to each option for MDOT and DOTD to complete. The risk matrix listed risk and probability/likelihood on a scale of 1 to 5 for the different options and components within each option.

Option 1 – Although MDOT had been monitoring U29 for over 15 years, this option represented the highest risk with moderate probability. With the bridge at its design life of 75 years, the pins could have shifted for several reasons such as wear or pier movement. Unfortunately, there was minimal information to support or dismiss theories. Ultimately, if the pin moved further within a 12 month period or became locked, there would be little to no warning signs outside of complete collapse. The probability was identified as moderate due to fact the lower pin at U29 downstream truss had not moved in 15 years, however, the pin at U49 upstream truss had. MDOT and DOTD decided this option was not preferred.

Option 2 – If successful, this option would represent the lowest risk; however, it was assigned a low probability of being successful. Based on the experience in 1996, the contractor was unsuccessful at resetting the lower pin at U29 and the non-destructive testing noted acoustic coupling between the lower pin and link which indicated potential fusing. If fused, the pin was not designed to rotate about the gusset which can be observed by the oblong hole in the gusset from the lower pin wear. The other lesson learned from the 1996 attempt was the fact the pin must be rotated prior to pushing back. It is anticipated the pin has grooves, and similar to a key in a lock, unless the pin is rotated while being pushed, any attempts would be futile. MDOT and DOTD decided this option was not preferred.

Option 3 - HNTB completed a comprehensive investigation of option 3 but the risk of damaging or finding damage on the existing link proved too high. Although the probability of damage on the existing link was low, the links are unable to be tested and are at their design life. Visual inspections have been limited due to special constraints and key sections would not be visible until the lower pin was removed. Contingency plans were contemplated in the event the links needed to be replaced; however, MDOT and DOTD decided this option was not preferred.

Option 4 – MDOT and DOTD unanimously agreed replacing the upper and lower pins and the link at U29 downstream truss and U49 upstream truss was the preferred option. This option had the highest probability of being successful with risk that could be mitigated through the design of HNTB’s temporary restraints.

Pin and Link Replacement

In order to remove the pins and link, a temporary bypass that locks the joint from moving in all directions was developed. It was important the temporary bypass had internal redundancy plus alternate load paths to mitigate the risk of any one component compromising the bridge when the pins and link were removed. A series of bypasses were used to lock the joint and the Pier was expected to flex under thermal loads.

The temporary restraints were comprised of four main components; Upper Longitudinal Restraint, Diagonal Bypass, Lower Longitudinal Restraint, and Splice Plate (Figure 10).

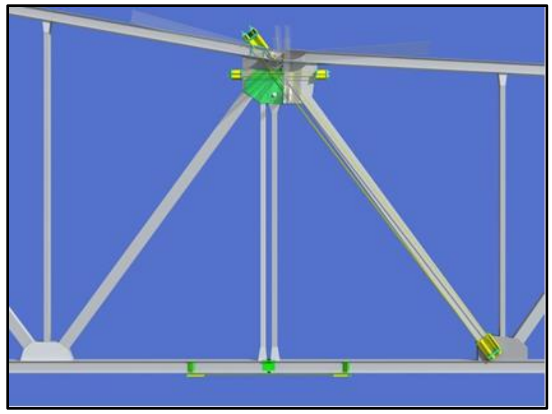


Figure 10 – Temporary Restraints

Upper Longitudinal Restraint (Figure 11) – Due to the fact U29 and U49 are expansion joints, the pins and link are free to rotate. When removing the link, the two gussets must be locked together. The upper longitudinal restraints use post-tensioning bars plus shim blocks to compress the two gussets together until the splice plate is installed. The upper longitudinal restraints are applied to both upstream and downstream trusses when removing the pins and links.

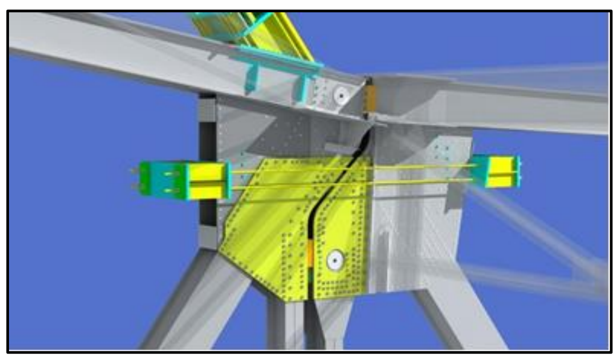


Figure 11 – Upper Longitudinal Restraints

Diagonal Bypass (Figure 12 & 13) –The majority of the load in the link is from the diagonal truss member on the suspended span (lower pin side of the gusset). The diagonal bypass was designed to unload the suspended span diagonal truss member and link. Once installed, the suspended span would bypass the lower pin and be transferred into the cantilever span gusset from above.

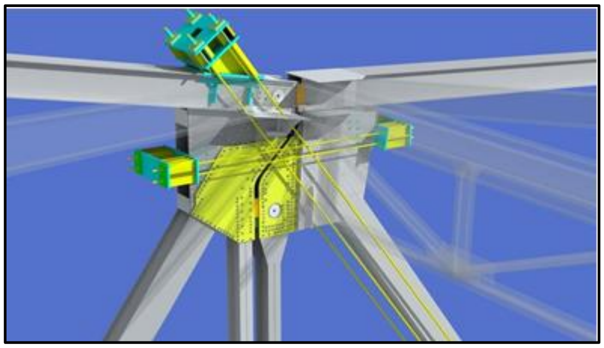


Figure 12 – Diagonal Bypass

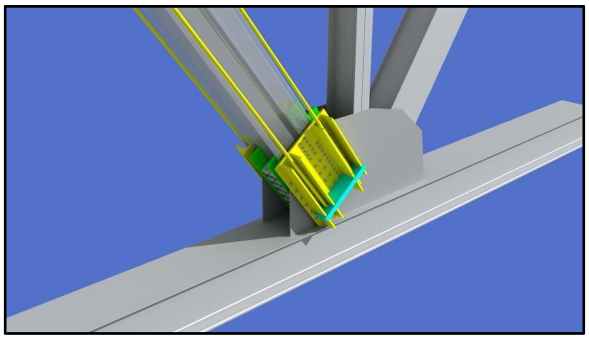


Figure 13 – Diagonal Bypass

Lower Longitudinal Restraint (Figure 14) – L29 and L49 bottom chord truss members currently are false chord members; however, they have similar properties to the other truss members. The Lower Longitudinal Restraint connects the two bottom chord members allowing them to act as an alternate load path. Shims were installed between the two members and post-tensioned to ensure they remained in compression.

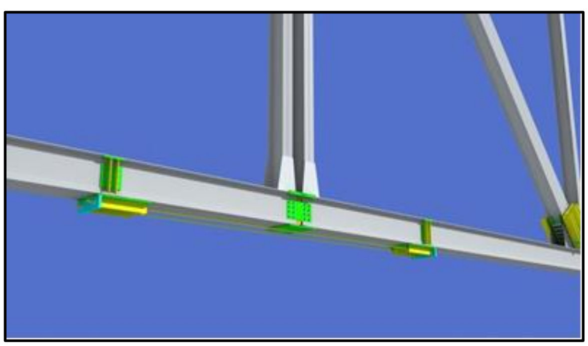


Figure 14 – Lower Longitudinal Restraints

Temporary Splice Plate (Figure 15) – As a means to control displacement and provide an alternate load path, a splice plate was designed to connect the suspended span gusset to the cantilever span gusset. The temporary splice plate required over 350 A490 bolts per truss which entailed removing existing rivets in the gusset or field drilling new holes. Because only one rivet could be removed at a time, each bolt was installed with a custom nut between the gusset and splice plate to ensure the splice plate bore uniformly on the middle nuts and middle nuts on the gussets. The force in the each bolt was calculated and bending in the bolt checked.

Cheek or shim plates were installed between the gussets and splice plate to provide additional friction force, however, the friction force was not included in the design of the splice plate or bolts.

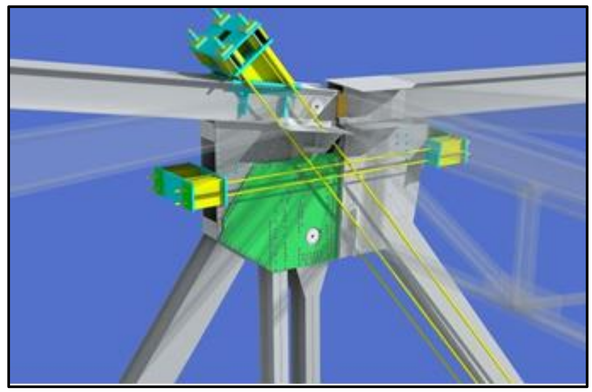


Figure 15 – Temporary Splice Plate

Redundant Load Path

In order to mitigate risk while the pin and link are removed, the temporary restraints were designed so that they had internal redundancy as well as additional load paths in the event one system is lost. Figure 16 and 17 & 18 illustrate the three load paths.

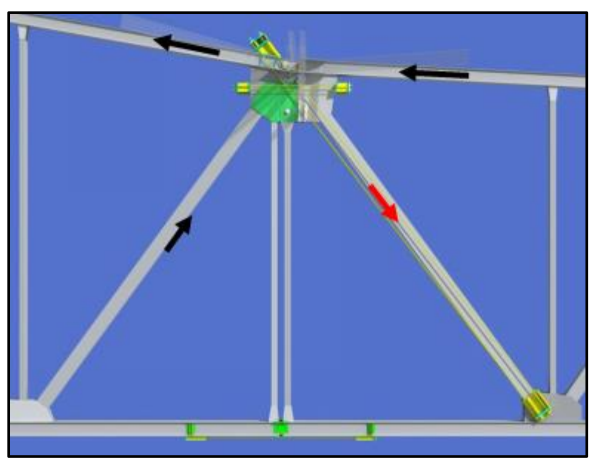


Figure 16 – Temporary Load Path A – Diagonal Bypass

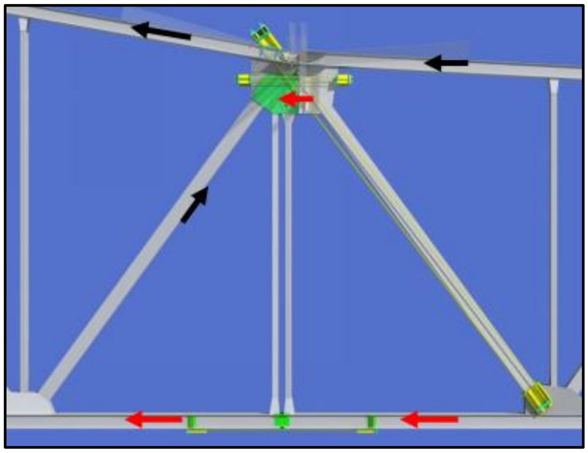


Figure 17 – Temporary Load Path B – Splice Plate and Lower Longitudinal Restraint

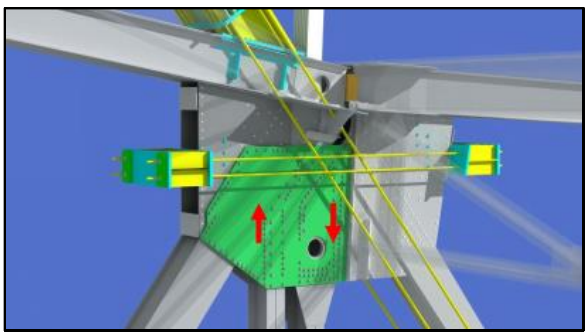


Figure 18 – Temporary Load Path C – Splice Plate

Construction

Overview

Typically MDOT projects are either design-bid-build or design-build. In the design-bid-build option, MDOT or its consultant prepares a set of plans and the project is advertised and any contractor may place a bid with the low bid winning. MDOT and FHWA agreed that due to unique nature of the work, plus the risk of a mistake or carelessness could result in collapse or severe damage to the bridge, MDOT decided to advertise a design-bid-build with a two-step process. Step one consisted of a request for qualification from contractors with a short list of qualified contractors. Two qualified contractors were shortlisted with both submitting bids based on plans developed by HNTB. C.E.C. out of Lafayette, Louisiana was the low bidder at $3.8 million and awarded the project.

Traffic Control

It was decided that because of the risk associated with removing the pin and link, the traveling public should not be on the bridge during the replacement. MDOT wisely decided to install crossovers and put traffic head to head on the eastbound bridge as well as re-synchronize traffic lights. Minimal to no queue was observed throughout the duration of the project.

U29 Misalignment

During installation of temporary restraints, it was observed that U29 upper pin gusset (cantilever span gusset) and lower pin gusset (suspended span gusset) near the lower pin were shifted inboard by 1.875" where they should have been centered with each other (Figure 19). The cantilever span gusset near the upper pin was shifted by ¾" and the cantilever span gusset appeared to have a slight rotation. Truss member U29-L30 also was kinked near the connection point at L30 (Figure 20). Based on review of the 1940 construction and erection records of the bridge, the suspended span from L22 was cantilevered out with the final tie-in between the suspended and the cantilever span at U29 (Figure 21). The misalignment was indicative of a geometric misalignment during erection of the bridge and the two spans were pulled together laterally in order to install the pins and link. It was speculated that U29 had locked-up lateral erection force which was being restrained by the existing pins and link.

In order to mitigate the locked-up erection forces, the anticipated load was calculated based on the observed deflection and checked against the top strut lateral restraints and found to be satisfactory. 200 plus additional A490 bolts were required at U29 splice plate to mitigate the additional bending plus an interior plate that engaged the entire bolt group installed. (Figure 22)

Figure 19 – U29 Offset

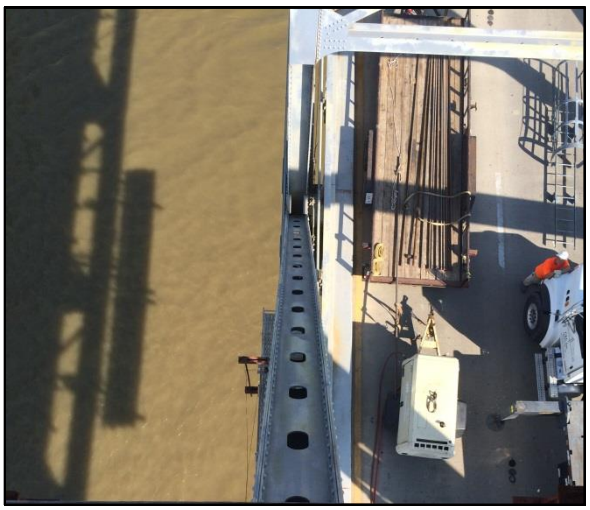


Figure 20 – U29-L30 Kink

Figure 21 – 1940 Construction

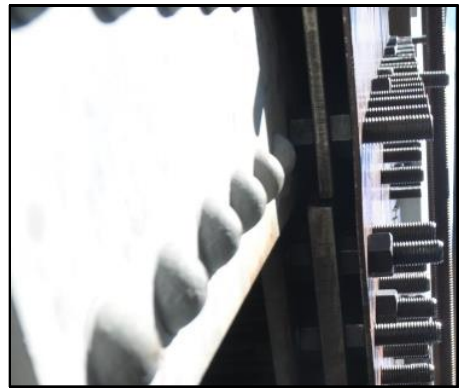


Figure 22 – U29 Middle Plate

Instrumentation

In order to ensure the temporary restraints were properly transferring the load off the pin and link as well as to evaluate any unforeseen losses in the restraints, strain gauges were installed on multiple truss members and the post-tensioning bars. The splice plates were also instrumented to evaluate stresses once the pins were removed.

Because the temporary restraints would change the boundary conditions of the bridge to fixed-fixed, adding additional load in the truss and forcing the Piers to flex, the Piers were inspected prior to and after locking each joint.

The initial inspection of the Piers revealed numerous cracks, as is expected for a mildly reinforced Pier at 75 years of age. No crack growth was observed in the post-inspection.

Based on the instrumentation output from the 8 links over a two week period it was obvious the bridge was behaving in a fixed-fixed condition. The existing link and pins would build up as much as 3.0 ksi of stress before breaking free and equalizing back to zero.

Sequence of Construction

As part of the contract plans, the contractor was required to submit a detailed sequence of construction demonstrating means and methods for removing the pin and link. The contract plans provided a suggested sequence of construction in which the contractor adopted with minor modifications. The contractor chose to remove the pins and link at U49 first, and based on lessons learned, some adjustments were made at U29. The following are the key steps to the sequence of construction with lessons learned from construction:

<u>Step 1 – Tension Diagonal Bypass</u> (Figure 23 and 24). L48 – U49 diagonal bypass was tensioned to remove the load in the existing truss diagonal member, link and pin. Stressing operation were conducted in increments and member stresses observed to ensure the bypass was functioning as anticipated. U49 existing link change in force was monitored and U49 diagonal bypass was tensioned to 10% over the anticipated force, resulting in the change in force in the link to be within 1% of the anticipated load (Table 1). Although the entire load would not be released until the pins were removed, it was preferred to minimize the load in the existing link to avoid the pins from binding and prevent sudden movement resulting from pin removal.

Figure 23 – Tensioning of Diagonal Bypass

Figure 24 – Tensioning of diagonal bypass

Table 1 – Diagonal Bypass

Member	Δ Load	Anticipated Load
U49 Diagonal Bypass	836 kips	760 kips
L48-U49	580 kips	761 kips
U49 Link	660 kips	655 kips
U29 Diagonal Bypass	782 kips	740 kips
L28-U29	699 kips	740 kips
U29 Link	634 kips	640 kips

Prior to tensioning U49 diagonal restraint, upper and lower shims were installed. The upper shims would transfer any horizontal force in the diagonal restraint. The lower shims would not be required until Step 2 but were chosen to be installed during Step 1 (Figure 25 and 26). During the stressing of the diagonal bypass, the lower shim shifted transversely by ¼”. As the diagonal restraints became fully engaged, it became clear that one of the post-tensioning bars was conflicting with the truss lateral bracing, potentially causing the shift at the lower shims. The portion of truss lateral bracing that was in conflict was cut further allowing the diagonal post-tensioning bars to adjust; however, because the upper bypass was engaged, the horizontal load from the upper bypass did not allow the shims between the two gussets to shift back horizontally.

Once the existing pin was removed and the new one installed, it was observed that the inboard and outboard lower gusset had walked out by ½". Fortunately the new lower pin was made longer and the pin bore directly on the gussets; however, the pin extension beyond the gusset was minimal. Although the gussets did not appear to walk when engaging the diagonal restraints, the existing pins may have been restraining them, and once removed, the gussets were free to walk.

For U29, the lower shims were not installed until after the diagonal bypass was engaged and prior to tensioning the upper longitudinal restraint. An additional stiffener plate was also installed and as a result, U29 outboard and inboard gusset did not walk.

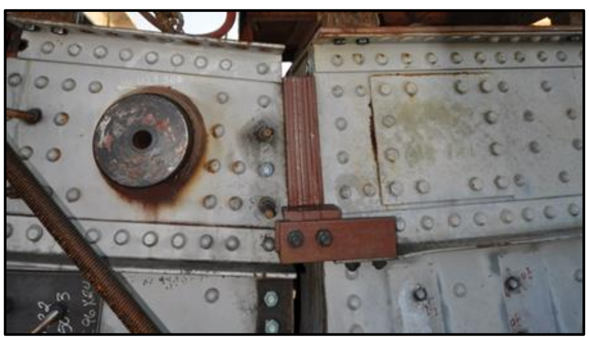


Figure 25 – Upper Shims

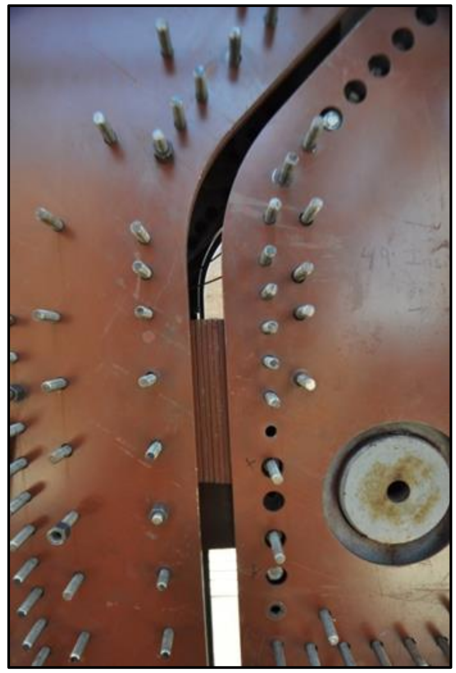


Figure 26 – Lower Shims

Step 2 – Tension Upper Longitudinal Restraint (Figure 27 and 28). Both upstream truss and downstream truss upper longitudinal restraints were tensioned to prevent the joint from moving longitudinally. The upper longitudinal restraints were designed for a 60 degree temperature drop but stressed to accommodate a 40 degree temperature drop based on the 10 day weather forecast.

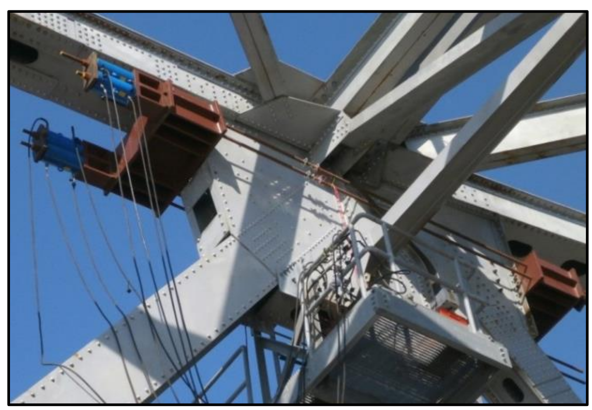


Figure 27- Upper Longitudinal Restraint

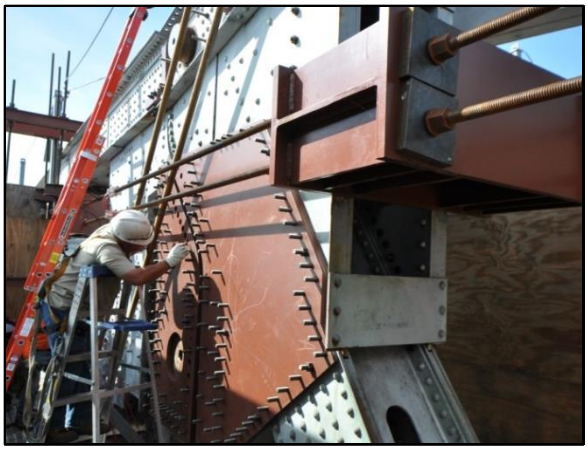


Figure 28- Upper Longitudinal Restraint

Step 3 – Weld Templates and Field Drill Splice Plate (Figure 29 and 30). Once the bridge was locked from moving, the splice plate templates were welded together and used to field drill the splice plates. Field drilling and installing the splice plates was challenging due to the 100 plus A490 bolts per face of gusset, but was completed with minimal to no incident.

Figure 29 – Splice Plate Template

Figure 30 – Field Drill Splice Plate

Step 4 – Install Top Strut Plates (Figure 31). Although there was a wind shear device at U29 and U49, the two top strut were connected together to provide lateral additional rigidity in the event there were any unexpected lateral forces when the link was removed.

Figure 31 – Top Strut Plate

Step 5 – Install Lower Longitudinal Restraints (Figure 32 and 33). Shims were installed between the two false chord members and post-tensioned together to ensure continuous bearing between members.

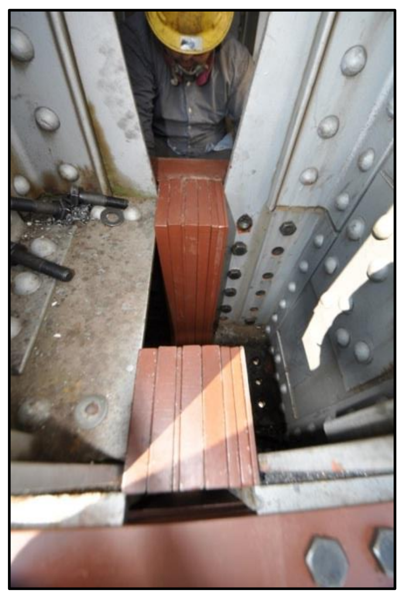


Figure 32 – Lower Longitudinal Restraint Shims

Figure 33 – Lower Longitudinal Restraints

Step 6 – Remove Pins (Figure 34 and 35). Because of the difficulty the previous contractor had with trying to reset the pins in 1997, the contractor elected to cut the pin with a diamond tipped wire saw. After cutting U49 upper pin, minimal change in force was observed in the link, and U49 and U29 splice plates saw about 1 ksi and 7.5 ksi of stress respectively (Table 2). It was speculated the higher stress in U29 was attributed to the misalignment of the truss. No movement was observed in either joint during removal of the pins.

The contractor attempted to push out U49 lower pin with hydraulics jacks after the upper pin was cut, but after applying 1,000 kips, minimal to no movement was observed. Ultimately, both faces of all pins required cutting and after the lower pins were removed, it became clear from the observed amount of grooving, the pins would not been able to be pushed out (Figure 36).

Figure 34 – Wire Saw

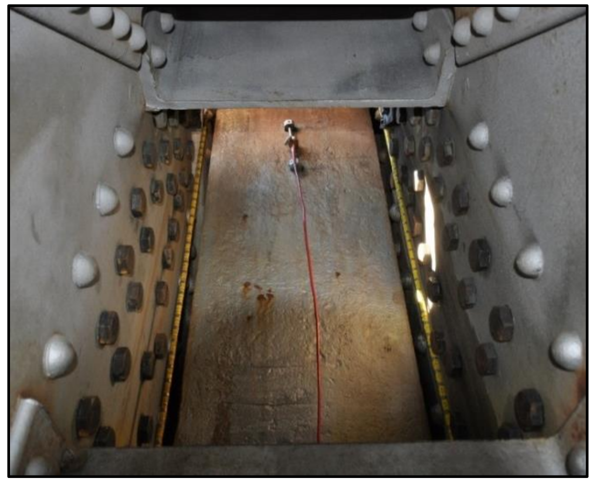


Figure 35 – Wire Saw Inside Truss

Figure 36 – U49 Lower Pin Drop Cut

Table 2 - U29 Splice Plate Maximum Stress

Inboard Gusset		
	Side 1 Stress, ksi	Side 2 Stress, ksi
Vertical Gage	0.472	-0.494
45 deg Gage	-4.614	4.264
Horizontal Gage	-0.985	-0.026
Outboard Gusset		
	Side 1 Stress, ksi	Side 2 Stress, ksi
Vertical Gage	3.09	-3.552
45 deg Gage	-2.066	4.117
Horizontal Gage	-5.631	7.535

Step 7 – Line Bore (Figure 37). The contractor line bored a 10½" to 10¾" hole through the existing gusset and new eyebars to ensure the new pins would bear properly and fit. With the existing link and pins removed, it was found that the existing upper pins at U29 and U49 were not plumb whereas the lower pins were. It is speculated this may have been part of the cause of the walking observed at the existing lower pins. It was also noted that U29 inboard and outboard gussets were not plumb and this was attributed to the locked-up erection forces in the gusset. New pins were bored plumb and in line with each other.

Figure 37 – Line Bore of Upper Pin

Step 8 – Install New Pins (Figure 38). Once the line bore was complete, the new pins were able to be installed with little difficulty. For the first location, U49, all four pins were machined and on site. However with the existing upper pin hole not being plumb and new hole required to be plumb, the existing upper original diameter of 10¼" was inadequate. The contractor sent U29 lower pin, which was 10¾" diameter, back to the machine shop to have it turned down to the needed diameter of 10½".

New pins were ordered for U29, however, they were not turned down until after the line boring was 50% complete.

Figure 38 – Installation of New Pins

Conclusion

After the new pins were installed, the temporary restraints were disengaged and load transferred to the new pins and eyebars. Table 3 includes the results from U29 and U49 eyebars. U49 eyebar loads appeared to be symmetric and behaved as a deep beam governed by Euler-Bernoulli. The inside eybar was 15% greater than the outside eyebar and it is thought that the inside gusset may carry more load due to the fact that the weight of roadway is transferred through the floor system which favors the inside gusset.

U29 loads were not as symmetric as U49 and heavily favor the outside gusset. The outboard eyebar was 44% greater than the inboard eyebar and it is thought that the misalignment in U29 was the primary culprit for the imbalance.

When comparing the total loads in Table 3, both U29 and U49 were within 3% of the dead loads shown on the 1940 contract plans.

Table 3 – U29 and U49 Eyebar loads

Location	U29	U49
Bar 1 (inboard)	70.9 kips	135.3 kips
Bar 2	105.4 kips	115.9 kips
Bar 3	119.9 kips	100.2 kips
Bar 4	115.6 kips	102.0 kips
Bar5	125.6 kips	104.1 kips
Bar 6 (outboard)	127.0 kips	115.7 kips
Total	656.5 kips	673 kips
DL in 1940 Plans	638 kips	655 kips

MDOT, HNTB and CEC all felt the project was a success and MDOT is anticipating replacing the remaining 12 pins and 6 links on a future project. The primary key to success was the partnership and determination between all the parties involved to make the project successful.

US 84 Mississippi River Bridge; Natchez-Vidalia Bridge

The Zofnass Program at Harvard University

Prof. S.N. Pollalis, D. Lappas, J. Rodriguez

22 February 2018

Prof. S.N. Pollalis prepared this case study with researchers at The Zofnass Program as the basis for research and class discussion rather than to illustrate either effective or ineffective handling of the design, the construction or an administrative situation.

The authors would like to thank James Gregg, Department Manager- Engineering, HNTB-Arlington and Jim Grant, Energy & Fueling Systems Director, HNTB-Bellevue.

Abstract

The rehabilitation of the US 84 Mississippi River Bridge showcases the importance of “doing the right project” instead of only “doing the project right.” It also proves that doing the right project is not only the most sustainable but can also be the most cost-effective option, supporting the argument that sustainability can cost less.

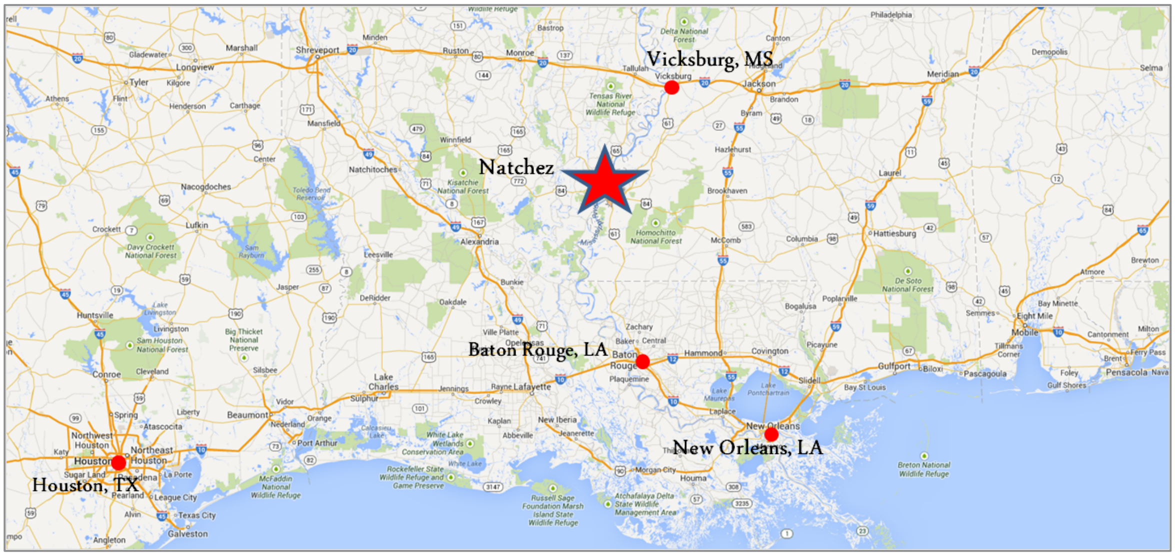
Works included the repair of two faulty joints of the truss bridge, which was then 75 years old and 25 years past its design lifetime. It was an operation of high technical complexity and with no similar precedent, one that put the bridge in a vulnerable position during repairs. Careful preparation and detailed risk analysis made the project a success. It extended the lifetime of the bridge by 40 years, avoiding the need to construct a new one. The rehabilitation had significant environmental benefits at a fraction of the cost of replacing the bridge. In this case, doing the right project required outside-the-box thinking, being next to the client and advising early in the process before the RFP was issued, seamless cooperation among all stakeholders, and technical expertise and excellent preparation to minimize risks.

Project Data

Project Name:	US 84 Mississippi River Bridge (Natchez-Vidalia Bridge)
Sustainability Savings:	Over $245 million savings Project cost $3.8 million, compared to at least $250 million cost for a new bridge
Project Type:	Bridge repair
Location:	Natchez (MS) & Vidalia (LA)
Area / Length:	527,616 ft^2 / 3,664 ft
Capacity:	2014 average daily traffic = 23,000 Two 12 ft lanes with no shoulder
Owner / Client :	Mississippi Department of Transportation (MDOT) & Louisiana Department of Transportation and Development (LADOTD); MDOT is the lead agency
Project Team:	Contractor: CEC, Inc
	Engineer/Designer: HNTB
	Facility/Project Manager: James Gregg, HNTB
	Consultants: HNTB
Project Lifespan	40-year extension
Current Status:	Complete
Funding model:	Traditional
Delivery Method:	Design–bid–build
Overall investment cost:	$3,562,676 (1940) $3.8 million (2014 rehab)
Design & Construction cost:	$5 million
O&M cost:	$500,000 per year
Source of funding:	Funded by state and federal gas taxes

Introduction and Project Description

The US 84 Mississippi River Bridge, also know as Natchez-Vidalia Bridge, is a twin 5-span cantilever truss bridge that carries US Routes 65, 84, and 425 across the Mississippi River between Natchez, Mississippi and Vidalia, Louisiana (see map). The original single bridge was also designed by HNTB in 1939 and opened to traffic in September 1940. Due to increased traffic, a second truss bridge, following the same design but wider, was opened to traffic in 1988. Today, the new bridge carries the heavier eastbound traffic and the original bridge the westbound traffic.



The Mississippi Department of Transportation (MDOT) and the Louisiana Department of Transportation and Development (LADOTD) share the responsibility for the operation and maintenance of the bridge. The first indication of a problem with the structural integrity of the original (1940) bridge came after an in-depth inspection in 1995. The inspection found that a truss pin had begun to shift. In 1996, an attempt was made to reset the pin but was unsuccessful. A later inspection in 2010 showed that two of its eight structural links were compromised as a second pin was shifting. An additional 0.5 inch of shift would mean the bridge had to be closed as unsafe. In 2010, the original bridge had already surpassed its design life by 20 years, and although the condition of the bridge posed no immediate risk, there was no way to create a warning system to alert officials if things deteriorated further.

HNTB was retained as a qualified consultant to the Bridge Department of Mississippi and was assigned the in-depth inspection of the bridge. HNTB was also asked to propose viable options for dealing with the problem. After several inspections it became apparent that age was taking its toll. Structural components lacking any redundancy had worn out and started shifting. Action was required to ensure the safety of the bridge.

HNTB presented five alternative solutions that were evaluated for their technical performance and economic feasibility. The five options were:

1) Restrain and monitor – This was the least intrusive option. It suggested adding restraints to the lower pin to prevent it from moving any further, combined with the development of a monitoring plan that would notify MDOT if the pin moved any further. Although low-cost, this option was not chosen as it was buying time rather than dealing with the problem. There were concerns that a restraint would not be able to hold the pin and would damage other components on the bridge. It would also disrupt the historical fabric of the bridge, changing the aesthetics.

2) Reset lower pins – This was attempted 15 years ago and was not successful. Reattempting it would most likely result in the same outcome.
3) Replace lower pins – Replacing the lower pin would entail drilling out the lower pin and line-boring a new hole in the existing link and gussets. This option was given consideration, but there were concerns that the link might be damaged when the pins were removed. If damaged, it would take several weeks to fabricate new links while the bridge would be closed to traffic and in a vulnerable position.
4) Replace link and lower and upper pins – This option required replacing the entire assembly. MDOT felt this was the best option as it provided a better balance between cost and risk and provided the best chance for success.
5) Replace the bridge – Replacing the bridge was not an appealing option due to lack of available funding. On top of that, replacing the bridge would require MDOT to open an Environmental Impact Assessment (EIS), which would take 3-5 years to complete before design and construction could start.

After assessing the pros and cons of the five options, they narrowed the selection to options 4 and 5: the replacement of lower and upper pins and links, or the replacement of the bridge, which is the standard procedure usually followed for bridges of that age in the region.

Economics played an important role in eliminating option 5, while longevity was the main criterion for choosing among options 1-4. The listing of the bridge as a candidate for historical status also influenced the final decision. The construction cost for a new bridge would have been at least $250 million. The construction cost for replacing the pins and links of the first two joints was estimated at $3.8 million; an additional $6M would be required for the preventive replacement of the remaining six joints. The $3.8 million construction cost breaks down to $133,100 for bridge monitoring, $2,670,800 for the pin and link replacement, and $1,016,261 for detour crossover and maintenance of traffic. Additional to construction, $1.1 million was the cost for design and construction inspection, for a total project cost of $4.9M. The project was funded by state and federal gas taxes. The cost was split between the states of Louisiana and Mississippi, with the Federal Highway Administration providing an 80% of the total cost.

Despite its being an option with high risk and a construction challenge, the replacement of lower and upper pins and links was finally selected. The decision was driven by option 4's significantly lower cost than option 5 and its sustainability.

HNTB continued with the design based on the existing on-call retainer contract. MDOT and HNTB prepared together the request for qualifications to short-list qualified contractors. Due to the risk and complexity of the project, they wanted a partner, not just a contractor, to follow and supplement the plan. They required contractors to submit their qualifications of personnel, requirements, and experience. Qualified contractors bid on a set of plans prepared by HNTB; CEC Inc. was awarded the project as a low bidder and MDOT served as the contracting agency for the repair. "Despite all of the risks and unknowns of the replacement process, the team of MDOT, LADOTD, HNTB, and CEC, Inc., attributes preparation and communications as the key to a well-run, successful project. Collectively, team members worked to add more years of service life to the bridge. Though coordination between two state agencies may be a challenge, this job turned out to be the opposite."[1]

An innovative approach was followed by HNTB and MDOT during design; they completed a risk matrix to identify any possible risk and examine mitigation measures. Thus, it was decided to replace not only the problematic lower pins but the whole assembly, including the links and upper pins, to increase the safety and longevity of the bridge. Similarly, it was decided to replace each single link with multiple eyebars. The existing links are single-forged members that carry the weight of bridge. As a single member, they offer no redundancy. To increase redundancy, five 2-inch eyebar plates were used to replace the existing single 10-inch eyebar. In this way, if one eyebar plate should crack due to fatigue, the crack would be limited to a single plate instead of the whole member.

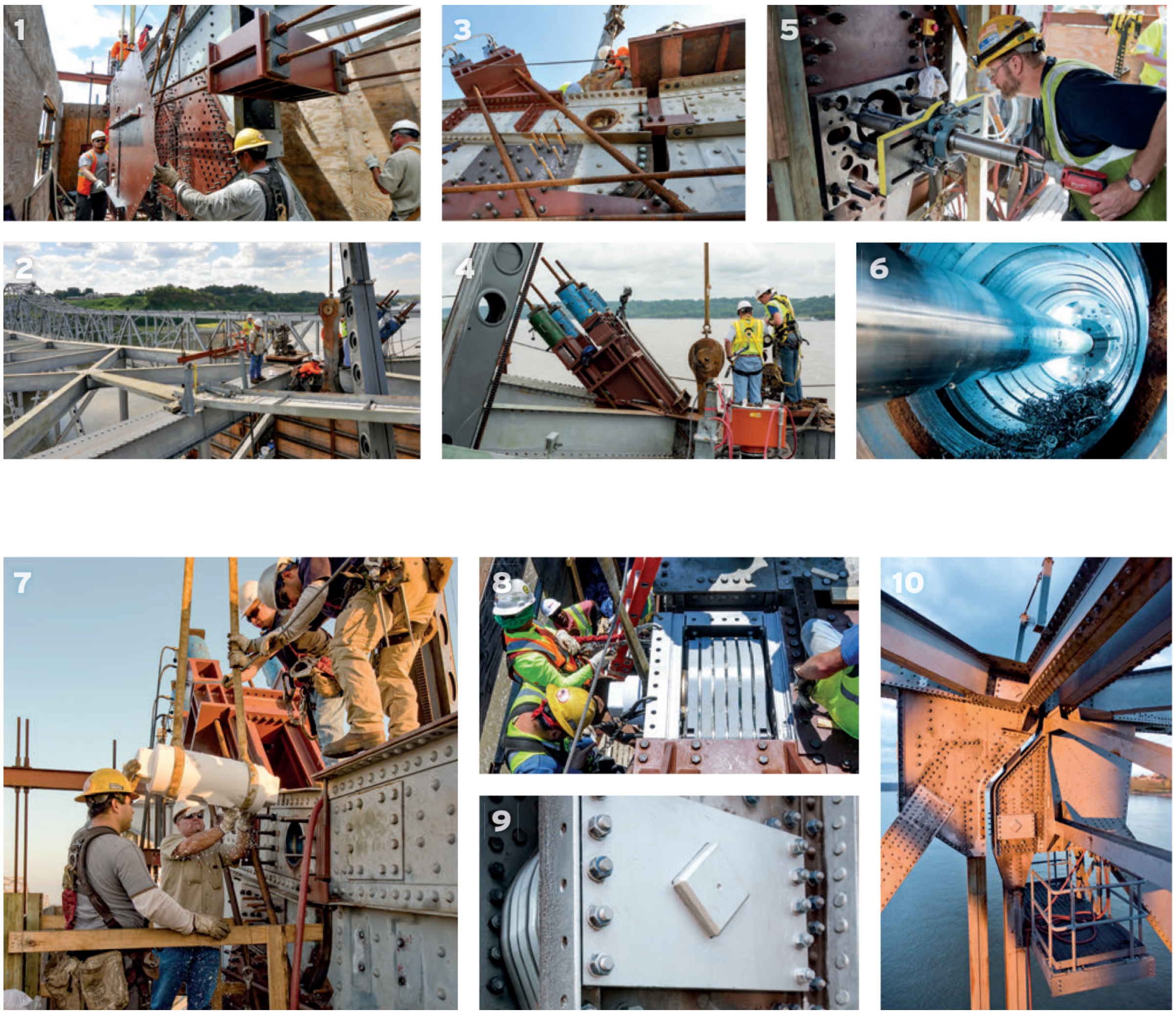
However, choosing the repair was not an easy decision; it carried risk and required innovative thinking and strong commitment from the client and the consultants. The bridge was already 25 years past its design life when work started, and replacing it with a new one is the standard procedure one would have expected for a bridge of that type and age.

The project is a first of its kind, since never before had a similar intervention been attempted on a vehicle bridge of that type and scale. Rehabilitation started in November 2014 and lasted eleven weeks; during that period the older bridge was shut down for traffic with the newer eastbound bridge accommodating traffic in both directions.

[1] "New Life for an Old Span," *HNTB Designer*, no. 105, p. 18.

The final cost for the 2014 rehabilitation project reached $3.8 million and was funded by state and federal gas taxes. Despite the technical uncertainties of the innovative restoration process that was chosen, the project was delivered on time and within budget.

Replacement Process[2]



The photos above show the steps that took place during the pin-and-link replacement process.

1. Employees from CEC, Inc., the contractor partner for the project, removed splice plate templates that were welded together so that holes could be drilled in the temporary splice plate, which was one inch thick. Fill plates were installed to ensure the splice plate was flush between the two gussets. More than 400 A490 bolts measuring 7/8 of an inch in diameter were used to fasten the temporary splice plate to the gussets. Horizontal post-tensioning bars were used to prevent the joint from moving.

[2] "New Life for an Old Span," *HNTB Designer*, no. 105, p. 19.

2. The project team removed the 4,500-pound forged link from the bridge by cutting the upper and lower pins with a wire saw.

3. During removal of the U29 link, a diagonal bypass was used to temporarily support the bridge. A one-inch splice plate was used to lock the upper joint, as well as act as a secondary load path if the diagonal bypass failed.

4. To facilitate removal of the forged link from inside the truss, the upper diagonal bypass was positioned on the cantilever span side of the truss to support the suspended span side at the adjacent lower joint (L28-U29 and L48-U49).

5. A subcontractor, In-Place Machine Company from Milwaukee, Wisconsin, worked around the clock during the replacement to measure and line-bore upper and lower pins simultaneously over a three-day period. The team spent 24 hours setting up and measuring before work began to ensure upper and lower pins were plumb and in line with each other.

6. A new hole was line-bored for the existing gusset and new eyebars. Because the existing lower pin hole was oblong from wear and the upper pin was not plumb, the diameter of the new pins was increased up to 3/4 of an inch to ensure proper fit and provide a clean bearing surface.

7. The contractor team installed new upper pins, which were packed in dry ice and transported from the machine shop to the job site, where ice was removed. Grease was applied prior to installation, allowing the new pins to slide into the newly bored holes with ease.

8. The team worked to install new upper pins through the existing gusset and six new eyebars. Both upper and lower pins were turned down in the machine shop just hours prior to installation to ensure a correct fit.

9. The newly installed eyebars are shown in place and secured with a retainer plate to provide a more robust method to prevent the pins from rotating or moving transversely.

10. The completed U49 with new eyebars and retainer plates provides the structural support needed to extend the life of the bridge.

Overview of the Main Sustainability Features of the Project

The sustainability benefits of this project start from the decision to rehabilitate the bridge and extend its lifetime by 40 years instead of building a new bridge.

Besides the substantial economic benefit, extending the lifetime of the existing bridge was environmentally and socially sustainable. In terms of environmental sustainability, a new bridge would have required a massive amount of material and energy resources, while a plan for deconstruction and recycling of the old bridge would have been necessary. The bridge is a vital link between Mississippi and Louisiana, significantly important for commerce and the local economy. The project ensured the use of the crossing for another 40 years. Moreover, transportation studies would most likely show that the newer eastbound bridge could not have carried traffic in both directions for the entire construction period, as would have been necessary for a new bridge to replace the old bridge in the exact same location. A possible closure of the bridge before a new one was constructed would have required over 70 miles of detour for trucks. With an estimated 200 trucks per day using the bridge, this would be an additional $3.0 million per year cost that local industry would have had to absorb, besides the environmental impact of the increased greenhouse gas emissions. On the other hand, a new alignment parallel to the old bridge would have had a significant impact on the riverbanks and would have required land acquisition.

Regarding social sustainability, the bridge, built in 1940, is listed as a historical candidate and eligible for National Register status. Replacing the bridge would have lost the historical eligibility, while adding permanent external bracing was not preferred by the historical society and the local community. Apart from that, the design and construction of a new bridge is a long process that takes up to 10 years, a period during which the structural integrity of the old bridge might have further deteriorated. The bridge is vital for the local economy, and a possible closure even for few years with traffic accommodated only by the eastbound bridge could have had a major impact on the community.

The sustainability performance of the project was confirmed by using the Checklist tool of the Envision® Rating System after the project was completed. The Checklist evaluation results are presented in more detail in the following section.

Envision® Rating.

This section examines the sustainability performance of the project after applying the self-assessment Checklist tool of the Envision® Rating System. HNTB did the self-assessment. Results are presented through the main five categories of impact of Envision®: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk.

Quality of Life

The Quality of Life category addresses a project's impact on host and affected communities, from the health and wellbeing of individuals to the wellbeing of the larger social fabric as a whole. These impacts may be physical, economic, or social. Quality of Life focuses on assessing whether infrastructure projects align with community goals, are incorporated into existing community networks, and will benefit the community in the long term. Community members affected by the project are considered important stakeholders in the decision-making process.[3] The Quality of Life category is divided into three subcategories: Purpose, Wellbeing, and Community.

[3] Envision® manual

				Y	N	NA	
1	QUALITY OF LIFE	PURPOSE	QL1.1 Improve Community Quality of Life	2	0	1	2 of 2
2			QL1.2 Stimulate Sustainable Growth and Development	0	0	3	0 of 0
3			QL1.3 Develop Local Skills and Capabilities	0	3	0	0 of 3
4		COMMUNITY	QL2.1 Enhance Public Health and Safety	1	0	0	1 of 1
5			QL2.2 Minimize Noise and Vibration	0	0	1	0 of 0
6			QL2.3 Minimize Light Pollution	0	0	1	0 of 0
7			QL2.4 Improve Community Mobility and Access	3	0	0	3 of 3
8			QL2.5 Encourage Alternative Modes of Transportation	0	0	2	0 of 0
9			QL2.6 Improve Site Accessibility, Safety and Wayfinding	3	0	0	3 of 3
10		WELLBEING	QL3.1 Preserve Historic and Cultural Resources	2	0	0	2 of 2
11			QL3.2 Preserve Views and Local Character	2	0	0	2 of 2
12			QL3.3 Enhance Public Space	0	2	0	0 of 2
			TOTAL	13	5	8	13 of 18

The project performed very well in the Quality of Life category, scoring positively on 13 out of 18 applicable questions. It did well on the credit QL1.1 Improve Community Quality of Life, since it eliminated the negative impacts a possible bridge failure would have had on nearby communities and has received broad community endorsement. As expected, the project did exceptionally well on the credits of the community subcategory and more specifically the credits QL2.1 Enhance Public Health and Safety, QL2.4 Improve Community Mobility and Access, and QL2.6 Improve Site Accessibility, Safety and Wayfinding. Finally, the listing of the bridge as historical candidate helped the project on the credits QL3.1 Preserve Historic and Cultural Resources and QL3.2 Preserve Views and Local Character. The applicable credits where the project could have performed better are QL1.3 Develop Local Skills and Capabilities, which promotes local employment and procurement, and QL3.3 Enhance Public Space, as the old and narrow structure of the bridge restricts any improvement in that issue.

Leadership

Successful sustainable projects require a new way of thinking about how they are developed and delivered. Project teams are most successful if they communicate and collaborate early on, involve a wide variety of people in creating ideas for the project, and take a long-term, holistic view of the project and its life cycle. This category encourages and rewards these actions on the view that, together with traditional sustainability actions such as reducing energy and water use, effective and collaborative leadership produces a truly sustainable project that contributes positively to the world around it. This category is divided into the three subcategories of Collaboration, Management, and Planning.

				Y	N	NA	
13	LEADERSHIP	COLLABORATION	LD1.1 Provide Effective Leadership and Commitment	1	2	0	1 of 3
14			LD1.2 Establish a Sustainability Management System	0	1	0	0 of 1
15			LD1.3 Foster Collaboration and Teamwork	3	0	0	3 of 3
16			LD1.4 Provide for Stakeholder Involvement	1	2	0	1 of 3
17		MANAGEMENT	LD2.1 Pursue By-product Synergy Opportunities	0	1	0	0 of 1
18			LD2.2 Improve Infrastructure Integration	0	0	3	0 of 0
19		PLANNING	LD3.1 Plan for Long-term Monitoring and Maintenance	1	1	0	1 of 2
20			LD3.2 Address Conflicting Regulations and Policies	0	1	1	0 of 1
21			LD3.3 Extend Useful Life	1	0	0	1 of 1
			TOTAL	7	8	4	7 of 15

The project performed fairly well in the Leadership category, scoring positively on 7 out of 15 applicable questions. It did very well on the credit LD1.3 Foster Collaboration and Teamwork, since the close collaboration between the client and the consultants and the understanding by all sides of the associated risks made possible the adoption of such an innovative approach and the successful delivery of the project. It also scored high on the credit LD3.3 Extend Useful Life, as it managed to extend substantially the lifetime of the bridge. The project dealt with some aspects covered by the credits LD1.1 Provide Effective Leadership and Commitment, LD1.4 Provide for Stakeholder Involvement, and LD3.1 Plan for Long-term Monitoring and Maintenance, but there was also room for improvement. Finally, credits that the project might have further taken into consideration if Envision® had been used from an early stage include LD1.2 Establish a Sustainability Management System and LD3.2 Address Conflicting Regulation and Policies.

Resource Allocation

Resources are the assets that are needed to build infrastructure and keep it running. This category is broadly concerned with the quantity, source, and characteristics of these resources and their impacts on the overall sustainability of the project. Resources addressed include physical materials (both those that are consumed and that leave the project), energy, and water. These resources are finite and should be treated as assets to use respectfully. Materials, Energy, and Water comprise the three subcategories of Resource Allocation.

				Y	N	NA	
22	RESOURCE ALLOCATION	MATERIALS	RA1.1 Reduce Net Embodied Energy	0	0	2	0 of 0
23			RA1.2 Support Sustainable Procurement Practices	0	3	0	0 of 3
24			RA1.3 Use Recycled Materials	1	1	0	1 of 2
25			RA1.4 Use Regional Materials	0	2	0	0 of 2
26			RA1.5 Divert Waste from Landfills	0	3	0	0 of 3
27			RA1.6 Reduce Excavated Materials Taken off Site	0	3	0	0 of 3
28			RA1.7 Provide for Deconstruction and Recycling	0	3	0	0 of 3
29		ENERGY	RA2.1 Reduce Energy Consumption	0	3	0	0 of 3
30			RA2.2 Use Renewable Energy	0	2	0	0 of 2
31			RA2.3 Commission and Monitor Energy Systems	0	0	3	0 of 0
32		WATER	RA3.1 Protect Fresh Water Availability	0	0	7	0 of 0
33			RA3.2 Reduce Potable Water Consumption	0	0	4	0 of 0
34			RA3.3 Monitor Water Systems	0	0	4	0 of 0
			TOTAL	1	20	20	1 of 21

The project had a poor performance in this category, covering only one of the 21 applicable points. However, if we examine the bigger picture, by "doing the right project" and avoiding the construction of a new bridge, the team saved a tremendous amount of natural resources. Still, the performance in this category pinpoints the importance of using a rating system such as Envision® from an early stage, as there is always room for improvement even if a project is sustainable by its nature. For example, issues covered by the credits RA1.2 Support Sustainable Procurement Practices, RA1.4 Use Regional Materials, and RA 1.7 Provide for Deconstruction and Recycling might have delivered a positive result had they been taken into consideration by the team at an early stage. On the other hand, the nature of the project as a targeted intervention doesn't offer an opportunity for improvement in aspects such as energy consumption. Actually, the credits of the Energy subcategory are on the verge of being applicable in this project, while the credits of the

Water subcategory are not applicable.

Natural World

Infrastructure projects have an impact on the natural world around them, including habitats, species, and nonliving natural systems. The way a project is located within these systems and the new elements it may introduce to a system can create unwanted impacts. This category addresses how to understand and minimize negative impacts while considering ways in which the infrastructure can interact with natural systems in a synergistic, positive way. These types of interactions and impacts have been divided into three subcategories: Siting, Land and Water, and Biodiversity.

				Y	N	NA	
35	NATURAL WORLD	SITING	NW1.1 Preserve Prime Habitat	0	0	5	0 of 0
36			NW1.2 Protect Wetlands and Surface Water	1	1	1	1 of 2
37			NW1.3 Preserve Prime Farmland	0	0	1	0 of 0
38			NW1.4 Avoid Adverse Geology	0	0	3	0 of 0
39			NW1.5 Preserve Floodplain Functions	2	0	4	2 of 2
40			NW1.6 Avoid Unsuitable Development on Steep Slopes	2	0	0	2 of 2
41			NW1.7 Preserve Greenfields	0	0	2	0 of 0
42		LAND & WATER	NW2.1 Manage Stormwater	1	1	0	1 of 2
43			NW2.2 Reduce Pesticide and Fertilizer Impacts	1	4	0	1 of 5
44			NW2.3 Prevent Surface and Groundwater Contamination	0	0	4	0 of 0
45		BIODIVERSITY	NW3.1 Preserve Species Biodiversity	2	2	0	2 of 4
46			NW3.2 Control Invasive Species	0	3	0	0 of 3
47			NW3.3 Restore Disturbed Soils	0	0	2	0 of 0
48			NW3.4 Maintain Wetland and Surface Water Functions	0	0	5	0 of 0
			TOTAL	9	11	27	9 of 20

The project did relatively well in the Natural World category, scoring on 9 out of 20 applicable points. Again in this category the bigger picture matters more, as avoiding building a new bridge has significantly protected the natural environment. As already mentioned, a new bridge would have been built in a new alignment, parallel to the existing bridge, which would have had a severe impact on the river and riverbank ecosystem. The selected option of rehabilitating the old bridge might not restore the natural habitat but has the minimum possible new impact on it; thus the high score on the credits NW1.5 Preserve Floodplain Functions and NW1.6 Avoid Unsuitable Development on Steep Slopes, and the good performance on credits such as NW1.2 Protect Wetlands and Surface Water and NW2.1 Manage Stormwater.

Climate and Risk

The general scope of the Climate and Risk category is twofold: minimizing emissions that may contribute to increased short- and long-term risks, and ensuring that infrastructure projects are resilient to short-term hazards or can adapt to altered long-term future conditions. The Climate and Risk category is divided into two subcategories: Emissionand Resilience.

The project has an average performance in the Climate and Risk category, scoring on two out of six applicable points. This is a demanding category of the Envision® System. The project did very well on the credit CR2.2 Avoid Traps and Vulnerabilities, but since it is a targeted intervention in an existing infrastructure project there was not much room for a better performance on credits associated with greenhouse gas emissions and resilience.

				Y	N	NA	
49	CLIMATE	EMISSION	CR1.1 Reduce Greenhouse Gas Emissions	0	1	1	0 of 1
50			CR1.2 Reduce Air Pollutant Emissions	0	0	2	0 of 0
51		RESILIENCE	CR2.1 Assess Climate Threat	0	1	0	0 of 1
52			CR2.2 Avoid Traps and Vulnerabilities	2	0	0	2 of 2
53			CR2.3 Prepare for Long-term Adaptability	0	1	0	0 of 1
54			CR2.4 Prepare for Short-term Hazards	0	0	2	0 of 0
55			CR2.5 Manage Heat Island Effects	0	1	0	0 of 1
			TOTAL	2	4	5	2 of 6

In Retrospect

The US 84 Mississippi River Bridge rehabilitation project stands out as an example of how "doing the right project" instead of only "doing the project right" can enhance sustainability and at the same time cost less. At $3.8 million, the project cost a fraction of the over $250 million that would be needed for a new bridge. In parallel, it avoided disturbance of the river ecosystem and heavy consumption of natural resources.

It also showcases that innovative and outside-the-box thinking can bring significant environmental, social, and economic benefits. A strong team collaboration is needed for this approach to be successful, with all stakeholders understanding the challenges of the project. In the US 84 Mississippi River Bridge project, both the client and the consultants understood the risks of the operations and worked closely during the whole process to overcome risks and successfully deliver the project. HNTB as the main consultant of the project showed responsibility, proposing a solution that would bring the company a much smaller contract and more complexity and risk for its designers.

This project reinforces the correlation between sustainability and useful lifetime. As most developed countries are facing the aging of their infrastructure, clients, consultants, and engineers become more aware that extending the useful life of a project can be a sustainable and cost-effective approach worth examining before they make decisions.

It should also be mentioned that even if a project has a positive sustainability performance by nature, a sustainability framework or a rating tool such as Envision® can ensure that the project is also executed sustainably ("do the project right"). The post-assessment of the US 84 Mississippi River Bridge project with the Envision® checklist tool proved that it was a sustainable project executed the right way. Still, the application of Envision® at an early stage would have given the project team a holistic perspective, further improving the sustainable performance of the project.

The US 84 Mississippi River Bridge project has established a precedent for repairing truss bridges and overturns the prevailing notion that bridges of that type and age should be replaced with new ones, thus saving millions of taxpayers' dollars.

Appendix A - Envision® Checklist

Envision Rating System
Pre-Assessment Checklist
Results Table

	Category	Subcategory	Credit	Y	N	NA	Score
1	QUALITY OF LIFE	PURPOSE	QL1.1 Improve Community Quality of Life	2	0	1	2 of 2
2			QL1.2 Stimulate Sustainable Growth and Development	0	0	3	0 of 0
3			QL1.3 Develop Local Skills and Capabilities	0	3	0	0 of 3
4		COMMUNITY	QL2.1 Enhance Public Health and Safety	1	0	0	1 of 1
5			QL2.2 Minimize Noise and Vibration	0	0	1	0 of 0
6			QL2.3 Minimize Light Pollution	0	0	1	0 of 0
7			QL2.4 Improve Community Mobility and Access	3	0	0	3 of 3
8			QL2.5 Encourage Alternative Modes of Transportation	0	0	2	0 of 0
9			QL2.6 Improve Site Accessibility, Safety and Wayfinding	3	0	0	3 of 3
10		WELLBEING	QL3.1 Preserve Historic and Cultural Resources	2	0	0	2 of 2
11			QL3.2 Preserve Views and Local Character	2	0	0	2 of 2
12			QL3.3 Enhance Public Space	0	2	0	0 of 2
			TOTAL	13	5	8	13 of 18
13	LEADERSHIP	COLLABORATION	LD1.1 Provide Effective Leadership and Commitment	1	2	0	1 of 3
14			LD1.2 Establish a Sustainability Management System	0	1	0	0 of 1
15			LD1.3 Foster Collaboration and Teamwork	3	0	0	3 of 3
16			LD1.4 Provide for Stakeholder Involvement	1	2	0	1 of 3
17		MANAGEMENT	LD2.1 Pursue By-product Synergy Opportunities	0	1	0	0 of 1
18			LD2.2 Improve Infrastructure Integration	0	0	3	0 of 0
19		PLANNING	LD3.1 Plan for Long-term Monitoring and Maintenance	1	1	0	1 of 2
20			LD3.2 Address Conflicting Regulations and Policies	0	1	1	0 of 1
21			LD3.3 Extend Useful Life	1	0	0	1 of 1
			TOTAL	7	8	4	7 of 15
22	RESOURCE ALLOCATION	MATERIALS	RA1.1 Reduce Net Embodied Energy	0	0	2	0 of 0
23			RA1.2 Support Sustainable Procurement Practices	0	3	0	0 of 3
24			RA1.3 Use Recycled Materials	1	1	0	1 of 2
25			RA1.4 Use Regional Materials	0	2	0	0 of 2
26			RA1.5 Divert Waste from Landfills	0	3	0	0 of 3
27			RA1.6 Reduce Excavated Materials Taken off Site	0	3	0	0 of 3
28			RA1.7 Provide for Deconstruction and Recycling	0	3	0	0 of 3
29		ENERGY	RA2.1 Reduce Energy Consumption	0	3	0	0 of 3
30			RA2.2 Use Renewable Energy	0	2	0	0 of 2
31			RA2.3 Commission and Monitor Energy Systems	0	0	3	0 of 0
32		WATER	RA3.1 Protect Fresh Water Availability	0	0	7	0 of 0
33			RA3.2 Reduce Potable Water Consumption	0	0	4	0 of 0
34			RA3.3 Monitor Water Systems	0	0	4	0 of 0
			TOTAL	1	20	20	1 of 21
35	NATURAL WORLD	SITING	NW1.1 Preserve Prime Habitat	0	0	5	0 of 0
36			NW1.2 Protect Wetlands and Surface Water	1	1	1	1 of 2
37			NW1.3 Preserve Prime Farmland	0	0	1	0 of 0
38			NW1.4 Avoid Adverse Geology	0	0	3	0 of 0
39			NW1.5 Preserve Floodplain Functions	2	0	4	2 of 2
40			NW1.6 Avoid Unsuitable Development on Steep Slopes	2	0	0	2 of 2
41			NW1.7 Preserve Greenfields	0	0	2	0 of 0
42		LAND & WATER	NW2.1 Manage Stormwater	1	1	0	1 of 2
43			NW2.2 Reduce Pesticide and Fertilizer Impacts	1	4	0	1 of 5
44			NW2.3 Prevent Surface and Groundwater Contamination	0	0	4	0 of 0
45		BIODIVERSITY	NW3.1 Preserve Species Biodiversity	2	2	0	2 of 4
46			NW3.2 Control Invasive Species	0	3	0	0 of 3
47			NW3.3 Restore Disturbed Soils	0	0	2	0 of 0
48			NW3.4 Maintain Wetland and Surface Water Functions	0	0	5	0 of 0
			TOTAL	9	11	27	9 of 20
49	CLIMATE	EMISSION	CR1.1 Reduce Greenhouse Gas Emissions	0	1	1	0 of 1
50			CR1.2 Reduce Air Pollutant Emissions	0	0	2	0 of 0
51			CR2.1 Assess Climate Threat	0	1	0	0 of 1
52			CR2.2 Avoid Traps and Vulnerabilities	2	0	0	2 of 2
53		RESILIENCE	CR2.3 Prepare for Long-term Adaptability	0	1	0	0 of 1
54			CR2.4 Prepare for Short-term Hazards	0	0	2	0 of 0
55			CR2.5 Manage Heat Island Effects	0	1	0	0 of 1
			TOTAL	2	4	5	2 of 6

Quality of Life

1. Purpose

QL 1.1 Improve Community Quality of Life

Intent: Improve the net quality of life of all communities affected by the project and mitigate negative impacts to communities.

Metric: Measures taken to assess community needs and improve quality of life while minimizing negative impacts.

Assessment Questions:	Yes	No	N/A	
Are the relevant community needs, goals and issues being addressed in the project?	○	○	◉	?
Are the potentially negative impacts of the project on the host and nearby communities been reduced or eliminated?	◉	○	○	?
Has the project design received broad community endorsement, including community leaders and stakeholder groups?	◉	○	○	?
Total	2	of	2	

QL 1.2 Stimulate Sustainable Growth and Development

Intent: Support and stimulate sustainable growth and development, including improvements in job growth, capacity building, productivity, business attractiveness and livability.

Metric: Assessment of the project's impact on the community's sustainable economic growth and development.

Assessment Questions:	Yes	No	N/A	
Will the project contribute significantly to local employment?	○	○	◉	?
Will the project make a significant increase in local productivity?	○	○	◉	?
Will the project make the community more attractive to people and businesses?	○	○	◉	?
Total	0	of	0	

QL 1.3 Develop Local Skills and Capabilities

Intent: Expand the knowledge, skills and capacity of the community workforce to improve their ability to grow and develop.

Metric: The extent to which the project will improve local employment levels, skills mix and capabilities.

Assessment Questions:	Yes	No	N/A	
Does the project team intend to hire and train a substantial number of local workers?	○	◉	○	?
Does the project team intend to use a substantial number of local suppliers and specialty firms?	○	◉	○	?
Will the project, through local employment, subcontracting and education programs, make a substantial improvement in local capacity and competitiveness?	○	◉	○	?
Total	0	of	3	

2. Wellbeing

QL 2.1 Enhance Public Health and Safety

Intent: Take into account the health and safety implications of using new materials, technologies or methodologies above and beyond meeting regulatory requirements.

Metric: Efforts to exceed normal health and safety requirements, taking into account additional risks in the application of new technologies, materials and methodologies.

Assessment Questions:	Yes	No	N/A	
Does the owner and the project team intend to identify, assess and institute new standards to address additional risks and exposures created by the application of new technologies, materials, equipment and/or methodologies?	◉	○	○	?

Total 1 of 1

QL 2.2 Minimize Noise and Vibration

Intent: Minimize noise and vibration generated during construction and in the operation of the completed project to maintain and improve community livability.

Metric: The extent to which noise and vibration will be reduced during construction and operation.

Assessment Questions:	Yes	No	N/A	
Will the project reduce noise and vibration to levels below local permissable levels during construction and operation?	○	○	◉	?

Total 0 of 0

QL 2.3 Minimize Light Pollution

Intent: Prevent excessive glare, light at night, and light directed skyward to conserve energy and reduce obtrusive lighting and excessive glare.

Metric: Lighting meets minimum standards for safety but does not spill over into areas beyond site boundaries, nor does it create obtrusive and disruptive glare.

Assessment Questions:	Yes	No	N/A	
Will the project be designed to reduce excessive lighting, prevent light spillage and preserve/restore the night sky?	○	○	◉	?

Total 0 of 0

QL 2.4 Improve Community Mobility and Access

Intent: Locate, design and construct the project in a way that eases traffic congestion, improves mobility and access, does not promote urban sprawl, and otherwise improves community livability.

Metric: Extent to which the project improves access and walkability, reductions in commute times, traverse times to existing facilities and transportation. Improved user safety considering all modes, e.g., personal vehicle, commercial vehicle, transit and bike/pedestrian.

Assessment Questions:	Yes	No	N/A	
Will the project provide good, safe access to adjacent facilities, amenities and transportation hubs?	◉	○	○	?
Will the project design take into consideration the expected traffic flows and volumes in and around the project site to improve overall mobility and efficiency?	◉	○	○	?
Has the project team coordinated the design with other infrastructure assets to reduce traffic congestion, and improve walkability and livability?	◉	○	○	?
Total	3	of	3	

QL 2.5 Encourage Alternative Modes of Transportation

Intent: Improve accessibility to non-motorized transportation and public transit. Promote alternative transportation and reduce congestion.

Metric: The degree to which the project has increased walkability, use of public transit, non-motorized transit.

Assessment Questions:	Yes	No	N/A	
Will the project be within walking distance of accessible multi-modal transportation?	○	○	◉	?
Through its design, will the project encourage the use of transit and/or non-motorized transportation?	○	○	◉	?
Total	0	of	0	

QL 2.6 Improve Accessibility, Safety and Wayfinding

Intent: Improve user accessibility, safety, and wayfinding of the site and surrounding areas.

Metric: Clarity, simplicity, readability and broad-population reliability in wayfinding, user benefit and safety.

Assessment Questions:	Yes	No	N/A	
Will the project contain the appropriate signage for safety and wayfinding in and around the constructed works?	◉	○	○	?
Will the project address safety and accessibility in and around the constructed works for users and emergency personnel?	◉	○	○	?
Will the project extend accessibility and intuitive signage to protect nearby sensitive sites or neighborhoods?	◉	○	○	?
Total	3	of	3	

3. Community

QL 3.1 Preserve Historic and Cultural Resources

Intent: Preserve or restore significant historical and cultural sites and related resources to preserve and enhance community cultural resources.

Metric: Summary of steps taken to identify, preserve or restore cultural resources.

Assessment Questions:	Yes	No	N/A	
Will the project minimize negative impacts on historic and cultural resources?	◉	○	○	?
Will the project be designed so that it fully preserves and/or restores historic/cultural resources on or near the project site?	◉	○	○	?
Total	2	of	2	

QL 3.2 Preserve Views and Local Character

Intent: Design the project in a way that maintains the local character of the community and does not have negative impacts on community views.

Metric: Thoroughness of efforts to identify important community views and aspects of local landscape, including communities, and incorporate them into the project design.

Assessment Questions:	Yes	No	N/A	
Will the project be designed in a way that preserves views and local character?	◉	○	○	?
Will the project be designed to improve local character, views or the natural landscape through preservation and/or restorative actions?	◉	○	○	?
Total	2	of	2	

QL 3.3 Enhance Public Space

Intent: Improve existing public space including parks, plazas, recreational facilities, or wildlife refuges to enhance community livability.

Metric: Plans and commitments to preserve, conserve, enhance and/or restore the defining elements of the public space.

Assessment Questions:	Yes	No	N/A	
Will the project make meaningful enhancements to public space?	○	◉	○	?
Will the project result in a substantial restoration to public space?	○	◉	○	?
Total	0	of	2	

CONTINUE ON TO THE LEADERSHIP CATEGORY →

Leadership

1. Collaboration

LD1.1 Provide Effective Leadership and Commitment

Intent: Provide effective leadership and commitment to achieve project sustainability goals.

Metric: Demonstration of meaningful commitment of the project owner and the project team to the principles of sustainability and sustainable performance improvement.

Assessment Questions:	Yes	No	N/A	
Has the project team issued public statements stating their commitment to sustainability?	◉	○	○	?
Is the project team's commitment to sustainability backed up by examples of actions taken or to be taken?	○	◉	○	?
Do these commitments and actions demonstrate sufficiently that sustainability is a core value of the project team?	○	◉	○	?
Total	1	of	3	

LD 1.2 Establish a Sustainability Management System

Intent: Create a project management system that can manage the scope, scale and complexity of a project seeking to improve sustainable performance.

Metric: The organizational policies, authorities, mechanisms and business processes that have been put in place and the judgment that they are sufficient for the scope, scale and complexity of the project.

Assessment Questions:	Yes	No	N/A	
Does the project team intend to establish a sound, workable sustainability management system that meets the requirements of the project?	○	◉	○	?
Total	0	of	1	

LD 1.3 Foster Collaboration and Teamwork

Intent: Eliminate conflicting design elements, and optimize system by using integrated design and delivery methodologies and collaborative processes.

Metric: The extent of collaboration within the project team and the degree to which project delivery processes incorporate whole systems design and delivery approaches.

Assessment Questions:	Yes	No	N/A	
Are the project owner and the project team intending to take a systems view of the project, considering the performance relationship of this project to other community infrastructure elements?	◉	○	○	?
Will the project owner and the project team establish a collaborative relationship on the project to achieve higher levels of sustainable performance?	◉	○	○	?
Will the project owner and the project team institute a whole systems design and delivery process with the objective of maximizing sustainable performance?	◉	○	○	?
Total	3	of	3	

LD 1.4 Provide for Stakeholder Involvement

Intent: Establish sound and meaningful programs for stakeholder identification, engagement and involvement in project decision making.

Metric: The extent to which project stakeholders are identified and engaged in project decision making. Satisfaction of stakeholders and decision makers in the involvement process.

Assessment Questions:	Yes	No	N/A	
Will key stakeholders in the project be identified and lines of communication established?	◉	○	○	?
Does the project team plan to engage with stakeholders and solicit stakeholder feedback?	○	◉	○	?
Will the project team establish a strong stakeholder involvement process designed to involve the public meaningfully in project decision-making?	○	◉	○	?
Total	1	of	3	

2. Management

LD 2.1 Pursue By-Product Synergy Opportunities

Intent: Reduce waste, improve project performance and reduce project costs by identifying and pursuing opportunities to use unwanted by-products or discarded materials and resources from nearby operations.

Metric: The extent to which the project team identified project materials needs, sought out nearby facilities with by-product resources that could meet those needs and capture synergy opportunities.

Assessment Questions:	Yes	No	N/A	
Will the project team establish a program to locate, assess and make use of unwanted by-products and materials on the project?	○	◉	○	?
Total	0	of	1	

LD 2.2 Improve Infrastructure Integration

Intent: Design the project to take into account the operational relationships among other elements of community infrastructure which results in an overall improvement in infrastructure efficiency and effectiveness.

Metric: The extent to which the design of the delivered works integrates with existing and planned community infrastructure, and results in a net improvement in efficiency and effectiveness.

Assessment Questions:	Yes	No	N/A	
Will the project team seek to optimize sustainable performance at the infrastructure component level?	○	○	◉	?
Will the project team seek to optimize sustainable performance by designing the project as an integrated system?	○	○	◉	?
Will the project be planned and designed so that its operation and functions are fully integrated with all infrastructure elements in the community?	○	○	◉	?
Total	0	of	0	

3. Planning

LD 3.1 Plan For Long-term Maintenance and Monitoring

Intent: Put in place plans and sufficient resources to ensure as far as practical that ecological protection, mitigation and enhancement measures are incorporated in the project and can be carried out.

Metric: Comprehensiveness and detail of long-term monitoring and maintenance plans, and commitment of resources to fund the activities.

Assessment Questions:	Yes	No	N/A	
Will the project have a plan for long term monitoring and maintenance?	◉	○	○	?
Will that plan be sufficiently comprehensive, covering all aspects of long-term monitoring and maintenance?	○	◉	○	?
Total	1	of	2	

LD 3.2 Address Conflicting Regulations and Policies

Intent: Work with officials to Identify and address laws, standards, regulations or policies that may unintentionally create barriers to implementing sustainable infrastructure.

Metric: Efforts to identify and change laws, standards, regulations and/or policies that may unintentionally run counter to sustainability goals, objectives and practices.

Assessment Questions:	Yes	No	N/A	
Will an assessment of applicable regulations, policies and standards be done, identifying those that may run counter to project sustainable performance goals, objectives and targets?	○	◉	○	?
Do the owner and the project team intend to approach decision-makers to resolve conflicts?	○	○	◉	?
Total	0	of	1	

LD 3.3 Extend Useful Life

Intent: Extend a project's useful life by designing a completed project that is more durable, flexible, and resilient.

Metric: The degree to which the project team incorporates full life-cycle thinking in improving the durability, flexibility, and resilience of the project.

Assessment Questions:	Yes	No	N/A	
Will the project be designed in ways that extend substantially the useful life of the project?	◉	○	○	?
Total	1	of	1	

CONTINUE ON TO THE RESOURCE ALLOCATION CATEGORY →

Resource Allocation

1. Materials

RA1.1 Reduce Net Embodied Energy

Intent: Conserve energy by reducing the net embodied energy of project materials over the project life.

Metric: Percentage reduction in net embodied energy from a life cycle energy assessment.

Assessment Questions:	Yes	No	N/A	
Does the project team plan to conduct an assessment of the embodied energy of key materials over the project life?	○	○	◉	?
Will the project achieve at least a 10% reduction in net embodied energy over the life of the project?	○	○	◉	?
Total	0	of	0	

RA 1.2 Support Sustainable Procurement Practice

Intent: Obtain materials and equipment from manufacturers and suppliers who implement sustainable practices.

Metric: Percentage of materials sourced from manufacturers who meet sustainable practices requirements.

Assessment Questions:	Yes	No	N/A	
Will the project team establish a preference for using manufacturers, suppliers and service companies that have strong sustainable policies and practices?	○	◉	○	?
Will the project team establish a sound and viable sustainable procurement program?	○	◉	○	?
Does the project team intend to source at least 15% of project materials, equipment, supplies and services from these companies?	○	◉	○	?
Total	0	of	3	

RA 1.3 Use Recycled Materials

Intent: Reduce the use of virgin materials and avoid sending useful materials to landfills by specifying reused materials, including structures, and material with recycled content.

Metric: Percentage of project materials that are reused or recycled.

Assessment Questions:	Yes	No	N/A	
Will the project team consider the appropriate reuse of existing structures and materials and incorporated them into the project?	◉	○	○	?
Will the project team specify that at least 5% of materials with recycled content be used on the project?	○	◉	○	?
Total	1	of	2	

RA 1.4 Use Regional Materials

Intent: Minimize transportation costs and impacts and retain regional benefits through specifying local sources.

Metric: Percentage of project materials by type and weight or volume sourced within the required distance.

Assessment Questions:	Yes	No	N/A	
Will the project team work to identify local/regional sources of materials?	○	◉	○	?
Are at least 30% of project materials locally sourced?	○	◉	○	?
Total	0	of	2	

RA 1.5 Divert Waste from Landfills

Intent: Reduce waste and divert waste streams away from disposal to recycling and reuse.

Metric: Percentage of total waste diverted from disposal.

Assessment Questions:	Yes	No	N/A	
Will the project team identify potential recycling and reuse destinations for construction and demolition waste generated on site?	○	◉	○	?
Will the project team develop an operations waste management plan to decrease and divert project waste from landfills and incinerators during construction and operation?	○	◉	○	?
Will the project divert at least 25% of project waste from landfills?	○	◉	○	?
Total	0	of	3	

RA 1.6 Reduce Excavated Materials Taken Off Site

Intent: Minimize the movement of soils and other excavated materials off site to reduce transportation and environmental impacts.

Metric: Percentage of excavated material retained on site.

Assessment Questions:	Yes	No	N/A	
Will the project be designed to balance cut and fill to reduce the amount of excavated material taken off site?	○	◉	○	?
When necessary, will the project team taken steps to identify local sources/receivers of excavated material?	○	◉	○	?
Will the project reuse at least 30% of suitable excavated material onsite?	○	◉	○	?
Total	0	of	3	

RA 1.7 Provide for Deconstruction and Recycling				
Intent: Encourage future recycling, up-cycling, and reuse by designing for ease and efficiency in project disassembly or deconstruction at the end of its useful life.				
Metric: Percentage of components that can be easily separated for disassembly or deconstruction.				
Assessment Questions:	Yes	No	N/A	
Will the project team assess whether materials specified can be easily recycled or reused after the useful life of the project has ended?	○	◉	○	?
Will the project be designed so that at least 15% of project materials can be easily separated for recycling or readily reused at the end of the project's useful life?	○	◉	○	?
Will the project team incorporate methods for increasing the likelihood of materials recycling when the project is operating?	○	◉	○	?
Total	0	of	3	

2. Energy

RA 2.1 Reduce Energy Consumption				
Intent: Conserve energy by reducing overall operation and maintenance energy consumption throughout the project life cycle.				
Metric: Percentage of reductions achieved.				
Assessment Questions:	Yes	No	N/A	
Will the project team conduct reviews to identify options for reducing energy consumption during operations and maintenance of the constructed works?	○	◉	○	?
Will the project team conducted feasibility studies and cost analyses to determine the most effective methods for energy reduction and incorporated them into the design?	○	◉	○	?
Is the project expected to achieve at least a 10% reduction in energy consumption?	○	◉	○	?
Total	0	of	3	

RA 2.2 Use Renewable Energy				
Intent: Meet energy needs through renewable energy sources.				
Metric: Extent to which renewable energy resources are incorporated into the design, construction and operation.				
Assessment Questions:	Yes	No	N/A	
Will the owner and project team identify and analyze options to meet operational energy needs through renewable energy?	○	◉	○	?
Will the project meet at least 25% of its energy needs through renewable energy?	○	◉	○	?
Total	0	of	2	

RA 2.3 Commission and Monitor Energy Systems				
Intent: Ensure efficient functioning and extend useful life by specifying the commissioning and monitoring of the performance of energy systems.				
Metric: Third party commissioning of electrical/mechanical systems and documentation of system monitoring equipment in the design.				
Assessment Questions:	Yes	No	N/A	
Does the owner and project team intend to conduct an independent commissioning of the project's energy and mechanical systems?	○	○	◉	?
Will the project team assemble the necessary information needed to train operations and maintenance workers in a way that facilitates proper training and operations?	○	○	◉	?
Will the design incorporate advanced monitoring systems, such as energy sub-meters, to enable more efficient operations?	○	○	◉	?
Total	0	of	0	

3. Water

RA 3.1 Protect Fresh Water Availability				
Intent: Reduce the negative net impact on fresh water availability, quantity and quality.				
Metric: The extent to which the project uses fresh water resources without replenishing those resources at their source.				
Assessment Questions:	Yes	No	N/A	
Will the project team assess project water requirements?	○	○	◉	?
Does the project team plan to conduct a comprehensive assessment of the project's long-term impacts on water availability?	○	○	◉	?
Will the project only access water that can be replenished in both quantity and quality?	○	○	◉	?
Will the project consider the impacts of fresh water withdrawal on receiving waters?	○	○	◉	?
Will the project discharge into receiving waters meet quality and quantity requirements for high value aquatic species?	○	○	◉	?
Will the project achieve a net-zero impact on water supply quantity and quality?	○	○	◉	?
Will the project restore the quantity and quality of fresh water surface and groundwater supplies to an undeveloped native ecosystem condition?	○	○	◉	?
Total	0	of	0	

RA 3.2 Reduce Potable Water Consumption				
Intent: Reduce overall potable water consumption and encourage the use of greywater, recycled water, and stormwater to meet water needs.				
Metric: Percentage of water reduction.				
Assessment Questions:	Yes	No	N/A	
Will the project team conduct planning or design reviews to identify potable water reduction strategies?	○	○	◉	?
Will the project team conduct feasibility and cost analysis to determine the most effective methods for potable water reduction and incorporated them into the design?	○	○	◉	?
Will the project achieve at least a 25% reduction in potable water consumption?	○	○	◉	?
Will the project result in a net positive generation of water, and water up-cycling, as a result of on-site purification or treatment?	○	○	◉	?
Total	0	of	0	

RA 3.3 Monitor Water Systems				
Intent: Implement programs to monitor water systems performance during operations and their impacts on receiving waters.				
Metric: Documentation of system in the design				
Assessment Questions:	Yes	No	N/A	
Will the owner and project team conduct an independent commissioning/monitoring of the project's water systems in order to validate the design objectives?	○	○	◉	?
Will the project design incorporate the means to monitor water performance during operations?	○	○	◉	?
Will the project integrate long-term operations and impact monitoring to mitigate negative impacts and improve efficiency?	○	○	◉	?
Will specific strategies be put in place to utilize monitoring and leak detection in order for the project to be more responsive to changing operating conditions?	○	○	◉	?
Total	0	of	0	

CONTINUE ON TO THE NATURAL WORLD CATEGORY →

Natural World

1. Siting

NW 1.1 Preserve Prime Habitat

Intent: Avoid placing the project – and the site compound/temporary works – on land that has been identified as of high ecological value or as having species of high value.

Metric: Avoidance of high ecological value sites and establishment of protective buffer zones.

Assessment Questions:	Yes	No	N/A	
Will the project team take steps to identify and document areas of prime habitat near or on the site?	○	○	◉	?
Will the project avoid development on land that is judged to be prime habitat?	○	○	◉	?
Will the project establish a minimum 300 ft. natural buffer zone around all areas deemed prime habitat?	○	○	◉	?
Will the project significantly increase the area of prime habitat through habitat restoration?	○	○	◉	?
Will the project improve habitat connectivity by linking habitats?	○	○	◉	?
Total	0	of	0	

NW 1.2 Protect Wetlands and Surface Water

Intent: Protect, buffer, enhance and restore areas designated as wetlands, shorelines, and waterbodies by providing natural buffer zones, vegetation and soil protection zones.

Metric: Size of natural buffer zone established around all wetlands, shorelines, and waterbodies.

Assessment Questions:	Yes	No	N/A	
Will the project avoid development on wetlands, shorelines, and waterbodies?	◉	○	○	?
Will the project maintain soil protection zones (VSPV) around all wetlands, shorelines, and waterbodies?	○	◉	○	?
Will the project restore degraded existing buffer zones to a natural state?	○	○	◉	?
Total	1	of	2	

NW 1.3 Preserve Prime Farmland

Intent: Identify and protect soils designated as prime farmland, unique farmland, or farmland of statewide importance.

Metric: Percentage of prime farmland avoided during development.

Assessment Questions:	Yes	No	N/A	
Will this project avoid development on land designated as prime farmland.	○	○	◉	?
Total	0	of	0	

NW 1.4 Avoid Adverse Geology

Intent: Avoid development in adverse geologic formations and safeguard aquifers to reduce natural hazards risk and preserve high quality groundwater resources.

Metric: Degree to which natural hazards and sensitive aquifers are avoided and geologic functions maintained.

Assessment Questions:	Yes	No	N/A	
Will the project team identify and address the impacts of sensitive or adverse geology?	○	○	◉	?
Will the project be designed to reduce the risk of damage to sensitive geology?	○	○	◉	?
Will the project be designed to reduce the risk of damage from adverse geology?	○	○	◉	?
Total	0	of	0	

NW 1.5 Preserve Floodplain Functions

Intent: Preserve floodplain functions by limiting development and development impacts to maintain water management capacities and capabilities.

Metric: Efforts to avoid floodplains or maintain predevelopment floodplain functions.

Assessment Questions:	Yes	No	N/A	
Will the project avoid or limit development within the design frequency floodplain?	◉	○	○	?
Will the project maintain pre-development floodplain infiltration and water quality?	○	○	◉	?
Will the project design incorporate a flood emergency operations and/or evacuation plan?	○	○	◉	?
Will the project maintain or enhance riparian and aquatic habitat, including aquatic habitat connectivity?	○	○	◉	?
Will the project maintain sediment transport?	◉	○	○	?
Does the project team intend to modify or remove infrastructure subject to frequent damage by floods?	○	○	◉	?
Total	2	of	2	

NW 1.6 Avoid Unsuitable Development on Steep Slopes

Intent: Protect steep slopes and hillsides from inappropriate and unsuitable development in order to avoid exposures and risks from erosion and landslides, and other natural hazards.

Metric: The degree to which development on steep slopes is avoided, or to which erosion control and other measures are used to protect the constructed works as well as other downslope structures.

Assessment Questions:	Yes	No	N/A	
Will the project team use best management practices to manage erosion and prevent landslides?	◉	○	○	?
Will the project team minimize or avoid all development on or disruption to steep slopes?	◉	○	○	?
Total	2	of	2	

NW 1.7 Preserve Greenfields

Intent: Conserve undeveloped land by locating projects on previously developed greyfield sites and/or sites classified as brownfields.

Metric: Percentage of site that is a greyfield or the use and cleanup of a site classified as a brownfield.

Assessment Questions:	Yes	No	N/A
Will the project team consider how the project can conserve undeveloped land?	○	○	◉
Will at least 25% of the project development be located on previously developed sites, that is, sites classified as greyfields or brownfields?	○	○	◉
Total	0	of	0

2. Land and Water

NW 2.1 Manage Stormwater

Intent: Minimize the impact of infrastructure on stormwater runoff quantity and quality.

Metric: Infiltration and evapotranspiration capacity of the site and return to pre-development capacities.

Assessment Questions:	Yes	No	N/A
Will the project be designed to reduce storm runoff to pre-development conditions?	◉	○	○
Will the project be designed to significantly improve water storage capacity?	○	◉	○
Total	1	of	2

NW 2.2 Reduce Pesticides and Fertilizer Impacts

Intent: Reduce non-point source pollution by reducing the quantity, toxicity, bioavailability and persistence of pesticides and fertilizers, or by eliminating the need for the use of these materials.

Metric: Efforts made to reduce the quantity, toxicity, bioavailability and persistence of pesticides and fertilizers used on site, including the selection of plant species and the use of integrated pest management techniques.

Assessment Questions:	Yes	No	N/A
Will operational policies be put in place to control and reduce the application of fertilizers and pesticides?	○	◉	○
Will the project include runoff controls to minimize contamination of ground and surface water?	○	◉	○
Will the project team select landscaping plants to minimize the need for fertilizer or pesticides?	◉	○	○
Will the project team select fertilizers and pesticides appropriate for site conditions with low-toxicity, persistence, and bioavailability?	○	◉	○
Will the project be designed to eliminate the need for pesticides or fertilizers?	○	◉	○
Total	1	of	5

NW 2.3 Prevent Surface and Groundwater Contamination

Intent: Preserve fresh water resources by incorporating measures to prevent pollutants from contaminating surface and groundwater and monitor impacts over operations.

Metric: Designs, plans and programs instituted to prevent and monitor surface and groundwater contamination.

Assessment Questions:	Yes	No	N/A	
Will the project team conduct or aquire hydrologic delineation studies?	○	○	◉	?
Will spill and leak prevention and response plans and design be incorporated into the design?	○	○	◉	?
Will the project design reduce or eliminate potentially polluting substances from the project?	○	○	◉	?
Will the project team seek to reduce future contamination by cleaning up areas of contamination and instituting land use controls to limit the introduction of future contamination sources?	○	○	◉	?
Total	0	of	0	

3. Biodiversity

NW 3.1 Preserve Species Biodiversity

Intent: Protect biodiversity by preserving and restoring species and habitats.

Metric: Degree of habitat protection.

Assessment Questions:	Yes	No	N/A	
Will the project team identify existing habitats on and near the project site?	◉	○	○	?
Will the project protect existing habitats?	◉	○	○	?
Will the project increase the quality or quantity of existing habitat?	○	◉	○	?
Will the project preserve, or improve, wildlife movement corridors?	○	◉	○	?
Total	2	of	4	

NW 3.2 Control Invasive Species

Intent: Use appropriate non-invasive species and control or eliminate existing invasive species.

Metric: Degree to which invasive species have been reduced or eliminated.

Assessment Questions:	Yes	No	N/A	
Will the project team specify locally appropriate and non-invasive plants on the site?	○	◉	○	?
Will the project team implement a comprehensive management plan to identify, control, and/or eliminate, invasive species?	○	◉	○	?
Will the project team implement a comprehensive management plan to prevent or mitigate the future encroachment of invasive species?	○	◉	○	?
Total	0	of	3	

NW 3.3 Restore Disturbed Soils				
Intent: Restore soils disturbed during construction and previous development to bring back ecological and hydrological functions.				
Metric: Percentage of disturbed soils restored.				
Assessment Questions:	Yes	No	N/A	
Will the project restore 100% of soils disturbed during construciton?	○	○	◉	?
Will the project restore 100% of soils disturbed by previous development?	○	○	◉	?
Total	0	of	0	

NW 3.4 Maintain Wetland and Surface Water Functions				
Intent: Maintain and restore the ecosystem functions of streams, wetlands, waterbodies and their riparian areas.				
Metric: Number of functions maintained and restored.				
Assessment Questions:	Yes	No	N/A	
Will the project maintain or enhance hydrologic connetion?	○	○	◉	?
Will the project maintain or enhance water quality?	○	○	◉	?
Will the project maintain or enhance habitat?	○	○	◉	?
Will the project maintain or restore sediment transport?	○	○	◉	?
Will wetlands and surface water be maintained or restored so as to have a fully functioning aquatic and riparian ecosystem?	○	○	◉	?
Total	0	of	0	

CONTINUE ON TO THE CLIMATE AND RISK CATEGORY →

Climate and Risk

1. Emissions

CR1.1 Reduce Greenhouse Gas Emissions

Intent: Conduct a comprehensive life-cycle carbon analysis and use this assessment to reduce the anticipated amount of net greenhouse gas emissions during the life cycle of the project, reducing project contribution to climate change.

Metric: Percent reduction of life-cycle net carbon dioxide equivalent (CO2e) emissions.

Assessment Questions:	Yes	No	N/A	
Will a life-cycle carbon assessment be conducted on the project?	○	◉	○	?
Based on that assessment, will the project be designed to reduce carbon emissions by at least 10%?	○	○	◉	?
Total	0	of	1	

CR 1.2 Reduce Air Pollutant Emissions

Intent: Reduce the emission of six criteria pollutants; particulate matter (including dust), ground level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, lead, and noxious odors.

Metric: Measurements of air pollutants as compared to standards used.

Assessment Questions:	Yes	No	N/A	
Will the project be designed in a way that substantially reduces dust and odors on the site?	○	○	◉	?
Will the project be designed in a way that substantially exceeds the National Ambient Air Quality Standards (NAAQS) for the six criteria pollutants?	○	○	◉	?
Total	0	of	0	

2. Resilience

CR 2.1 Assess Climate Threat

Intent: Develop a comprehensive Climate Impact Assessment and Adaptation Plan.

Metric: Summary of steps taken to prepare for climate variation and natural hazards.

Assessment Questions:	Yes	No	N/A	
Will the project team develop a Climate Impact Assessment and Adaptation Plan?	○	◉	○	?
Total	0	of	1	

CR 2.2 Avoid Traps and Vulnerabilities

Intent: Avoid traps and vulnerabilities that could create high, long-term costs and risks for the affected communities.

Metric: The extent of the assessment of potential long-term traps, vulnerabilities and risks due to long-term changes such as climate change and the degree to which these were addressed in the project design and in community design criteria.

Assessment Questions:	Yes	No	N/A	
Will a comprehensive review be conducted to identify the potential risks and vulnerabilities that would be created or made worse by the project?	◉	○	○	?
Is there an intent by the owner or the project team to alter the design to reduce or eliminate these risks and vulnerabilities?	◉	○	○	?
Total	2	of	2	

CR 2.3 Prepare for Long-Term Adaptability

Intent: Prepare infrastructure systems to be resilient to the consequences of long-term climate change, perform adequately under altered climate conditions, or adapt to other long-term change scenarios.

Metric: The degree to which the project has been designed for long-term resilience and adaptation.

Assessment Questions:	Yes	No	N/A	
Will the project be designed to accommodate a changing operating environment throughout the project life cycle?	○	◉	○	?
Total	0	of	1	

CR 2.4 Prepare for Short-Term Hazards

Intent: Increase resilience and long-term recovery prospects of the project and site from natural and man-made short-term hazards.

Metric: Steps taken to improve protection measures beyond existing regulations.

Assessment Questions:	Yes	No	N/A	
Will a hazard analysis be conducted covering the likely natural and man-made hazards in the project area area?	○	○	◉	?
Will the project be designed so that is it is able to recover quickly and cost-effectively from short-term hazard events?	○	○	◉	?
Total	0	of	0	

CR 2.5 Manage Heat Island Effects

Intent: Minimize surfaces with a low solar reflectance index (SRI) to reduce localized heat accumulation and manage microclimates.

Metric: Percentage of site area that meets SRI Criteria.

Assessment Questions:	Yes	No	N/A	
Will the project be designed to reduce heat island effects by reducing the percentage of low solar reflectance index (SRI) surfaces?	○	◉	○	?
Total	0	of	1	