Reconstruction of Canadian National Railway Br. 173.20 over the Fox River
Planning, Design and Construction Considerations
Oshkosh, Wisconsin

Authors:

Mark Paull, PE
Canadian National Railway
Construction Engineer
17641 South Ashland Ave
Homewood, IL 60430
708.332.3745

Christian Brown, PE; Manab Medhi, PE
HNTB Corporation
715 Kirk Drive
Kansas City, MO 64105
913.221.3327

Jonathon Bennett
Edward Kraemer and Sons, Inc.
Field Engineer
530 Bay Shore Drive
Oshkosh, WI 54901
608.963.3538

ABSTRACT

The existing three-span single track Fox River Bridge at CN Railway M.P. 173.20, Neenah Subdivision, was in need of rehabilitation or reconstruction in order to support reliable service on CN’s core line between Winnipeg to Chicago. Located in downtown Oshkosh, Wisconsin, the bridge supports train traffic carrying primarily grain, pot ash, sulfur and forest products. During peak grain season, 22 trains per day at an operating speed of 25 mph pass over the structure. The Fox River Bridge is located in close proximity to the popular Lake Winnebago, requiring the existing swing span to open over 1,600 times per year during the recreational boating season that lasts from May to late October each year.

Due to the age of the existing bridge, limitations of load capacity and periodic operational problems throughout the years, CN decided to evaluate alternatives to rehabilitate or reconstruct the existing structure. In 2009, CN embarked on a Three Phase project to implement improvements at the Fox River Crossing, which culminated with the on-line replacement of the historic bridge that will be fully completed in Fall 2013. The Three Phase project consisted of:

- Phase 1: Project Planning and Conceptual Design of recommended alternative, including a detailed inspection, rating and investigation of various alternatives for the
reconstruction or replacement of the bridge, providing guidance for the recommended alternative and the basis for the National Environmental Policy Act (NEPA) documentation.

- **Phase 2**: Preliminary Design, Final Design and NEPA documentation, including preliminary design and refinement of the Phase 1 recommended alternative, development of final design and construction documents, and the completion of the Environmental Assessment and procurement of all necessary permits in the environmentally sensitive area.
- **Phase 3**: Complete reconstruction of the historic bridge on the existing alignment, including environmental constraints for drilled shaft construction, waterline capbeams, two separate 10-hour change-out windows for the new approach span installations and a 36-hour change-out window for the new movable span.

To replace the existing 180’ movable span and 2-150’ fixed truss spans, a new span configuration on the existing alignment was designed consisting of a 147’ rolling bascule span, 5-57’ deck plate girder spans and one 40’ deck plate girder span. To accommodate these new spans, 6 new piers supported on drilled shafts were required with modifications to the two existing abutments.

This paper will detail the planning and design of the new structure, the agency coordination and permitting necessary to replace the historic swing span and adjacent fixed truss spans, and the construction challenges leading to the phased implementation of the new rolling lift bascule span which will be fully was installed during a 36-hour track window in August 2013.

### 1.0 INTRODUCTION

The existing three-span single track Fox River Bridge at CN Railway M.P. 173.20, Neenah Subdivision, was in need of reconstruction or replacement in order to support reliable service on Canadian National’s core line between Winnipeg to Chicago. Located in downtown Oshkosh, Wisconsin, the bridge supports a train traffic level of approximately 20 trains per day, seven days a week, carrying grain, pot ash, sulfur and forest products at an operating speed of 25 mph. The Fox River Bridge is located in close proximity to the popular Lake Winnebago, requiring the swing span to open over 1,600 times per year during the recreational boating season that lasts from May to late October each year.

The project consists of 3 phases. **Phase 1**: Project Planning and Conceptual Design of recommended alternative, **Phase 2**: Preliminary Design, Final Design and NEPA documentation, **And Phase 3**: Complete reconstruction of the historic bridge on the existing alignment. This paper discusses the preliminary study on different feasible alternatives to come up with the final alternative, the final design features and the construction processes of the project. Design is per American Railway Engineering and Maintenance-of-way (AREMA) Manual of Standard Practice, using E-90 loading.
2.0 EXISTING BRIDGE

The Fox River Bridge, built circa 1899, was an open deck, single track, three-span, through truss steel railroad bridge. The North and South approach spans were 148 feet respectively, while the through truss swing span over the navigation channel was 176 feet, for a total bridge length of 472 feet abutment to abutment. The swing span pivot pier was of stone masonry construction, resting on driven timber piling. The rest piers and abutments were of similar design; however strengthening measures were taken at both rest piers. Each rest pier had four 54-inch drilled shafts with rock sockets connected to the rest pier with a reinforced concrete pier cap. The swing span was designed to be operated by a bridge tender stationed at the bridge; however, the bridge has been modified for remote operation and was controlled by the central train dispatching system in Homewood, Illinois.

Figure 1: Existing 1899 Span Arrangements

3.0 PHASE 1

Phase 1 consisted of planning and Conceptual Design of recommended alternative, including a detailed inspection, rating and investigation of various alternatives for the reconstruction or replacement of the bridge, providing guidance for the recommended alternative and the basis for the NEPA documentation.

3.1 INSPECTION AND RATING OF THE EXISTING BRIDGES:

During the week of June 22, 2009, HNTB performed a physical inspection of the bridge including structural, electrical and mechanical facilities that are integral with the operation of the movable span. Survey and underwater inspection of the bridge site were also carried out. Following major observations were made:

- **Structural:** General section loss of approximately 10% and pack rust due to age of the structure was found on the various members such as chords, diagonals and connections. In general, the cursory inspection showed the structure to be in fair condition given its age. The key area of concern was the floor system. In addition to monitoring its condition, a new floor system, will be required to provide the structure with a longer service life and desired load carrying capacity.
- **Mechanical:** The center bearing, rollers, and track need to be replaced if a swing span rehabilitation was performed. The rack and pinion gears needs to be replaced.
- **Electrical:** From an electrical and controls standpoint, the bridge is in good condition. That said, during the inspection, several deficiencies were noted.
- **Underwater Inspection:** The abutments are both in generally good condition with little mortar loss. Piers 2 & 4 had been rehabilitated with drilled shafts and a cast in place concrete cap that show little deterioration; there was horizontal cracking in the pier caps that should be monitored. The original masonry aspects of piers 2 & 4 have widespread deficiencies including random areas of mortar loss (some 2’ long with 18” penetration), moderate deterioration of the timber grillage, large undermining voids (up to 5’) with exposed timber support piles, timber piles no longer in contact with the timber grillage, and grout bags present but not in contact with the timber grillage. The pivot pier (3) is in overall satisfactory condition with only random and minor joint mortar section loss. The timber grillage around this pier was exposed but the piles are not. Inspection should be repeated in 2-3 years.

A thorough rating of the existing swing span and approach span trusses was carried out after the physical inspections were done. It was concluded that, in general, the Fox River Bridge approach trusses and swing span rated as expected for vintage 1899 lattice truss spans. This structure type was economical in its day; however it was considered “light” by today’s standards and the lack of hangers and posts complicates the rating of the diagonals. The floor system cracks were a concern, and should be closely monitored in the event that the members were not replaced in the near future. Complete rehabilitation of these trusses was recommended in order for them to meet the CN design criteria of E-90. The existing substructure was adequate for E80 loading conditions. To maintain this rating, repairs to the rest piers are recommended and should be performed as soon as possible.

### 3.2 FEASIBLE ALTERNATIVES STUDY:

This phase of the project included detailed inspection, rating and investigation of various feasible alternatives for the reconstruction or replacement of the bridge that met CN and AREMA structural, track and signal design standards. Throughout this phase a Project Development Report was prepared that was the basis for the NEPA documentation, but made specific recommendations as to the best way to meet the stated objectives. HNTB evaluated five distinct alternatives for the rehabilitation or replacement of the existing Fox River Bridge:

- **Alternative 1:** Complete rehabilitation and strengthening of the existing bridge.
- **Alternative 2:** Replacement of the existing superstructure with a new steel superstructure resting on the existing substructure.
- **Alternative 3:** Construction of a new movable span and approaches on a parallel alignment to the East of the existing structure.
- **Alternative 4:** Complete replacement of the existing bridge on the existing alignment.
- **Alternative 5:** Complete replacement of existing bridge on a parallel alignment or existing alignment by using an existing movable span having been retired and relocated to the project site.

Although there are many possible arrangements and combinations of spans and span types, each alternative meets the same external requirements: United State Coast Guard (USCG) vertical and horizontal clearance requirements, material availability and preference, railroad operational requirements, and historic and environmental constraints. Each alternative had taken
into account all of these constraints as well as the results of the inspection and rating as part of the Phase I Study. Each alternative was presented to CN with respective detailed construction sequencing including track and marine outages, construction schedules and preliminary cost estimates. A “Weighted Ranking” evaluation process was used to select the best alternative. Project team concluded that Alternative 3, construction of a new rolling lift bascule span on an offset alignment to the East of the existing structure met or exceeded CN selection criteria. HNTB was directed to proceed with this alternative. However, after 60% final design of the project was completed, due to a challenge to the permit process of the new bridge in a new alignment, CN decided to go with the Alternative 4: construction of a new rolling lift bascule span on the existing alignment. The span arrangement study and preliminary design were again carried out for the alternative 4, aiming at salvaging the already completed design as much as possible.

4.0 PHASE 2

Phase 2 consisted of preliminary Design, Final Design and NEPA documentation, including preliminary design and refinement of the Phase 1 recommended alternative, development of final design and construction documents, and the completion of the Environmental Assessment and procurement of all necessary permits in the environmentally sensitive area.

4.1 PRELIMINARY DESIGN:

The design criteria were established. A replacement movable span must provide a clearance envelope as prescribed the USCG: that is a 23’ vertical clearance and 125’ horizontal clearance. New structures would be designed per the current AREMA specifications. The live load would be Cooper E-90 loading with diesel impact at a speed of 60 MPH. New structures will conform to CN guidelines for Track and Structures. HNTB evaluated two types of bascule spans, a Scherzer Rolling Lift bridge, commonly referred to as a rolling bascule, as well as a Trunnion bascule. Both structures would effectively meet the clearance requirements, and they both have advantages and disadvantages. The rolling bascule structure-type has been in service on railroads for nearly 100 years. Single-leaf, through truss rolling bascule span is generally used for applications in which the horizontal clearance requirement is less than 175 feet. The alternative to the rolling bascule is a trunnion bascule structure. Instead of rolling back on a track frame, a trunnion bascule opens about a single point, a “pin” referred to as a trunnion. A trunnion bascule span does not translate, and can sometimes require less room to operate. That being said, the trunnion bearings themselves must absorb live load and need to be designed accordingly. Positive aspects of a trunnion bascule are similar to that of a rolling bascule with the main difference being the live load path. Owner preference plays a significant role in the selection of a rolling bascule over a trunnion bascule span.

Positive aspects of a rolling bascule span over a swing span or trunnion bascule include:

- Live load transfer through structure supports and bearings, resulting in this application being more common in railroad bridge applications due to the intense live and impact loads.
- Rail joints do not require articulated mechanisms found on swing spans.
- As the rolling lift translates horizontally away from the navigation channel during span openings, an unlimited vertical clearance is possible when the span is rotated open to approximately 80 degrees.
- There are no rail locks, easier bars, end lifts or center wedges; only the span locks at the leaf tip which results in few interlocked steps needed to engage the drive motors. This results in a somewhat simpler control system.
- Easy to inspect and maintain due to exposed track girder and rolling surface.

Having considered the advantages and disadvantages, along with the site-specific constraints related to each bascule type, the decision was made to advance the concept of a rolling bascule.

4.2 FINAL SPAN ARRANGEMENTS

Top of Rail is maintained at 756.50 (NAVD 88) and standard low water elevation is 746.21 (NAVD 88). The final arrangements consist of one 147’-0” rolling lift bascule span, five 57’-2 ½” Deck plate girder span, one 40’-0” Deck plate girder span and a track girder.

![Figure 2: Newly Designed and Constructed Span Arrangements](image)
4.3 CROSS SECTION

The bascule truss was designed with a floor system consisting of floorbeams spaced at 24’-6” (maximum) and 4 stringers spaced at 2’-6” spanning between the floorbeams. Vertical clearance of 24’-0” is provided from the top of rail. Trusses are spaced at 22’-0” apart. Approach deck plate girders have 4 built-up sections spaced at 3’-0” spacing. After several iterations, it was concluded that these arrangements provided the most efficient structures considering the available limited structural depth.
4.4 MATERIALS

High-strength Grade 50 weathering steel was selected for low maintenance requirements. Grade 70 is not economical due to excessive live-load deflections. High-strength steel bolts conforming to the requirements of ASTM A325 Type 3 were specified. Allowable bolt stresses are in accordance with AREMA specifications, except that the allowable bolt shear is 13.5 ksi for bolts subjected to moment tension. Structural concrete was designed to have minimum 28 day strength of 5000 psi for the pier caps and drilled shafts.

Open decks were used over ballast decks. Ballast decks are heavier and needs additional 8”-12” of ballast between the top of rail and low steel, which is an issue with maintaining conformance to freeboard. An open timber deck was selected to achieve a lighter dead load. Walkways composed of sections of galvanized bar gratings were designed on both sides of the
track. Walkways were supported on extended ties not exceeding 7 feet and designed for 100 psf loads. Galvanized handrails were provided at all locations.

4.5 BUILT-UP Vs. ROLLED SHAPED

A study was conducted in order to determine the most efficient section for the Deck Plate girders. Both built-up and standard rolled sections were considered in the study with 4 and 6 beams system. It was finally concluded that a 4 beams with 3’- 5 ½” section depths would provide adequate clearances from top of standard water elevation and be 23% more efficient than an equivalent rolled shape with 3’-6” section depth. Also, built-up sections provide 14” clear distance between the flanges of the beams which was adequate to install the diaphragms. After a similar study for the floor system of the bascule truss, built-up section were selected for the floor beams and standard rolled shapes were selected for the 4 stringer system.

4.6 FINAL DESIGN

4.6.1 GENERAL

Based on the preliminary study, a single leaf bascule warren truss span was designed with a segmental girder and a counterweight. The warren truss has 5 floor panels of 24’-6” long and 1 end panel of 21’-6” long. Floor beams are 36” deep built up sections. Stringers are 21” deep standard rolled sections. The AREMA fracture control plan outlined in Chapter 15 applies to tension chords, tension diagonals, hangers and floorbeam. Stringers are not fracture critical members since a redundant 4 stringer system is used. Trusses are cambered for dead load plus a live load of 3000.0 lbs. per foot of track.

The 57’- 2 ½” approach span Deck Plate girders were designed as a built-up sections with a 41.5” total section depth. The 40’-0” Deck span was designed as a built-up section with 27” section depth. The 40’-0” deck span fits within the 7’-6” deep track girder on top which, the segmental girder of the bascule span rolls.

Segmental girders were designed as built up sections with a working line radius of 25’-3”. One end of the segmental girder is bolted to the node L6 of the truss and other end is connected to the counterweight. Each of the counterweight is designed as a hollow closed cell box. Outer cells are designed with stiffeners, internal bracing system and tie-rods in order to facilitate concrete pours. One face of the counterweight box was made slanted in order to maintain adequate clearances between bottom corner of the counterweight box and the top of water when the bascule span is opened to the 60 degree opening angle.
4.6.2 3-D MODELING OF THE TRUSS

A three-dimensional model of the truss was created and analyzed for different loading conditions. Analysis also included the wind load effect on the truss at its different opening conditions. AREMA chapter 15 was used appropriately to design the members for different loading conditions. Lateral bracing system was designed in order to resist and distribute the loads generated by wind. Two traction frames are assumed, one at each end of the bridge to distribute the longitudinal live loads. Reducing to one frame would require a heavier bottom bracing section which was not feasible without increasing the structure depth.

Figure 5: Bascule Truss with Node names and dimensions

Figure 6: Bascule Truss 3-D model in closed condition
4.6.3 CLEARANCE CHECK AND BALANCE CALCULATIONS

Special attention is needed with movable spans in order to check the clearances of the span to any structural, mechanical, electrical components including walkways, rack frames, ties and rails while the span is operated. Similarly, thorough and accurate balance calculations are extremely important during the design phase of the project. In order to ensure these two critical items, at final stage of the plan creation, two separate design teams were tasked to do the calculations independently and final results of both teams were compared iteratively until a deviation less than 3% was achieved.

5.0 PHASE 3 – Construction

Complete reconstruction of the historic bridge on the existing alignment, including environmental constraints for drilled shaft construction, waterline cap beams, two separate 10-hour change-out windows for the new approach span installations and a 36-hour change-out window for the new movable span. A 120-hour closure to navigation traffic was also set in place. On August 19, 2013, the 36-hour change-out schedule commenced in which the existing swing span was removed along with two temporary spans. To accommodate the installation of the final bascule span elements, the existing swing span pivot pier and rest piers were demolished. The bascule span elements that were installed during the final change-out included the fully assembled bascule span (complete with all mechanical and electrical components), 2 rack frames, a track girder, a 40'-0” DPG span and a 57'-2 ½” DPG span. Rail service across the completed structure was reinstated at the conclusion of the 36-hour change-out period. After another 36 hours, with the completion of counterweight concrete placement and final balance adjustments, the new bascule span opened for the first time. With additional fine-tuning of the span balance and bridge controls, the new bascule span was open to Fox River navigation traffic within the designated 120-hour navigation closure.
6.1 ACKNOWLEDGEMENTS

Owner

Canadian National Railway
17641 South Ashland Ave
Homewood, IL 60430
   Nigel Peters
   Sandro Scola
   George Nowak
   Aneesh Bethi

Construction Manager

URS Corporation
100 South Wacker Drive
Suite 500, Chicago, IL 60606
312.939.1000
   Julie Bandt
   Don Yetter
Reconstruction of CN Bridge 173.20 - Neenah
Planning, Design and Construction Considerations

Mark Paull, PE - - CN
Christian Brown, PE - - HNTB
John Bennett, PE - - EKS
Existing Br. 173.20 - Neenah

- Three span through truss
- Open deck
- Approach span lengths of 148'
- Center swing span of 175'
- Structure founded on masonry piers supported by timber piles
- Rest piers strengthened with drilled shafts
Existing Bridge Data

- Three steel lattice trusses constructed in 1899
- 480’ Total Length
- Single track on CN’s core route between Winnipeg and Chicago
- 20 Trains per day at 25 mph maximum
- Swing Span provides two 64’ navigation channels
- 1600 opening per year
- Remote control operation
- Live load carry capacity
- Operational issue

Project Phases

- Phase 1 - Project Planning and Conceptual Design of Recommended Alternative
  - June 2009 - March 2010
- Phase 2 - Preliminary Design, Final Design and NEPA Documentation
  - October 2010 - July 2011
- Phase 3 - Reconstruction of the historic bridge on the existing alignment
  - October 2011 - August 2013 (Bascule Installation)

Phase 1 Tasks

- Task 1 - Phase I Study Preparation
- Task 2 - Track, Signal & Remote Operation Implications
- Task 3 - Structural, Mechanical & Electrical Inspections
- Task 4 - Bridge Survey & Basemap
- Task 5 - Underwater Inspection
- Task 6 - Superstructure & Substructure Ratings
- Task 7 - Alternatives Analysis, Construction Sequence & Outages
- Task 8 - Cost Estimates & Project Schedule
- Task 9 - Permit Requirements
- Task 10 - Alternatives Evaluation Matrix and Alternative Selection
Inspections

Superstructure and Substructure Ratings

Superstructure
- Normal and Maximum ratings per 2009 AREMA
- E80, 286k and 315k
- 40 MPH
- Multiple members below E80

Substructure
- Timber Piles
- Drilled Shafts
- Abutments
- Rest Piers
- Pivot Pier

Rehabilitation/Replacement Schemes

Summary of Base Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Alignment</th>
<th>Primary Element</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Existing</td>
<td>• Rehabilitate Superstructure*&lt;sup&gt;*&lt;/sup&gt;</td>
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<tr>
<td></td>
<td></td>
<td>• Rehabilitate Substructure</td>
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<tr>
<td>2</td>
<td>Existing</td>
<td>• Replace Superstructure*&lt;sup&gt;*&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td>• Rehabilitate substructure</td>
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<tr>
<td>3</td>
<td>Existing</td>
<td>• Complete bridge replacement (superstructure* and</td>
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<tr>
<td></td>
<td></td>
<td>substructure)</td>
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<tr>
<td>4</td>
<td>New</td>
<td>• Complete bridge replacement (superstructure* and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>substructure)</td>
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*Includes Mechanical and Electrical for movable span

Developing Alternatives

Replacement Schemes - -Alt. 3 and 4

- Bascule Bridge on Existing Alignment
- Bascule Bridge on Adjacent Alignment
- Swing Span on Existing Alignment
- Vertical Lift Span on Existing Alignment
### Evaluation of Alternatives

#### Evaluation Criteria

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<td>Impacts to Rail (construction)</td>
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<td>Impacts to Navigation (construction)</td>
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<td>Channel Maintenance</td>
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<td>Bridge O&amp;M</td>
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<td>Construction Risks</td>
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#### Estimated Base Bid Costs

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<td>Rehabilitation</td>
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<td>On-line Bascule</td>
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<td>Off-line Bascule</td>
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<td>On-line Vertical Lift</td>
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### Truss Rehabilitation

- Strengthen/Replace upper chords
- Strengthen/Replace lattice members
- Strengthen/Replace end posts
- Replace gusset plates and diaphragms
- Replace floorsystem

### Floorsystem Rehabilitation

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<thead>
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<th>Step</th>
<th>Activity</th>
<th>Estimated Duration</th>
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<tr>
<td>1</td>
<td>Remove Deck/Track Panels</td>
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</tr>
<tr>
<td>2</td>
<td>Install Stringer Support Beams</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>Unbolt Laterals</td>
<td>0.50</td>
</tr>
<tr>
<td>4</td>
<td>Unbolt &amp; Remove Stringers</td>
<td>1.50</td>
</tr>
<tr>
<td>5</td>
<td>Unbolt &amp; Remove Floorbeam</td>
<td>1.50</td>
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<tr>
<td>6</td>
<td>Install &amp; Bolt Floorbeam</td>
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<tr>
<td>7</td>
<td>Install and Bolt Stringers</td>
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<tr>
<td>8</td>
<td>Reconnect Laterals</td>
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<tr>
<td>9</td>
<td>Remove Stringer Support Beams</td>
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</tr>
<tr>
<td>10</td>
<td>Install Deck/Track Panels</td>
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</table>

Time for 1 panel: 11.00 hrs.
Total Panels: 31

Time for end FB: 6 hrs.
Total FBs: 3

Total time: 360 hours
Over multiple work windows

### Alternative 3

- Constructability

- Track Alignment
Phase 2 - Design and Environmental

- Preliminary Design - Off-Alignment Alternative
  - Optimize Movable Span
  - Span Arrangement
  - Subsurface Investigation
  - Refine Construction Sequence
- Final Design, Plans & Specs - On-Alignment Alternative
  - Finalize Span Configuration
  - Finalize Construction Sequence
  - Finalize Cost Estimate

NEPA Documentation
- USCG Bridge Permit
- Wisconsin SHPO
- EPA
- City of Oshkosh

Final Design Criteria
- AREMA
- CN Guidelines for Track & Structures
- CE-90 Live Load
- Rolling Bascule; overhead machinery
- DC Motors
- PLC control with RC capabilities
- Navigation Clearances:
  - 23’ Vertical
  - 125’ Horizontal
- Staged Construction
  - Window 1 - 12 hours
  - Window 2 - 12 hours
  - Window 3 - 40 hours (120 hours for navigation)

Replacement Bridge Data
- Three - 57’-2 ½” ODPG spans (5-7)
- 40’-0” ODPG span(4)
- 147’-0” Rolling Bascule span (3)
- Two 57’-2 ½” ODPG spans (1-2)
- 6 new piers; 2 drilled shafts each
- Waterline capbeams
- Rehabilitated abutments

Environmental Requirements
- USCG lead federal agency
- Environmental Assessment (NEPA)
- Supporting Agencies:
  - EPA - contaminated soils
  - USACE - dredging; substructure removal
  - USFWS - threatened and endangered species
  - Wisconsin SHPO - Section 106
  - Wisconsin DNR - water quality certification
  - City of Oshkosh - property and easements
Phase 3 - Construction
- Substructure
- Superstructure Erection
- Span Replacement

Substructure - Drilled Shafts

Substructure - Pier Caps

Steel Erection

Fixed Truss Replacement - 12 hour work block

Truss Removal / Float-Out
- Span weight 150 tons
- Span Length 148 feet
Swing span removal/bascule installation required months of planning to limit the work block to 36 hours. Navigation closure limited a maximum of 120 hours.
Phase 2 - Removals & Track Girders

Phase 3 - Pier Demo & Rack Frame Installation
Phase 4 - Bascule Float-In
Phase 5- Balancing & Testing
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- Wisconsin SHPO