

BRIDGE REMOVAL STRATEGIES MEMORANDUM

October 25, 2007

1.0 INTRODUCTION

Currently, the water supply for the City of Portland crosses the Sandy River via a truss bridge, the Conduit 2/4 Bridge, erected in 1893. Several bridge issues have been identified that place the City's water supply at some risk. These issues include the truss bridge's vulnerability to collapse in a seismic or river scour event and (due to the ease of public access to the conduits) risk of vandalism or terrorism. As part of the Design-Build contract, these issues will be addressed by removing the conduits from the bridge and placing them in a tunnel underneath the Sandy River.

The Conduit 2/4 Bridge carries two conduits and an 8" waterline and is comprised of several short eastern approach spans and a 300 foot pin truss span. This document discusses the issues involved with the disposition of the pin truss span of the Conduit 2/4 Bridge.

2.0 "HISTORIC" NATURE OF THE BRIDGE

Although this bridge is not listed as a historic bridge, it is eligible to be listed and as such, a disposition process similar to that of a historic bridge (the Section 106 process) must be followed.

As part of this disposition process, all viable strategies must be explored. The Basis of Design Report indicates that a variety of bridge disposition options could be considered. These include:

- a. Remove, dismantle and scrap Pipeline Bridge. Since the bridge is eligible for historic listing, provide standard historic documentation before removal.
- b. Remove the bridge and preserve it all or part of it at another location such as Dodge Park or somewhere desired by Clackamas County or SHPO.
- c. Preserve the bridge, remove the conduits and conduct preservation/structural work for seismic, possibly use it as a bike/pedestrian path.
- d. Preserve the bridge and empty conduits.
- e. Change ownership of the bridge to another party (unlikely given its 300' length).

A disposition strategy that warrants further discussion is one that focuses on keeping the bridge a functioning element of the infrastructure. This is accomplished by seeking a new owner, location and function for the bridge. Components of this strategy include:

Inter-Agency MOA-

The Portland Water Bureau (PWB) has entered into discussions with the State Historic Preservation Office (SHPO) <http://egov.oregon.gov/OPRD/HCD/>, in order to reach an agreement on a disposition strategy for the truss portion of the Conduit 2/4 Bridge.

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The results of these discussions and subsequent agreement should culminate in the development of a Memorandum of Agreement (MOA) between PWB and SHPO. The MOA should also include an agreement for the disposition of the bridge, if a new owner is not found at the end of an agreed upon time frame.

Components of the signed MOA should be included in the appropriate Performance Specifications of the Design-Build contract.

It is important to note that, at the present time, SHPO has not concurred that the bridge's approach spans are excluded from the Section 106 process, nor have they provided an indication on whether they would agree on a bridge disposition action, if a new owner is not found at the end of an agreed upon time frame.

Historic Documentation-

As a part of this disposition strategy, the historic qualities of the Conduit 2/4 Bridge could also be documented through Historic American Engineering Record (HAER) guidelines (<http://www.nps.gov/hdp/haer/index.htm>) prior to the Design-Build contract.

Design-Builder Scope of Work-

The Design-Build contractor would follow the Contract Performance Specifications for removing the truss, transporting the truss components and storing it in preparation for a new owner.

Recommendation:

Develop a Memorandum of Agreement between the Agency and SHPO that outlines the disposition of the Conduit 2/4 Bridge.

3.0 POTENTIAL FOR REUSE-

Pedestrian Use-

A conceptual level analysis has been performed to compare the truss's original design allowance to that required to carry pedestrian live loading and the self weight (dead load) of a deck.

From this analysis, it has been determined that it is feasible for the truss span to be fitted with a timber deck and stringers that would provide a 12 foot wide pedestrian walkway. The analysis assumed a pedestrian live load of 85 psf or a 10,000 lb maintenance vehicle. Concrete and steel pedestrian deck options were also considered, but these deck options placed a demand on the truss that was slightly higher (5-10%) than the original design allowance. In the July 1996 report, *Structural Analysis and Inspection Report with Recommended Improvements*, analysis indicated that the top cord members (in compression) were overstressed by 7%. Reducing the load and lowering the load demand would reduce this amount of overstress.

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As a side note, the Lusted Road Bridge rehabilitation included the addition of a pedestrian walkway. Some consideration has been given to an option of leaving the Conduit 2/4 Bridge in place and converting it to a pedestrian bridge. Anecdotal pedestrian volumes do not appear to warrant a second pedestrian crossing at this location.

Seismic Design Code Deficiencies-

There is a perception, that keeping the bridge for pedestrian use would require seismic upgrading. This perception may be related to the 1997 repair to the Lusted Road Bridge (directly adjacent to the Conduit 2/4 Bridge), which upgraded the bridge to resist seismic forces. The primary difference between the Lusted Road Bridge and reusing the Conduit 2/4 Bridge for pedestrian use is that the Lusted Road Bridge is open to vehicular traffic. Seismic upgrade requirements are somewhat subjective for pedestrian bridges and it is likely that a “pedestrian only” bridge owner may determine that the bridge need not be subject to seismic retrofit requirements.

Wind Load Design Code Deficiencies-

Although the bridge owner may determine that the bridge does not need to meet seismic design standards, a more common load that should be addressed is wind loading. In the July 1996 report, *Structural Analysis and Inspection Report with Recommended Improvements*, wind load analysis indicated that many of the top cord and vertical members were significantly overstressed and recommended additional bracing or reinforcing. Of the 482 components analyzed, approximately 1/3 of them were found to be overstressed.

In the time since the July 1996 Report, AASHTO has rewritten the Bridge Design Code, from Load Factor Design “LFD” to Load Resistance Factor Design “LRFD”. For the purposes of our situation, it is unlikely that a change in the design code would significantly alter the results of the 1996 analysis.

The design code establishes allowable stress limits to ensure that each component can resist the appropriate loads within the material’s elastic range (i.e. no damage allowed). The owner may decide to accept some damage (but not collapse) to the bridge, by accepting higher allowable stress limits. Higher allowable stress limits could allow some members to exceed their elastic range, but not allow members to reach their failure point. Even with accepting higher allowable stress limits, 20-25% of the truss members would still be overstressed and in need of replacement.

Recommendation:

Analyze the truss components for the maximum wind force anticipated and determine which members are over the allowable stress limit and (of these members), determine which members are stressed to the point of likely damage. Only the members that are likely to experience damage are candidates for replacement.

4.0 BASELINE TRUSS CONDITION-

As part of the Design-Builder’s truss removal, transportation and storage activities, there is a risk that truss components could become damaged during these activities. The damage could hinder the future reassembly process and even impact the structural capacity of the truss.

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Data from routine inspections and ultrasonic testing of selected pins is available but does not provide enough detailed condition information on each truss component to serve as a baseline condition document. It is important to present a Truss Component Baseline Condition Survey (that establishes the structural condition of each truss component) to the Design-Builder and give him the opportunity to verify or question the stated condition of each member. The Truss Component Baseline Condition Survey should be included in the Engineering Data section of the procurement documents.

Any truss component that has been damaged as a result of removal, transportation or storage by the Design-Builder must be replaced in kind by the Design-Builder. If the damage is minor, it may be in the best interest of the Agency to entertain a repair proposal instead of replacing the component. Prior to Agency acceptance of the truss components in the storage yard, the Agency should inspect each truss component to verify that the baseline condition has not changed.

Recommendation:

Develop a Truss Component Baseline Condition Survey, for inclusion into the Engineering Data.

5.0 REMOVAL CONSIDERATIONS-

There are two primary considerations for the removal of the truss:

- Can the truss be temporarily supported in a single span or with multiple temporary bents.
- Can the truss be removed component by component, in multiple sections or in one section.

There are several factors that will impact the best course of action for removal. These factors include the duration of the In-Water work period, the overall length of the truss (300' single span), the fragility of the truss components, the experience level of the Contractor performing the bridge removal work and, due to the desire to reassemble and reuse the truss, the project's intolerance to disassembly damage.

Temporary Shoring -

The removal of a truss involves installing temporary shoring to each panel point. This temporary shoring transfers the dead load (self weight) of the truss, from the truss itself to the temporary shoring. With this accomplished, the loading at the pin joint is significantly reduced, enabling the pin and the connecting members to be removed.

Temporary Bents-

With the relatively short in-water work period of approximately 1 ½ months, it would be advantageous for the contractor to devise a removal scheme that minimizes the work time within the Ordinary High Water (OHW) zone. The environmental regulatory agencies are interested in whether temporary bents within the Ordinary High Water (OHW) zone, will or will not be necessary for truss removal.

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From a site visit, the OHW zone appears to be in the approximate range of 300 feet. It may be possible for a Design-Builder to devise a rather sophisticated temporary shoring plan that single spans the 300+ feet and does not require temporary bents, but this may not be realistic. With the bridge removal being a minor cost of the project, it is likely that the removal contractor will be versed in more conventional means of temporary shoring. For permitting purposes, it is reasonable to assume that 2 or 3 temporary bents will be necessary (within the OHW zone) to support the temporary shoring.

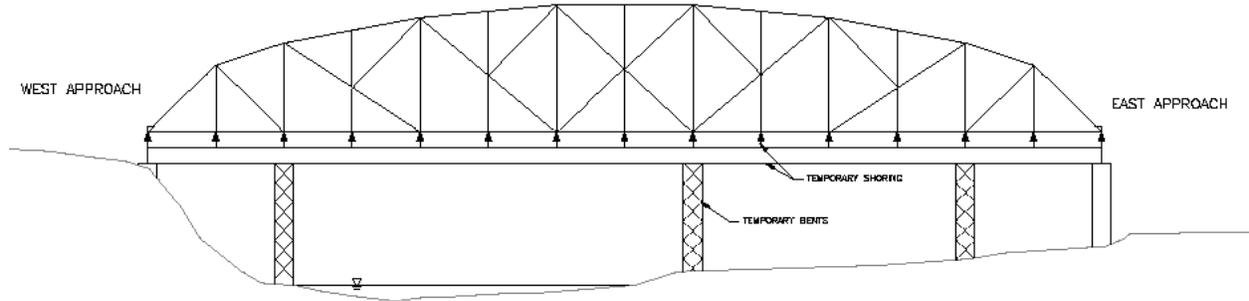


Figure 1. Temporary Shoring and possible Temporary Bent locations

Basic Truss Removal Options-

The removal of the truss span can be accomplished by several methods including removing it component by component, in multiple sections or even with a more sophisticated method of sliding it off site in one section. The contractor will need to balance the requirement of removing the bridge during the in-water work window with the requirement to not damage the truss components during removal.

Remove Truss, Component by Component

The truss in its existing configuration is stable and has a clearly defined load path. The stringers and the conduits are supported by the floor beams. The floor beams are supported by the truss verticals. Figure 2 shows the existing state of axial load in the truss members. The top chords including the end posts are in compression. The bottom chords are in tension. The verticals located at even-numbered panel points carry compression. The other verticals and the diagonals carry tension. As members are being removed from the truss, the load path will change and some members will be unloaded or even change from tension to compression. Some members such as the vertical rods located at odd-numbered panel points and the diagonals will buckle if they are in compression. Therefore, it is important that the sequence of truss member removal and the sequence of loading and unloading each truss member be carefully studied.

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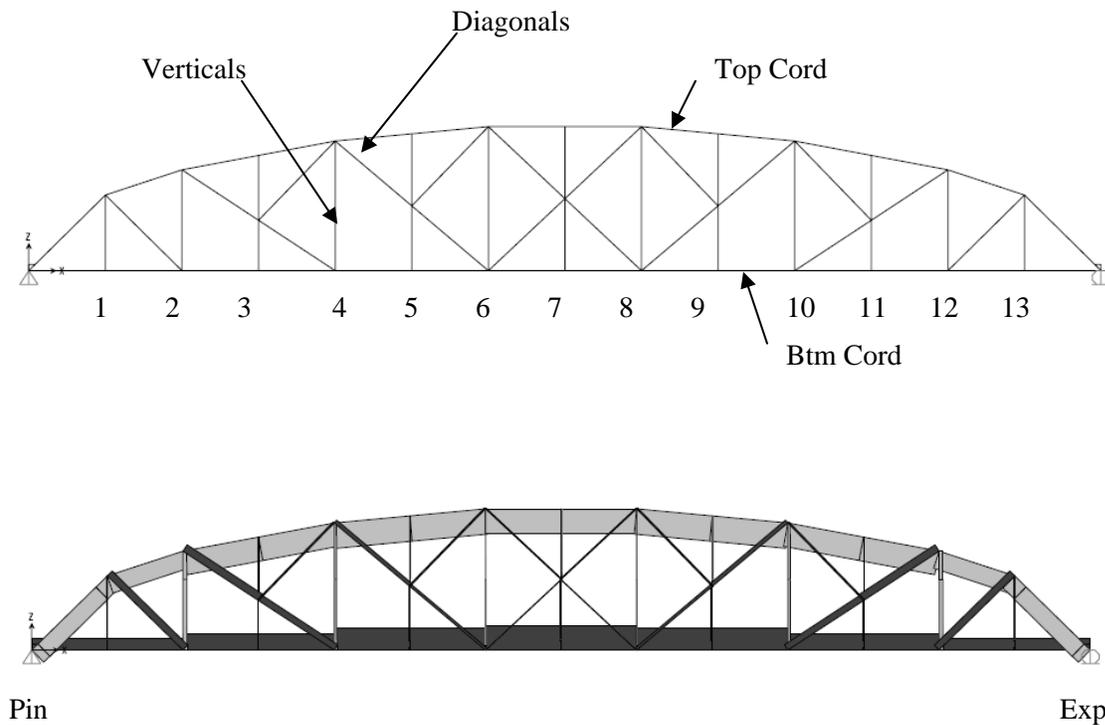


Figure 2 Existing truss. The lower diagram shows axial force in the truss members. Lighter shading indicates member that are in compression. Darker shading indicates members that are in tension.

The choice of removal sequence will ultimately depend on the contractor's means and methods. The sequence postulated below should maintain the stability of the truss as members are removed, provided the contractor can develop restraints and supports noted. Additionally, the sequence below assumes no cutting of the members will be permitted due to the historic preservation requirements.

Step 1

If the conduits have not been removed by this stage, they should be removed now before removing truss members. As shown in Figure 3, each conduit is supported on a pair of brackets. There does not appear to be a positive attachment between the brackets and the conduit. Therefore, the conduits can be raised slightly using jacks and lowered onto pipe rollers installed above the floor beams but under the conduits. To avoid conduits rolling sideways, temporary struts may be installed intermittently between the two conduits. The conduits can be then be cut in halves at midspan of the truss and pulled away from each end. Removing conduits from one end only may be possible, but is not recommended because this will create unsymmetrical loading on the truss.

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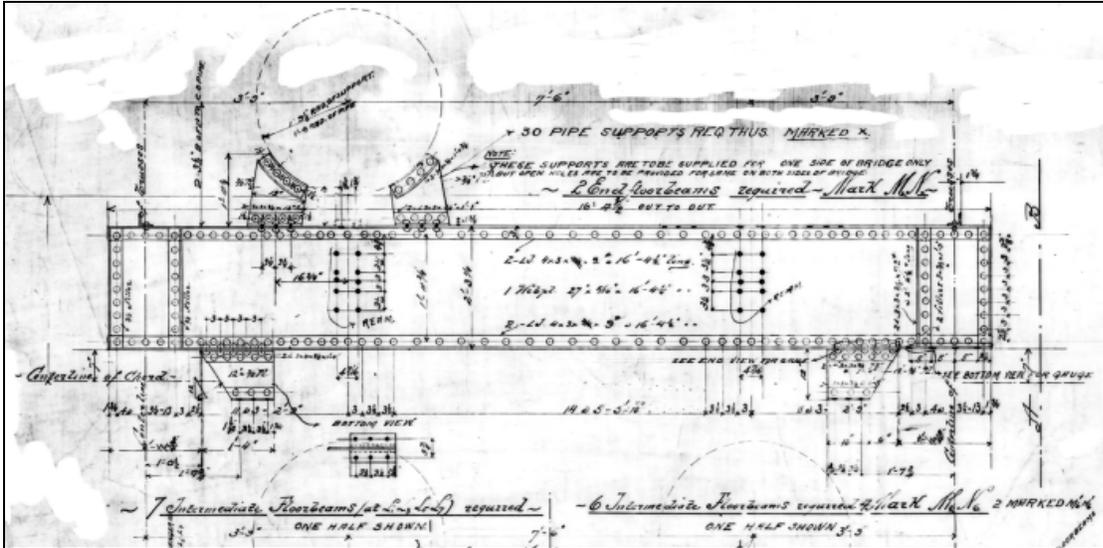


Figure 3 An excerpt from the as-constructed drawing showing a typical floor beam and conduit support. The second big conduit on the right is not shown.

Before removing the truss members, temporary shoring should be erected under the truss at each panel point. Timber planking may be installed spanning the floor beams to provide a level working platform for further removal of the truss.

Step 2

After the floor beams have been supported, the diagonals and verticals located at odd numbered panel points are no longer needed for the stability of the truss. Therefore, these members can theoretically be removed. However, these members cannot practically be removed without removing the lower chords and the upper chord first due to the configuration of the pinned connection (see Figure 4).

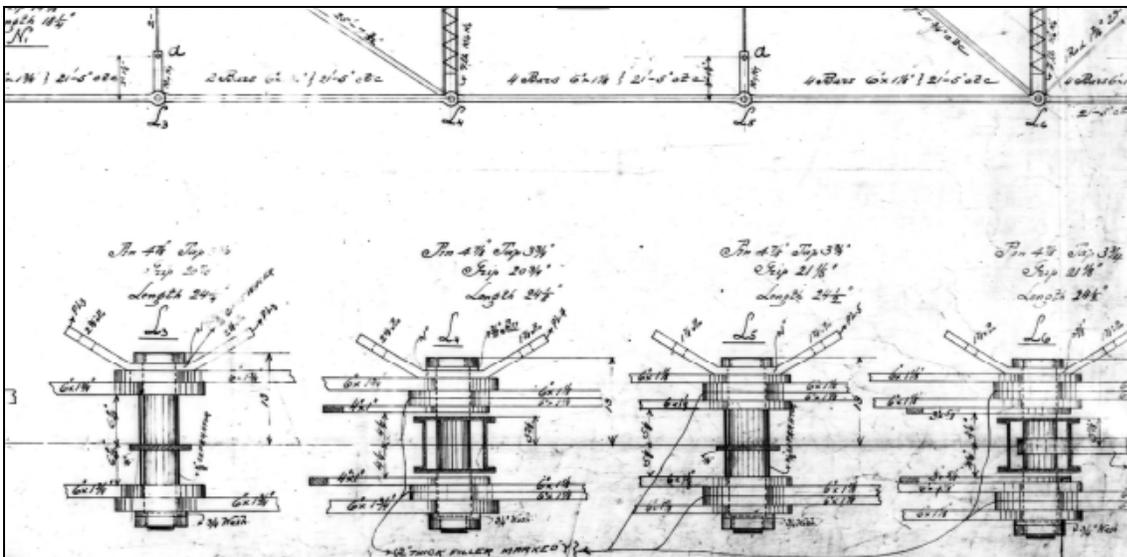


Figure 4 An excerpt from the as-constructed drawing showing lower pinned connections. Verticals, diagonals and lower chords joining at a panel point cannot be removed independently of each other due to the sequence of their assembly and the presence of the pin.

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At this stage, the top chords including the end posts will still be in compression and will tend to spread the truss longitudinally apart. This compression force has been resisted by tension in the lower chords which tie the truss together longitudinally. Thus, in order to remove the lower chords, an alternative longitudinal tensile load path must be developed to resist the arching compression from the top chords. We believe that the stringers and their connections at the floor beams can be made into a continuous tension member from one end of the truss to the other end (see Figure 5). Alternatively, a temporary longitudinal compression strut may be built at the expansion end of the truss to resist the horizontal component of the end post compression. Figure 6 shows the state of axial force in the remaining members at this stage. In this figure, it is assumed that the stringers are used as the longitudinal tie. The vertical rods and the diagonals are not shown in the figure because they do not serve any functional needs. They, however, cannot yet be physically removed because the top chords have not been removed.

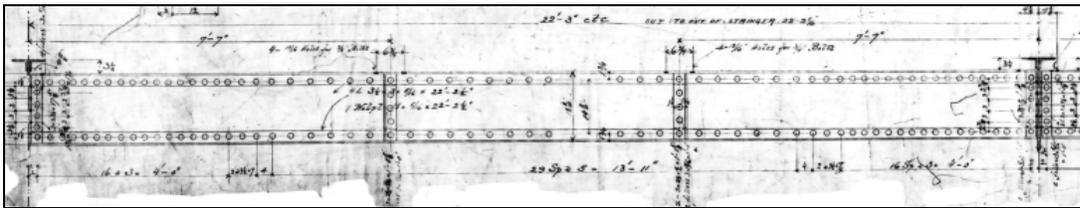


Figure 5 An excerpt from the as-constructed drawing showing a typical stringer detail and stringer to floor beam connection.

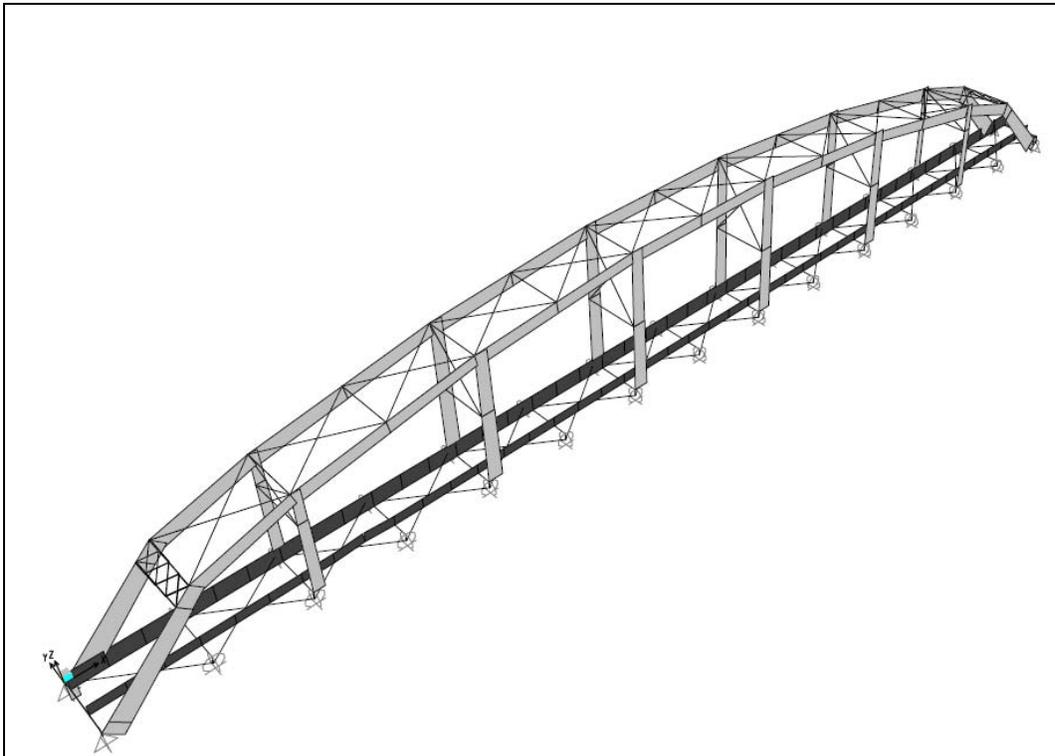


Figure 6 Axial force in the truss members after 1) vertical supports are provided at all floor beams, 2) removal of lower chords and 3) removal of diagonals and vertical rods at odd numbered panel points. Lighter shading indicates members that are in compression. Darker shading indicates members that are in tension.

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Step 3

Beyond this stage, single components of the top chord cannot be removed without requiring additional falsework and temporary bracings to support the remaining top chord members and the remaining verticals. The upper pinned connections do not permit the transfer of any tensile force between adjacent top chord members (see Figure 7). Per the original design, the top chord members simply bear against the pin and each other at panel points U2, U2, U4, and U6. If a piece of the top chord is removed, the arching effect in the top chords will diminish and there will no longer be a compression in the top chord to hold the top chord segments together. Thus, at this stage, falsework should be erected to support all the top chord segments (L0-U1, U1-U2, U2-U3-U4, U4-U5-U6, and U6-U7). Additionally, temporary diagonal bracing should be erected to support the remaining verticals. The upper pins can then be removed. Subsequently, the top chords and the verticals can be removed. Finally, the remainder of the truss including the floor beams and the stringers can finally be removed.

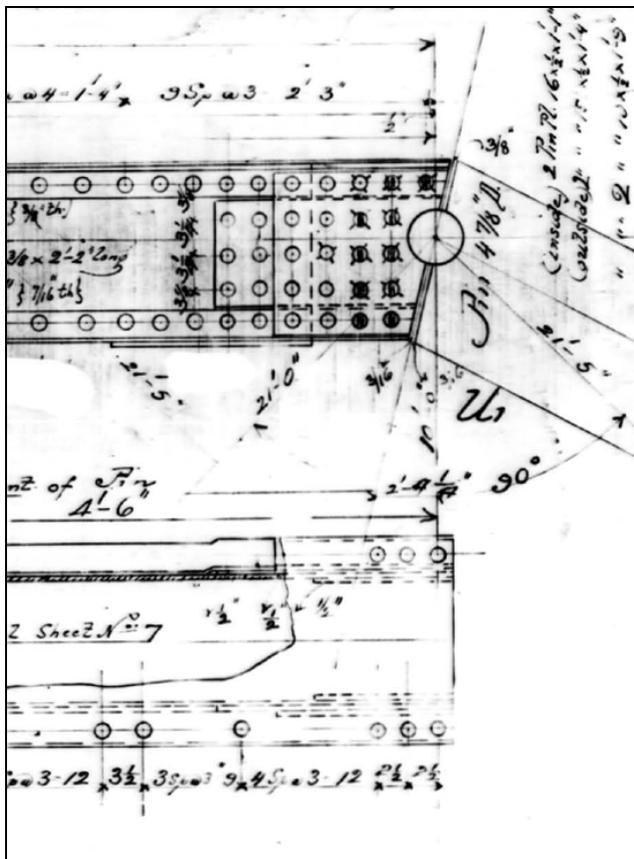


Figure 7 An excerpt from the as-constructed drawing showing a typical upper pinned connection. This shows a bearing connection detail was used. This detail does not accommodate the transfer of tension across the joint.

Remove Truss in Sections-

Although it is desirable to remove the truss in sections in order to expedite the removal process, the removal of the truss in sections may not be feasible. As explained in the previous section (Remove Truss, Component by Component) and shown in Figure 4, the original pinned connection design does not permit independent removal of individual members joining at a panel point. The members will have to be removed in the reverse order of the original installation sequence. Additionally, the upper pinned

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connections are bearing-only connections and do not permit tension transfer across the joint. As such, any section removal sequence that will reduce the compression in the upper chord to zero will lead to an unstable structure. After these considerations, removing the truss in sections can only be made with extensive bracing and shoring such that there may not be an advantage to be gained over removing the truss component by component.

Removal Entire Truss in a Single Section –

It may be possible for the entire truss to be moved off the foundation in a single section, to a staging yard for subsequent component-by-component disassembly on the ground. By not performing the time consuming task of component-by-component disassembly of the truss within the Ordinary High Water (OHW) zone, the impact of in-water work period restriction on the project schedule will be reduced. The component-by-component disassembly of the truss on the ground should also be safer as compared to doing the same over the water and high above the ground. As will be elaborated below, the challenge of removing the entire truss in a single section requires large cranes or specialized moving equipment. The removal of the entire truss in a single section will also cause disruption of the traffic on SE Lusted Road and SE Marsh Road, and will potentially require removal of some trees in the Dodge Park.

Due to the length of the truss (300 ft), the truss will need to be supported at least at both ends during the removal. The structural analysis model prepared in 1996, as part of “Structural Analysis and Inspection Report with Recommended Improvements” was used to estimate the dead load reactions of the truss. Based on this analysis model, the dead weight of the truss is approximately 110 tons. Empty conduits will add approximately 55 tons. Because of the heavy weight of the conduits, it is recommended that the conduits be removed prior to the truss relocation. It is not recommended, however, to remove other members of the truss before the relocation because component removal will reduce the rigidity of the truss and increase the racking vulnerability during the move.

A schematic layout of the truss removal using two units of self-propelled modular transporters (SPMTs) is shown in Figure 8. SPMTs were developed for lifting heavy machinery and have seen increased usage on infrastructure projects. Each wheel of the SPMT can turn and this steering capability will be beneficial in reducing the area needed to be cleared and graded to provide an unobstructed path for moving the truss from its current location to the staging area. One unit of SPMT will support the east end of the truss. Another similar unit of SPMT will support the west end of the truss. A series of temporary shoring, supported on temporary bents will be needed under the footprint of the existing truss to support the west SPMT as the bridge is being moved out of the river. It is anticipated that the first leg of the movement will be a straight path following the length of the existing truss. Once the bridge is moved beyond the east pier, rotational movement can be made. It will require a number of back-and-forth and rotational movements before the truss reaches the staging area.

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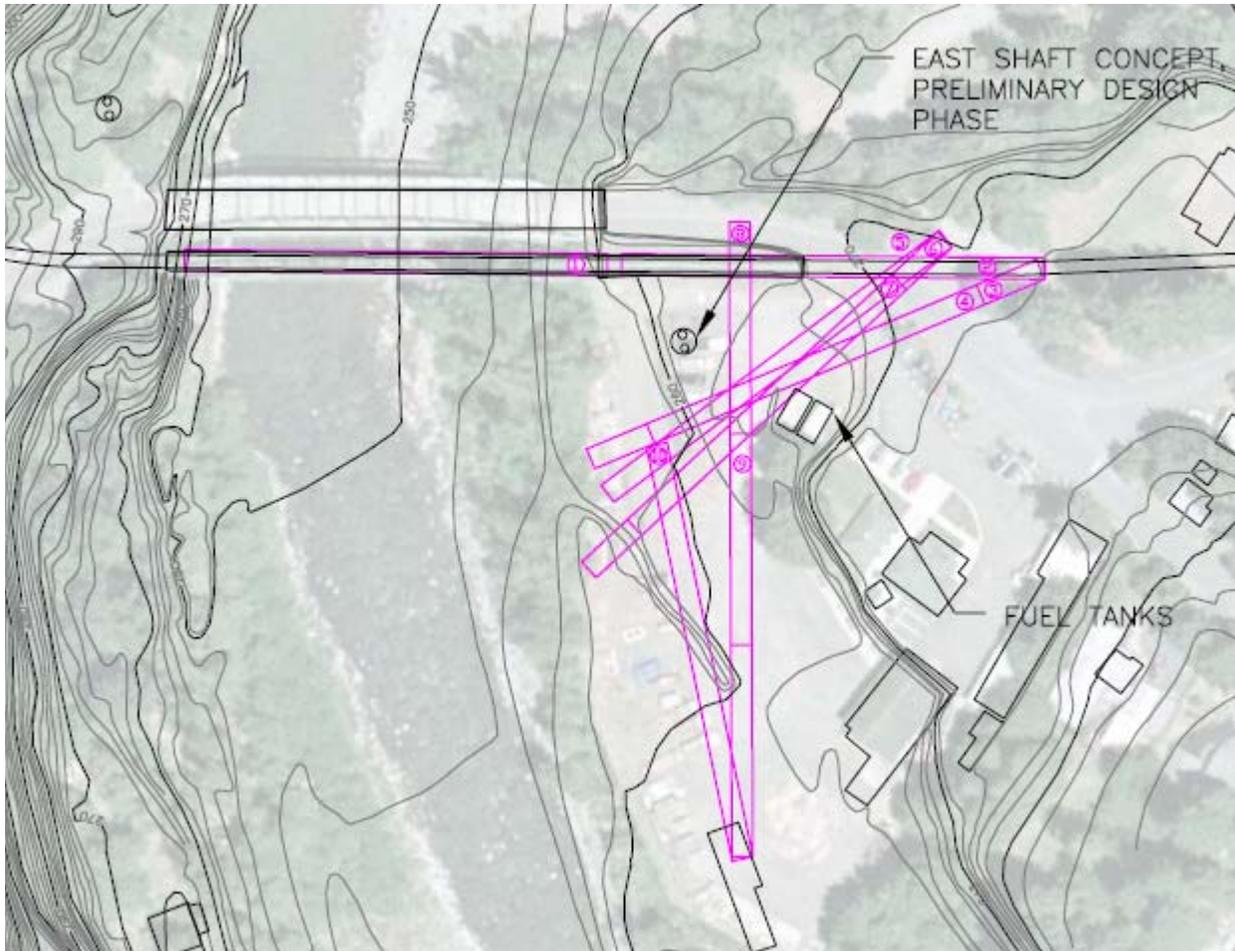


Figure 8 Schematic diagram showing removal of the entire truss in once piece using self-propelled modular transporters (SPMTs). One unit of SPMT will support the “west” end of the truss. The other unit of SPMT will support the “east” end. It will require multiple maneuvering before the truss reaches the staging area.

Alternatively, a schematic layout of the truss removal using two cranes is shown in Figure 9. Due to the extreme length of the truss, the weight of the truss and the site constraint, we anticipate the use of lattice boom crawler cranes. Even so, the size of the cranes will be large due to the high moment demand (lifting weight times radius from crane center of rotation to the lifting point). We estimate that two 825-ton Manitowoc 18000 MAX-ER cranes or similar will be required. One crane will be positioned north of the Lusted Road Bridge and the other crane will be positioned near the intersection of SE Lusted Road and SE Marsh Road. The positions of the two cranes were selected such that each crane will maintain the boom length and radius as each end of the truss rotates from its current location to the new location in the staging area. The maximum radius from each crane to its lifting point is approximately 320 ft. Based on the charts provided by the crane manufacturer, the allowable load is 115 kips or 57 tons, which is slightly greater than 55 tons of anticipated reaction of the truss. As compared with the removal using SPMTs, the removal using cranes should be relatively quicker because temporary shoring and bents are not needed. The challenge, however, is to get the crane components to the construction site and minimize the disturbance to Dodge Park.

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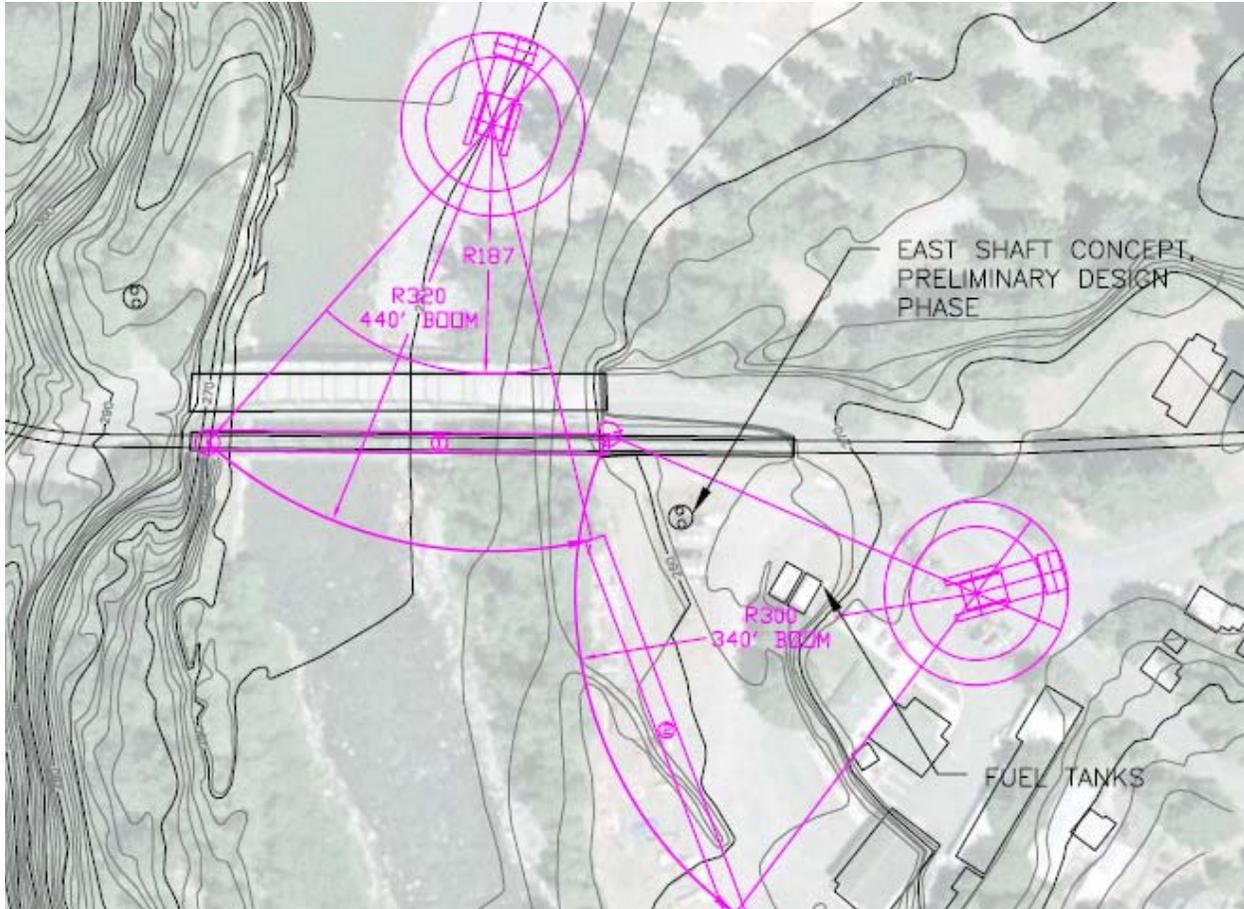


Figure 9 Schematic diagram showing removal of the entire truss in one piece using two cranes positioned as shown.

Presence of Lead Paint-

It is believed that the existing bridge paint system contains lead-based paint. Overall the paint system is in good condition with only minor areas of flaking paint. Regardless, the contractor will need to be aware of the presence of lead paint and contain it (as well as construction debris) keeping it out of the river.

Due to the fairly good condition of the paint system, it is advised, not to require the Design-Builder to remove the lead paint. However, it is reasonable to assume that lead paint flakes may become dislodged during any handling of the truss components and measures should be taken to address this situation.

6.0 STORAGE CONSIDERATIONS-

Size of Storage Area-

Once the truss is removed, it must be transported to a storage location and properly stored. Transportation and proper storage of the truss components will also be the responsibility of the Design-Builder. To this end, he will be required to develop and submit a Truss Component Storage Plan that follows some basic criteria, such as providing:

- Details for storing the components off the ground, with adequate airflow and ventilation around each component.

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- Details for supporting each member in a fashion that does not induce stresses that place the member beyond its elastic state.
- Details for providing accessibility to each component, for Agency inspection.
- Details for providing corrosion protection for portions of elements with exposed bare metal.
- Map showing the location of each truss component, by component tag.

Figure 10 depicts a concept for a storage area plan. From this concept, the minimum area required for storage is 50' x 150' (7500 SF).

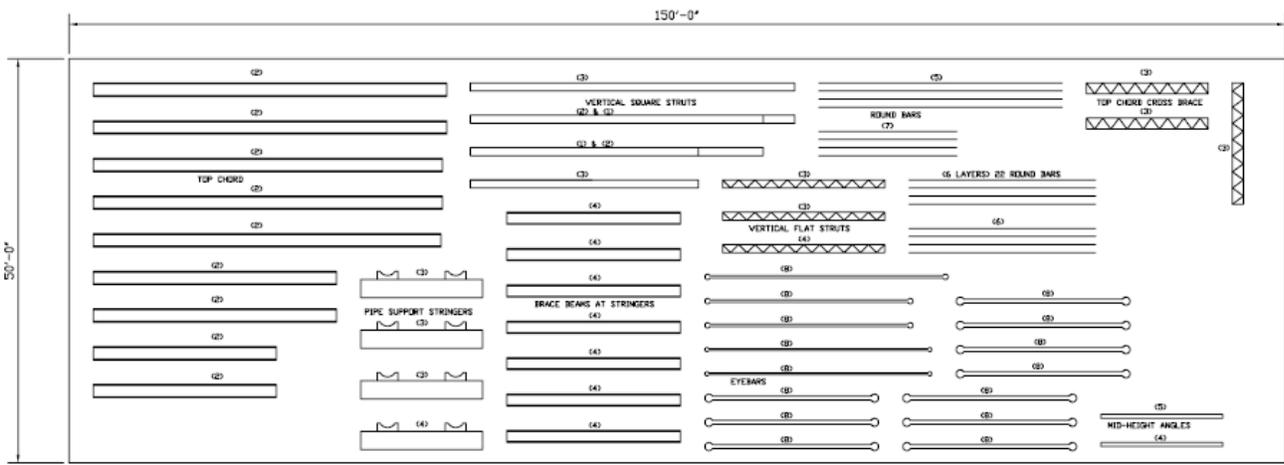


Figure10. Schematic diagram showing a storage area concept.

A conceptual cost estimate was investigated, should the Agency desire to store the truss components in a covered storage area. According to the 2007 RSMMeans Heavy Construction Cost Data (p. 569), Warehouses and Storage Buildings have an average square foot (SF) price range of \$37.50/sf to \$77/sf. For storage purposes it is reasonable to assume covered storage could be much less than these values and cost in the range of \$20/sf to \$30/sf. The conceptual cost range is therefore \$150,000 - \$225,000 for covered storage.

Recommendation:

The Agency should provide a storage location address and responsible contact person name, for inclusion into PS-50.

1.0 PUBLIC OPINION-

At the present time, it is unclear whether the public would express an opinion regarding the complete removal of the Conduit 2/4 Bridge. Through discussions with SHPO, several ideas have surfaced, including retaining and relocating portions of the truss portals to memorialize the bridge and relocating the bridge to a new location and converting it for pedestrian use.

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In addition to the on-going discussions with SHPO, it is proposed to develop a detailed public involvement plan that will be executed during the project and would include public meetings at various project stages.