



Impact of Railcar Weight Changes on Bridges of the State of Wisconsin- Owned Railroad System

Westbrook Associated Engineers, Inc., and E80 Plus Constructors, LLC

Final Report No. 0092-05-13

August 2006

WISCONSIN DOT

PUTTING RESEARCH TO WORK

Wisconsin Department of Transportation Research, Development & Technology Transfer

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Technical Report Documentation Page

1. Report No. 0092-05-13	2. Government Accession No	3. Recipient's Catalog No	
4. Title and Subtitle Impact of Railcar Weight Changes on Bridges of the State of Wisconsin-Owned Railroad System		5. Report Date August 2006	6. Performing Organization Code
7. Authors Westbrook Associated Engineers, Inc., E80 Plus Constructors, LLC		8. Performing Organization Report No.	
9. Performing Organization Name and Address Westbrook Associated Engineers, Inc. 619 E. Hoxie St., Spring Green, WI 53588 and E80 Plus Constructors, LLC, 600 Bassett Street, DeForest, WI 53532		10. Work Unit No. (TRAIS)	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Wisconsin Department of Transportation, Council on Research 4802 Sheboygan Ave., Room 851 Madison, WI 53707		13. Type of Report and Period Covered Final report	14. Sponsoring Agency Code
15. Supplementary Notes			
<p>16. Abstract</p> <p>Bridges on the state-owned Wisconsin railroad system are reaching their original design capacity due to increased railroad car weight limits. The condition of a majority of these railroad bridges has created additional concern. This report is the result of a railroad bridge assessment study commissioned by the Wisconsin Department of Transportation to determine the impact of 286,000-pound (286 kip) railcars (on state-owned railroad system bridges). The objective of the study was to evaluate a sample number of bridges by inspecting their current condition, determining their load carrying capacity, estimating their remaining useful life, and make repair and retrofit recommendations, to facilitate the heavier cars. Twenty-six sample bridges were evaluated. These are comprised of three steel bridges, one concrete bridge, twenty timber bridges and two bridges with combined timber and steel spans. These bridges were located on both the Milwaukee and the Monroe subdivisions of the Wisconsin & Southern Railroad Company.</p> <p>It was found that overall there is a need to perform a sizable amount of maintenance, repair and capital construction work to prepare the project bridges for sustained 286 kip operations. The rating analysis suggests that many of the timber trestle bridges will not be able to carry sustained 286 kip rail car traffic without accelerated deterioration of the structures. Deficiencies in the standard timber trestle bridges already present at the current load levels will be aggravated by 286 kip railcar loads. The steel and concrete bridges rated are adequate for carrying 286 kip railcar traffic.</p> <p>The study notes that the sample of steel and concrete bridges may not be representative of the remaining bridges in the Wisconsin & Southern inventory, and that further evaluation should be performed.</p> <p>Inspections of the project bridges found that, while conditions varied widely, overall the condition of the bridges was fair to poor. Several years of deferred maintenance were evident, particularly amongst those bridges on the Monroe Subdivision. The steel bridges included in the study were found to be in fair to good condition with a lesser number of defects per bridge.</p> <p>Over the next 5 years, \$2.93 million will be required to bring the study bridges up to a condition that can sustain continuous 286 kip operations. Extrapolating that value to the entire state-owned rail system indicates as much as \$24.2 million is needed to upgrade all bridges.</p>			
17. Key Words		18. Distribution Statement	
		No restriction. This document is available to the public through the National Technical Information Service 5285 Port Royal Road Springfield VA 22161	
18. Security Classif.(of this report) Unclassified	19. Security Classif. (of this page) Unclassified	20. No. of Pages 77	21. Price

FINAL STUDY REPORT

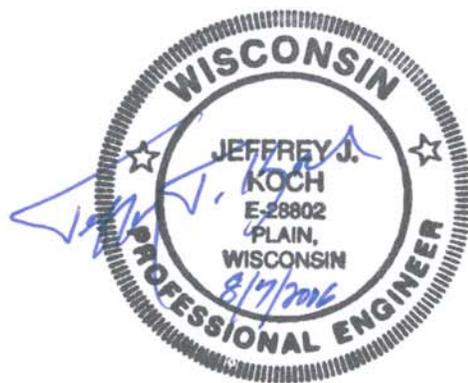
IMPACT OF RAILCAR WEIGHT CHANGE ON BRIDGES OF THE STATE OF WISCONSIN OWNED RAILROAD SYSTEM

WISDOT PROJECT I.D. 0092-05-13

Wisconsin Department of Transportation

Wisconsin & Southern Railroad

August 2006



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INTRODUCTION & EXECUTIVE SUMMARY

Wisconsin & Southern Railroad Milwaukee Subdivision Monroe Subdivision

August 2006



INTRODUCTION

Bridges on the state-owned Wisconsin railroad system are meeting their original design capacity due to increased railroad car weight limits. The age and condition of a majority of these railroad bridges has created additional concern. This report is the result of a railroad bridge assessment study commissioned by the Wisconsin Department of Transportation to determine the impact of 286,000-pound (286 kip) railcars on state owned railroad system bridges. The objective of the study was to evaluate a sample number of bridges by inspecting their current condition, determining their load carrying capacity, estimating their remaining useful life, and make repair and retrofit recommendations to facilitate the heavier cars. Westbrook Associated Engineers, Inc. with E80 Plus Constructors, LLC has prepared the following report.

The 26 sample bridges evaluated are located on two rail lines operated by Wisconsin & Southern Railroad Co. (WSOR). All of the bridges were originally constructed by the Chicago, Milwaukee, St. Paul & Pacific Railroad between 1900 and 1965. Five of the bridges are located on the Milwaukee Subdivision between Hartford and Slinger and 21 are located on the Monroe Subdivision from Janesville to Monroe. These are comprised of three steel bridges, one concrete bridge, 20 timber bridges and two bridges with combined timber and steel spans. A detailed bridge list is provided on the following page. The steel structures consist of nine simple spans - one pony truss and eight deck plate girder spans. All of the timber bridges inspected are pile trestles and all but one are open deck bridges. The concrete bridge inspected is a simple reinforced concrete slab and is the only bridge inspected that is a double track structure.

All of the sample bridges were inspected using a two-man bridge inspection crew. The inspecting engineers noted current bridge conditions and deficiencies. Recommendations for repairs are based on a priority rating from one to five as a measure of the importance of the repair at the time of the inspection. The on-site inspection notes, recommendations, required repairs, priority lists, original field inspection reports and photographs are compiled in a supplementary bridge inspection report that accompanies this document.

The load carrying capacities, or ratings, of the bridges were calculated from data collected using the inspection reports, existing plans and on-site examinations. Three standard timber trestle bridge plans were rated as they were originally designed, since most of the bridges were built based on these plans. Five timber trestle bridges were then rated according to their current condition to serve as a comparison. All six steel and concrete bridges were rated according to their current condition.

Using the inspection findings and the load rating data, the effect of operating the 286 kip railcars on the bridges was assessed and the findings are presented in this report. Recommendations based on these findings have been provided to correct any significant defects.

BRIDGE LIST

Milwaukee Subdivision - Survey Bridge List

Bridge #	Milepost	Location	Spans	Type	Length
D-58	121.5	Hartford, WI	1	ODPG	46'
D-64	124.5	Hartford, WI	1	ODPG	25'
D-78	130.2	Woodland, WI	3	14' BDPT	42'
D-125.5	132.7	Iron Ridge, WI	1	CONC. SLAB	32'
D-88	138.6	Horicon, WI	6	WSB/BDPG	188'

Monroe Subdivision - Survey Bridge List

Bridge #	Milepost	Location	Spans	Type	Length
F-28	11.5	Janesville, WI	3	BDPG	110'
F-30	12.4	Janesville, WI	3	14' ODPT	41'
F-34	13.4	Janesville, WI	3	16' ODPT	47'
F-40	15.5	Hanover, WI	3	16' ODPT	48'
F-50	16.5	Hanover, WI	2	14' ODPT	29'
F-52	16.6	Hanover, WI	8	16' ODPT	128'
F-60	18.3	Hanover, WI	3	16' ODPT	46'
F-62	19.8	Orfordville, WI	3	16' ODPT	48'
F-68	22.3	Orfordville, WI	1	14' ODPT	14'
F-76	25.5	Brodhead, WI	5	14' ODPT	70'
F-80	26.7	Brodhead, WI	3	16' ODPT	48'
F-82	28.7	Brodhead, WI	8	16' ODPT	128'
F-84	28.9	Brodhead, WI	13	14' ODPT/PRT/ODPG	294'
F-90	30.3	Brodhead, WI	6	16' ODPT	96'
F-92	30.5	Brodhead, WI	4	16' ODPT	64'
F-108	33.4	Juda, WI	3	16' ODPT	48'
F-114	35.4	Juda, WI	3	14' ODPT	42'
F-116	35.5	Juda, WI	3	14' ODPT	41'
F-120	36.6	Juda, WI	3	16' ODPT	48'
F-122	36.9	Juda, WI	3	14' ODPT	42'
F-134	38.7	Juda, WI	5	14' ODPT	70'

BDPT: Ballasted Deck Pile Trestle
ODPT: Open Deck Pile Trestle
BDPG: Ballasted Deck Plate Girder
ODPG: Open Deck Plate Girder
PRT: Pony Riveted Truss
WSB: Wood Span Bridge

EXECUTIVE SUMMARY

Since the late 1990's the use of 286,000 pound (286 kip) rail freight cars has increased dramatically on Class 1 railroads throughout North America. As the use of 286 kip cars has increased on the Class 1 railroads in the State of Wisconsin, more of them are now being interchanged with the shortline and regional railroads in the state. Over time, it is expected that 286,000 pound cars will become the norm just as the 263,000 pound cars that preceded them. At the same time, the condition of the bridge infrastructure on Wisconsin's shortline and regional railroads is declining due to the effects of age, wear, and decay. Many individuals within the rail industry are concerned that the aging bridge infrastructure will no longer be able to withstand the increased loadings from sustained 286 kip cars. The goal of this project is to evaluate the condition of a sample group of railroad bridges and determine what work is required to make these structures viable for sustained and safe operation of 286 kip cars.



Heavier Loads – A 286,000 pound rail freight car.

The evaluation of the bridges in this project found that overall there is a need to perform a sizable amount of maintenance, repair and capital construction work to prepare the project bridges for sustained 286 kip operations.

The rating analysis suggests that many of the timber trestle bridges will not be able to carry sustained 286 kip railcar traffic without accelerated deterioration of the structures. A rating summary for standard timber trestle bridges is shown in Table 1. Standard designs H-6140 and H-6160 are open deck pile trestle bridges with 14'-0" and 16'-0" spans respectively. Standard design H-7040 is a 14'-0" ballasted deck pile trestle. With one exception, all the timber bridges surveyed in this report were open deck. In terms of percent capacity, the ratings for standard design H-6160 show that 286 kip railcar loading is 105% of normal carrying capacity and 88% of maximum carrying capacity. Railcar loads and structural load ratings are discussed in the section *Structural Analysis and Rating – Methodology*.

Executive Summary (Continued)

For this report, Wisconsin & Southern Railroad, the operator of the railroad lines in the study, provided the car length and axle spacings for the 286 kip railcar loading. Ratings for this car and the Cooper E80 locomotive are shown in Table 1 for standard design timber trestle bridges and in Table 2 for site-specific designed steel and concrete bridges.

Table 1 – Standard Timber Trestle Bridge Ratings

Bridge Plan #	Cooper E Rating		Eq. Cooper E load for WSOR 286k Railcar	286k Railcar Rating	
	Normal	Maximum		Normal	Maximum
H-6140	E 70	E 84	E 58.4	321	383
H-6160	E 53	E 63	E 55.5	273	326
H-7040	E 86	E 104	E 58.4	387	470

Note: The Cooper E rating is a measure of the load carrying capacity of a railroad bridge. It is based on the axle load and spacing for locomotives and cars shown on page 12. The equivalent Cooper E load is the applied load that will create the same load effect as a 286 kip railcar load, and is independent of the load rating. It is a means for comparing the 286 kip railcar load with both the normal and maximum Cooper E ratings. In the table above, an equivalent Cooper E load of E 55.5 creates the same load effect as a 286 kip railcar load for bridge H-6160. Since the normal E rating is less than the equivalent Cooper E load, the 286 kip railcar rating will be less than a 286 kip railcar load.

For the standard timber trestle bridges, 286 kip railcar loads will aggravate deficiencies already present at current load levels. The 16'-0" trestles may sustain greater damage. Two specific deficiencies are noted: the ability of the stringers to carry the load with respect to bending, and more critically, the ability of the piling to transfer the load to the ground. Analysis shows that loads applied to the piling are very near their intended design capacities. Furthermore, actual pile capacities could be less than stated, and in many cases poor pile spacing noted in the field has created an increase in load distributed to the center piles. This has manifested in the form of pile settlement, often noted in the inspection report.

The six steel and concrete bridges rated are adequate for carrying 286 kip railcar traffic. In terms of standard Cooper E rating, all of the bridges rated below E80 at normal levels. Most rated above normal level for carrying 286 kip railcar traffic, with bridge F-84 rating slightly below normal levels for 286 kip railcar loading. A rating summary for steel and concrete bridges is shown in Table 2. The condition of the steel in the girder and truss bridges was good to fair. Section loss due to corrosion was minimal. For steel and concrete bridges, AREMA allows a reduction in impact load depending on track speed. Bridges D-58, D-125.5 and F-84 were rated using a reduced impact load according to classified track speed, and the remaining bridges were rated using full impact regardless of track speed. With regular maintenance and inspection all six concrete and steel bridges will continue to remain in service.

Executive Summary (Continued)

Table 2 – Steel and Concrete Bridge Ratings

Bridge #	Cooper E Rating		Eq. Cooper E load for WSOR 286k Railcar	286k Railcar Rating	
	Normal	Maximum		Normal	Maximum
D-58 ¹	E 66	E 99	E 56.5	336	506
D-64	E 77	E 117	E 62.5	351	585
D-88	E 67	E 91	E 53.5	358	491
D-125.5 ¹	E 68	E 113	E 58.0	336	560
F-28	E 77	E 119	E 60.0	371	566
F-84 ¹	E 56	E 88	E 59.5	268	418

1. Rating values include a reduction in impact load based on current maximum track speed.

Please note, the sample of steel and concrete bridges may not be representative of remaining bridges in the Wisconsin & Southern inventory. Further evaluations should be performed to determine the carrying capacities of the remaining bridges.

Inspection of the project bridges found that, while conditions varied widely, overall the condition of the bridges was fair to poor. Several years of deferred maintenance was evident, particularly amongst the timber bridges that were inspected on the Monroe Subdivision.

A majority of the defects located were identified on timber bridges. Several defective timbers were identified, including defective caps, stringers and deck timbers. Active pile settlement was also identified at several bridges and this settlement was substantial and extensive in some locations. The recommendations from the inspection include reconstruction of five timber trestles and timber repairs on nearly all of the remaining timber bridges. Repair recommendations included the replacement of all the stringers in five bridges, the replacement of the tie decks on fourteen bridges, the replacement of 36 caps, and other miscellaneous repairs.

Executive Summary (Continued)



Defective Stringers - Timber stringers exhibiting decay at a pier cap.

The steel bridges included in this project were found to be in fair to good condition with lesser number of defects per bridge. The most significant defect was the pier settlement observed at Bridge F-84 on the Monroe Subdivision. This defect represents a significant amount of the maintenance costs associated with all the steel and concrete bridges in the study. There were no steel or concrete bridges within the sample group that were recommended for replacement based on the inspection findings.

It is important to note that the number of timber bridges (21) included in the study was greater than the number of steel and concrete bridges (6). Additionally, 33% (2 of 6) of the sample of steel and concrete bridges had been recently rehabilitated, compared to only 9.5% (2 of 21) of the timber bridges that were recently rehabilitated. For this reason, the findings of fair to poor conditions on the timber bridges in this study are likely to be more typical of the timber bridges on the remainder of the Wisconsin & Southern. The findings of moderate to good conditions on the steel and concrete bridges may be less typical of the steel and concrete bridges on the remainder of the Wisconsin & Southern.

Executive Summary (Continued)

A significant investment will be needed in order to prepare the project bridges for sustained 286 kip traffic. Over the next five years it is estimated that approximately \$2.93 million will be required to bring the study bridges up to a condition that can sustain continuous 286 kip operations. Simple extrapolation of this value over the entire state owned rail system indicates that as much as \$24.7 million is needed to upgrade all of the rail bridges owned by the state and operated by the Wisconsin & Southern. This extrapolated value is subject to change based on the condition and rated capacity of those bridges outside the sample set.

The following table itemizes the estimated costs by bridge and by priority. Those items that are capital improvements have been italicized and bolded.

Table 3 – Summary of Estimated Costs per Bridge:

Bridge #	2nd Priority	3rd Priority	4th Priority	TOTAL
D-58	-	-	-	0.00
D-64	-	-	\$5,000	\$5,000
D-78	-	\$12,500	\$4,500	\$17,000
D-125½	-	-	\$37,750	\$37,750
D-88	-	\$50,250	\$54,500	\$104,750
F-28	-	\$145,250	\$97,250	\$242,500
F-30	-	\$18,750	\$2,000	\$20,750
F-34	-	-	\$28,750	\$28,750
F-40	-	\$50,750	\$5,000	\$55,750
F-50	\$5,000	\$14,250	\$5,000	\$24,250
F-52	-	\$68,250	\$10,000	\$78,250
F-60	-	-	\$226,500	\$226,500
F-62	\$29,750 ¹	-	\$9,250 ¹	\$39,000¹
F-68	-	-	-	0.00
F-76	\$47,000	\$32,000	-	\$79,000
F-80	-	\$11,000	\$226,500	\$237,500
F-82	-	\$24,500	\$65,500	\$90,000
F-84 MS	-	\$203,500	\$26,500	\$230,000
F-84 WA	-	\$19,500	\$469,000	\$488,500
F-90	-	\$331,250	-	\$331,250
F-92	\$14,250	\$19,750	\$38,500	\$72,500
F-108	-	-	\$226,500	\$226,500
F-114	-	\$41,750	\$26,500	\$68,250
F-116	-	-	-	0.00
F-120	-	-	\$26,750	\$26,750
F-122	-	\$10,750	\$19,250	\$30,000
F-134	\$9,000	\$86,750	\$20,750	\$116,500
TOTAL	\$105,000	\$1,194,000	\$1,578,000	\$2,927,000

1. Bridge F-62 has been rebuilt, this estimated cost would no longer be applicable.

Note: Costs associated with capital improvements are shown bold and in italics.

Executive Summary (Continued)

In their present condition, the estimated service life remaining in many of the bridges is less than five years. Service life is defined as the approximate length of time until a structural deficiency puts the bridge out of service or the length of time until a bridge can no longer carry its intended load. It is not absolute. Service life may increase with maintenance and upkeep or may decrease with damage, decay, or by carrying loads heavier than originally intended. On bridges where maintenance repairs are required, the out of service condition will be isolated to individual components and the bridge will be salvageable with repairs. On bridges where capital construction is required, pile settlement has diminished the long-term effectiveness of any repairs and rendered the bridge unsalvageable. Timber bridges that do not require capital expenditures have an estimated service life with recommended repairs and future maintenance of not more than twenty years. With recommended repairs and future maintenance, the concrete and steel bridges may last twenty years or more.

The service life estimates are based on the assumption that car weights will not increase beyond the proposed 286 kip cars during the next twenty years. Factors such as a dramatic increase in the frequency or weight of traffic may result in many of the bridges becoming unserviceable. The timber bridges examined are already 40-60 years old and the concrete and steel bridges range from 80-120 years old. Given their age and the fact that car weights tend to increase, it is difficult to predict what bridges will still be in service after twenty years.

With the work outlined in this study, railroad bridges on the lines owned by the State of Wisconsin are capable of sustained 286 kip railcar traffic. However, the age of the bridges, current rate of decay, and increasing rail weights will eventually require additional capital outlays. Many bridges will not meet long-term service requirements and should be replaced. Also, the bridges covered by this report represent only 10% of the bridges on the WSOR lines. Numbers from this study may be extrapolated to provide an estimate of the extent of repair and repair costs, but information regarding the condition and rating of the remaining bridges is unavailable.

To efficiently manage the remaining service life of the state's aging railroad bridges over the next twenty years, the two following recommendations should be put into practice: First, an inspection and rating of all the bridges in the state-owned inventory should be completed so that a fiscal plan for future expenditures can be drafted within the next two years. Second, establish a routine maintenance and inspection program to prolong the service life of existing bridges and to help facilitate long-term replacements on a bridge-by-bridge basis. A fiscal plan in conjunction with a routine maintenance and inspection program will help to apportion funds where they are most needed and allow time to accumulate the funds necessary for future improvements.

BRIDGE RATINGS

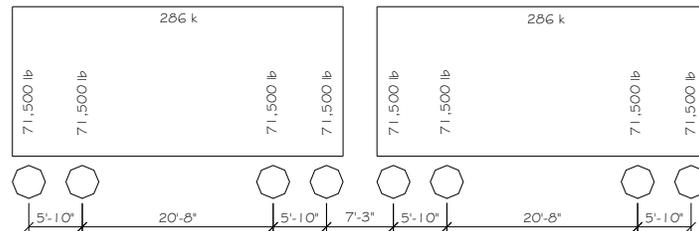
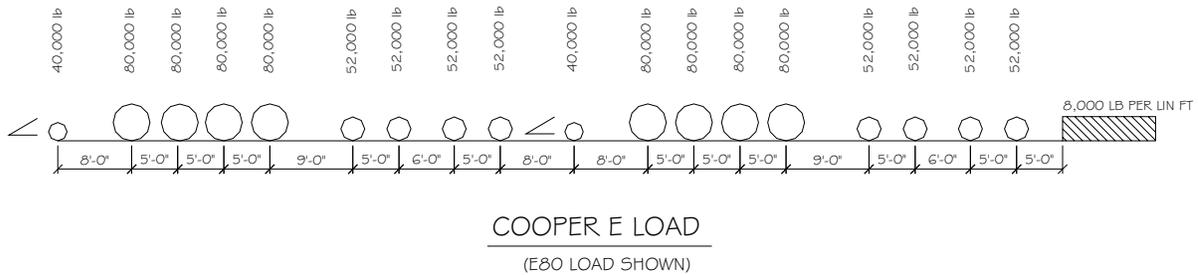
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STRUCTURAL ANALYSIS AND RATING - METHODOLOGY

For each analysis, a Cooper E80 load and a 286 kip railcar load were applied to the structure to determine the maximum *load effect*. Load effect is defined as the stresses or internal forces in a member caused by the applied load and may refer to axial tension or compression, bending, or shear. Maximum load effect is the largest internal force as compared to the member's structural capacity and may occur at different locations for each applied load. This relationship, load effect versus structural capacity, is the basis for determining the *load rating*. Diagrams for the Cooper E80 load and a 286 kip railcar load are shown below.



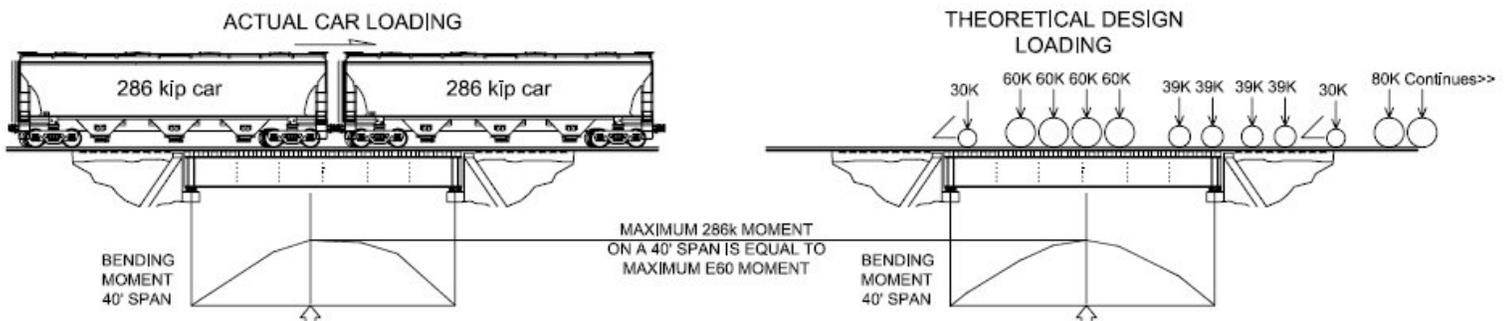
A load rating is a measure of a structure's carrying capacity – how much live load a structure may safely carry in addition to the dead load already present. The applied loads (Cooper E80 load & 286 kip railcar load) are only a basis for analysis. The final load ratings are a proportion of the initial applied loads. AREMA assigns two levels of bridge ratings. For concrete and steel bridges, these are *normal* and *maximum*. Normal rating is the load level that can be carried by the existing structure for its expected service life. The normal rating is otherwise known as the day-to-day “inventory” load level. Maximum rating is the load level that the structure can support at infrequent intervals. As the name suggests, maximum load level is the point at which a structure may begin to sustain damage, reducing its useful life. For Timber bridges, the levels are *Regularly Assigned Equipment or Locomotives* and *Equipment or Locomotives Not Regularly Assigned*, which are similar to normal and maximum levels respectively.

Structural Analysis and Rating - Methodology (Continued)

Load ratings may also be defined as the load a structure can carry while maintaining a certain factor of safety. For steel bridges, the normal rating level maintains a factor of safety of approximately 1.80 and the maximum rating level maintains a factor of safety of approximately 1.25. Please note that these factors are approximate and may vary due to load effect and controlling limit states. Factors of safety for timber are more difficult to determine because of variations among pieces which otherwise seem to be alike. Allowable stresses for timber are based on the strength of the weakest pieces that may occur in the grade, so it is difficult to estimate the exact point of failure. See AREMA Chapter 7, section 2.3.19 – Factor of Safety, Variability. The normal rating level factor of safety for timber is generally between 1.5 and 2.0. Maximum rating stresses for timber are approximately 20% higher than normal rating stresses, so factors of safety at maximum levels would range from 1.25 to 1.7.

In this report, overall load ratings are expressed in terms of Cooper E load and 286 kip railcar load. Please note, a *286 kip railcar load* is the specified axle configuration with a total applied load of 286,000 pounds per car and is the basis for analysis. A *286 kip railcar rating* may be less than or greater than 286,000 pounds depending on the carrying capacity of the structure, but will have the same axle configuration as the initial applied load.

In addition to load ratings, this report provides an *equivalent Cooper E load* for the 286 kip railcar. Since Cooper E loadings do not follow the configuration of a particular car, an equivalent rating must be created for each car type. The equivalent Cooper E load is the applied load that will create the same load effect as a series of 286 kip railcar loads, and is independent of the load rating. For instance, the 286 kip cars shown below result in the same bending moment on a 40 ft span as an E 60 load. The equivalent Cooper E load depends on two variables: load pattern and span length. Even though the 286 kip railcar load pattern does not change, the equivalent Cooper E load will differ from structure to structure. So while the 286 kip cars below are equivalent to an E 60 load on a 40 ft span, the same cars would be equivalent to an E 58 load on a 14 ft span or an E 56 load on a 16 ft span. This report uses the equivalent Cooper E load as a means for comparing the 286 kip railcar loads with both the normal and maximum Cooper E ratings.



RATING OF STANDARD TIMBER TRESTLE PLANS

Three typical “standard timber trestle” bridge types were rated for structural capacity based on Cooper E loading and 286 kip railcar loading. These ratings serve as a measure for all the timber bridges in the WSOR inventory as they were built according to standard plans. These standard bridge ratings may then be compared to as-built conditions and revised accordingly. Five bridges inspected on the Monroe Subdivision of the Wisconsin & Southern between Janesville and Monroe were re-rated for comparison and are included in the next section.

The timber bridge ratings were determined according to guidelines set forth by AREMA Chapter 7, Section 2.10 – Rules for Rating Existing Wood Bridges and Trestles. Allowable stresses for rating may be referenced there. Timber stringers were evaluated for bending, horizontal shear, and for bearing against the pier cap. Timber pier caps were evaluated for bearing against pile ends. Lastly, piles were evaluated for load capacity. A study sponsored by the American Short Line and Regional Railroad Association (ASLRRA) and the Federal Railroad Administration was consulted on a limited basis. The study, titled “Capability Evaluation of Short Line Timber Trestles to Handle 286 kip Loads,” provided useful information, but the methods for analysis were not entirely consistent with the scope of this study.

The standard timber trestle bridge plans specified Douglas Fir per the Chicago, Milwaukee, St. Paul & Pacific Railroad specifications. A copy of the specification was not available at the time of this report, therefore timber grades were assumed to be Douglas Fir-Larch No. 1 or better. Corresponding engineering design values were determined from AREMA Chapter 7, Section 2.7 - Allowable Unit Stresses for Stress-Graded Lumber. These allowable unit stresses are then converted to *permissible* unit stresses for rating according to AREMA Chapter 7, Section 2.10.14 – Unit Stresses. Two permissible unit stress levels are assigned for rating: Regularly Assigned Equipment or Locomotives and Equipment or Locomotives Not Regularly Assigned. These rating levels will hereafter be referred to as Normal and Maximum, respectively. This is consistent with terminology used for rating steel and concrete bridges.

To facilitate rating calculations, an Excel spreadsheet was created. The spreadsheet determines rating values based on user input for bridge geometry, material properties, and applied loads. Stringer moment, shear, and reaction values may be based on simple-span conditions or an average of simple-span and continuous conditions per AREMA Chapter 7, Section 2.10.5c. The user has the option for both. A partially continuous analysis will yield a reduced bending moment, however shear and pier reaction will increase. All values in this report were based on simple-span conditions to yield the best results for horizontal shear, a controlling load effect.

Equivalent Cooper E loads were also calculated for comparison. As discussed above, the equivalent Cooper E load creates the same load effect as the 286 kip railcar for the given bridge. Below are equivalent Cooper E loads for each span and three separate load effects.

Rating of Standard Timber Trestle Plans (Continued)

Table 4 - Equivalent Cooper E Loads for WSOR 286 kip Railcar

Standard Design	H-6140	H-6160	H-7040
Equivalent Cooper E Load for Bending =	E 58.4	E 55.5	E 58.4
Equivalent Cooper E Load for Shear =	E 67.2	E 68.2	E 67.2
Equivalent Cooper E Load for Bearing =	E 58.6	E 59.5	E 58.6

Two limiting rate factors exist for the five timber trestle bridges: stringer bending and pile load. Stringer bending is the controlling factor determining the rating values for each bridge. The standard designs for the 14'-0" trestles rate above 286 kip criteria at normal load levels. The standard design for the 16'-0" open deck pile trestle does not make normal load rating, but is above 286 kip criteria at maximum load levels. This leaves pile load and corresponding pile settlement as the critical issue.

Many of the timber piles are loaded beyond their capacity due to poor pile spacing. This is evident as pile settlement and is often noted in the inspection report. Pile loads were determined using the AREMA method for division of pile load among piles in a bent as discussed in Chapter 7, Section 2.4.5 - Bents. The pile loads based on ASLRRA distributions were not used for rating, as they do not make any consideration for pile spacing, however they are included in the calculations for comparison.

Another area of concern was horizontal shear in the stringers. AREMA basic allowable stresses for shear are quite conservative, but do allow increases given the condition of the timber. For rating purposes, it was assumed that no splits or checks greater than the width of the timber were present. This is consistent with inspection findings, which did not note any signs of distress related to horizontal shear (splitting near the ends of stringers).

Rating of Standard Timber Trestle Plans (Continued)

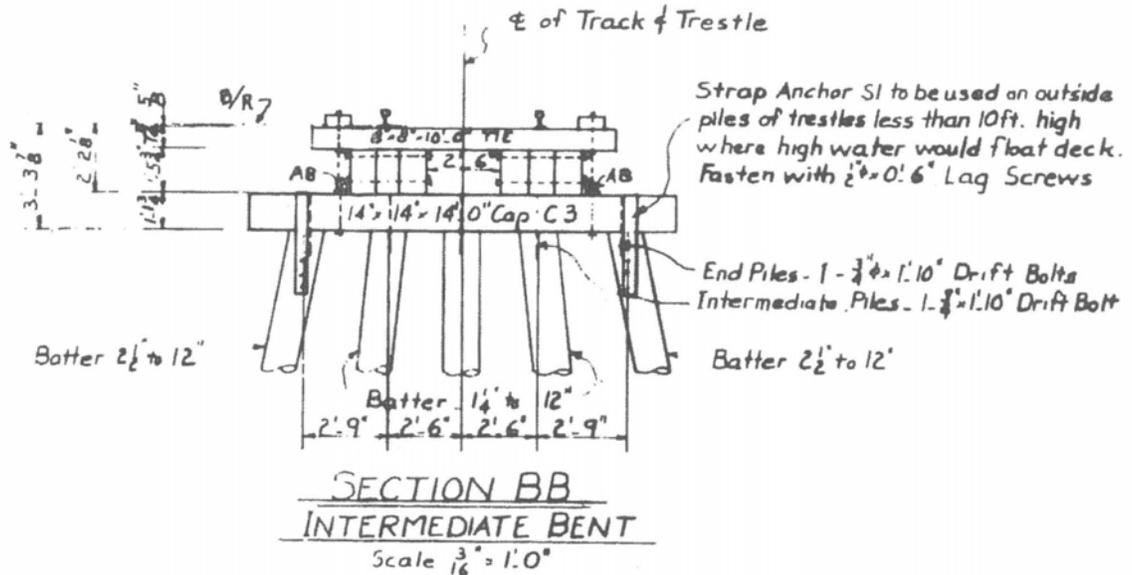


Pile Settlement – Note daylight shining between pile and cap.

Standard design H-6140 is an open-deck pile trestle bridge design with 14'-0" spans center-to-center of bents. Stringers consist of three 10"x18" timbers joined together under each line of rail. Bents consist of 14"x14" timber pile caps and five 14" diameter piles tapering to 9" minimum. Overall Cooper ratings for the H-6140 design are E 70 at normal level and E 84 at maximum level based on stringer bending. The normal and maximum ratings exceed the equivalent Cooper E load of E 58.4 for bending; therefore the superstructure is adequate to carry 286 kip railcar traffic.

Pile loads for the 286 kip railcar loading were 9.1 tons on the exterior piles, 21.9 tons on the intermediate piles, and 20.7 tons on the center pile. The standard plans specified that timber piles be driven to refusal or 25 ton capacity. Noting that pile loads are dependent upon their spacing per AREMA methods, this design may be adequate to carry 286 kip railcar traffic. However actual pile capacities could be less than stated, and improper pile spacing will increase pile loads.

Rating of Standard Timber Trestle Plans (Continued)



Typical Cross Section, Standard Drawings H-6140 & H-6160

Standard design H-6160 is an open-deck pile trestle bridge design with 16'-0" spans center-to-center of bents. Stringers consist of three 10"x18" timbers joined together under each line of rail. Bents consist of 14"x14" timber pile caps and five 14" diameter piles tapering to 9" minimum. Overall Cooper ratings are E 53 at normal level and E 63 at maximum level based on stringer Bending.

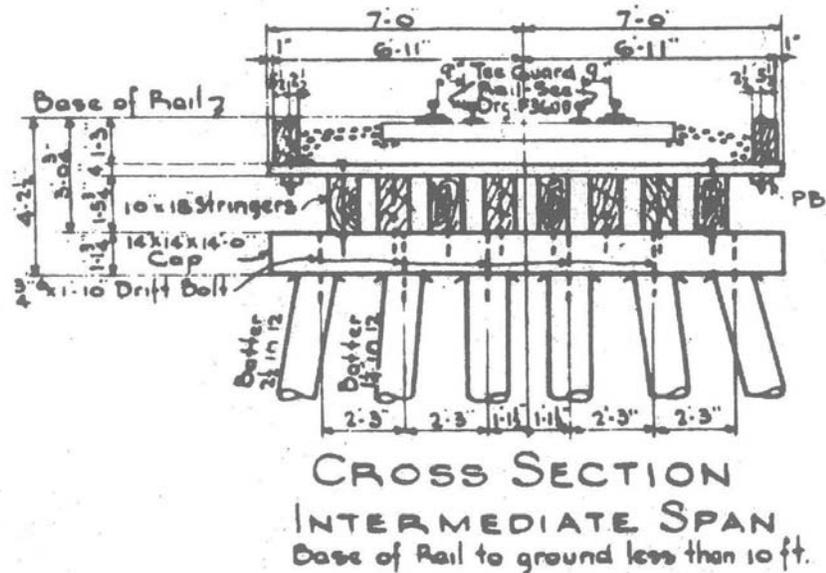
With an equivalent Cooper E load of E 55.5 for bending, the stringer stresses due to 286 kip railcar traffic will exceed AREMA normal rating stresses but are not high enough to cause significant damage. The stringers will be able to carry 286 kip railcar traffic at the cost of a reduction in the remaining useful service life.

Pile loads for the 286 kip railcar loading were 10.1 tons on the exterior piles, 24.4 tons on the intermediate piles, and 23.0 tons on the center pile. The standard plans specified that timber piles be driven to refusal or 25 ton capacity. As stated previously, actual pile capacities could be less than stated, and improper pile spacing will increase pile loads. Pile settlement is evident on many of the 16'-0" trestles inspected.

Rating of Standard Timber Trestle Plans (Continued)

Standard drawing H-7040 is a ballast deck pile trestle bridge design with 14'-0" spans center-to-center of bents. Stringers consist of eight 10"x18" timbers equally spaced underneath the ballast deck. Bents consist of 14"x14" timber pile caps and six 14" diameter pile tapering to 9" minimum. Overall Cooper ratings are E 86 at normal load level and E 104 at maximum level based on bending. These rating levels exceed 286 kip railcar traffic load criteria.

Pile loads for the 286 kip railcar loading were 8.7 tons on the exterior piles, 21.8 tons on the intermediate piles, and 17.9 tons on the center piles. The standard plans specified that timber piles be driven to refusal or 25 ton capacity. This design is adequate to carry 286 kip railcar traffic, and bridge D-78, the only ballasted deck trestle bridge inspected, did not exhibit any pile settlement.



Typical Cross Section, Standard Drawing H-7040

RATING SUMMARY - STANDARD TIMBER TRESTLE PLANS

Drawing H-6140, Open-Deck Pile Trestle – 14'-0"

Timber Stringer ratings

For Bending

Normal Cooper E Rating =	E 70	
Maximum Cooper E Rating =	E 84	
Normal 286 Kip Railcar Rating =	345	Kip
Maximum 286 kip Railcar Rating =	411	Kip

For Horizontal Shear

Normal Cooper E Rating =	E 75	
Maximum Cooper E Rating =	E 90	
Normal 286 Kip Railcar Rating =	321	Kip
Maximum 286 kip Railcar Rating =	383	Kip

For Bearing Against Pier Cap

Normal Cooper E Rating =	E 128	
Maximum Cooper E Rating =	E 152	
Normal 286 kip Railcar Rating =	625	Kip
Maximum 286 kip Railcar Rating =	743	Kip

Timber Piles - Load Capacity Calculations at the Pier Bent

Based on AREMA Figures for 5 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	29.34	tons
Exterior Pile Load =	12.18	tons
Center Pile Load =	27.67	tons
For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	21.93	tons
Exterior Pile Load =	9.10	tons
Center Pile Load =	20.69	tons

Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 87	
Maximum Cooper E Rating =	E 104	
Normal 286 kip Railcar Rating =	425	Kip
Maximum 286 kip Railcar Rating =	506	Kip

Drawing H-6160, Open-Deck Pile Trestle – 16'-0"

Timber Stringer ratings

For Bending

Normal Cooper E Rating =	E 53	
Maximum Cooper E Rating =	E 63	
Normal 286 kip Railcar Rating =	273	Kip
Maximum 286 kip Railcar Rating =	326	Kip

For Horizontal Shear

Normal Cooper E Rating =	E 65	
Maximum Cooper E Rating =	E 78	
Normal 286 kip Railcar Rating =	276	Kip
Maximum 286 kip Railcar Rating =	331	Kip

For Bearing Against Pier Cap

Normal Cooper E Rating =	E 116	
Maximum Cooper E Rating =	E 138	
Normal 286 kip Railcar Rating =	560	Kip
Maximum 286 kip Railcar Rating =	667	Kip

Timber Piles - Load Capacity Calculations at the Pier Bent

Based on AREMA Figures for 5 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	32.10	tons
Exterior Pile Load =	13.32	tons
Center Pile Load =	30.28	tons
For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	24.39	tons
Exterior Pile Load =	10.12	tons
Center Pile Load =	23.01	tons

Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 79	
Maximum Cooper E Rating =	E 94	
Normal 286 kip Railcar Rating =	380	Kip
Maximum 286 kip Railcar Rating =	453	Kip

Drawing H-7040, Ballast Deck Pile Trestle – 14'-0"

Timber Stringer ratings

For Bending

Normal Cooper E Rating =	E 86	
Maximum Cooper E Rating =	E 104	
Normal 286 kip Railcar Rating =	423	Kip
Maximum 286 kip Railcar Rating =	512	Kip

For Horizontal Shear

Normal Cooper E Rating =	E 90	
Maximum Cooper E Rating =	E 110	
Normal 286 kip Railcar Rating =	387	Kip
Maximum 286 kip Railcar Rating =	470	Kip

For Bearing Against Pier Cap

Normal Cooper E Rating =	E 161	
Maximum Cooper E Rating =	E 193	
Normal 286 kip Railcar Rating =	789	Kip
Maximum 286 kip Railcar Rating =	946	Kip

Timber Piles - Load Capacity Calculations at the Pier Bent

Based on AREMA Figures for 6 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	28.06	tons
Exterior Pile Load =	11.22	tons
Center Pile Load =	23.07	tons
For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	21.77	tons
Exterior Pile Load =	8.71	tons
Center Pile Load =	17.90	tons

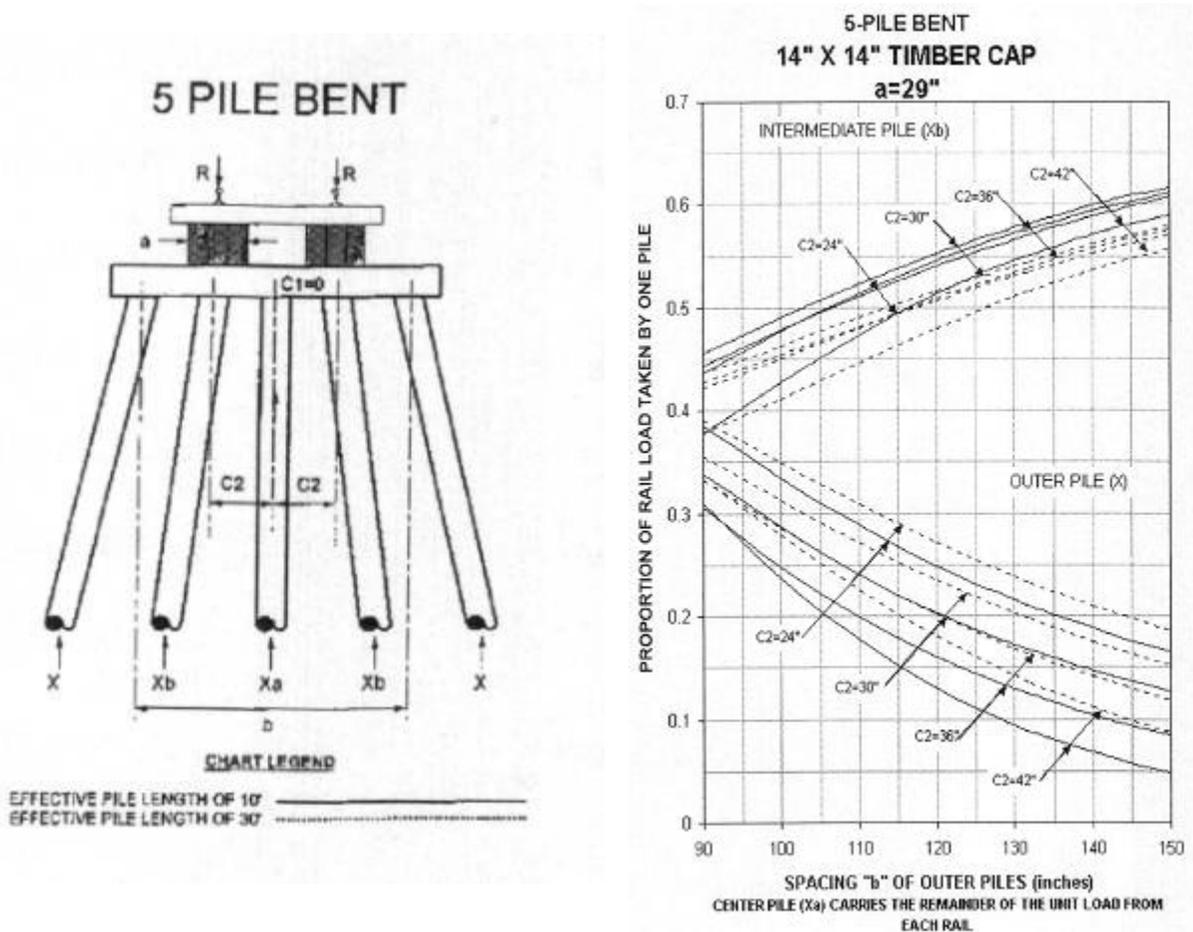
Check Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 92	
Maximum Cooper E Rating =	E 112	
Normal 286 kip Railcar Rating =	452	Kip
Maximum 286 kip Railcar Rating =	548	Kip

RATING OF AS-BUILT TIMBER TRESTLE BRIDGES

Five Wisconsin & Southern Railroad trestle bridges were rated for comparison with the standard plans. The bridges F-52, F-62, F-68, F-108, and F-116 were first inspected and included in the preliminary report. The report noted two primary areas of concern: decay deterioration and pile settlement. Any members exhibiting significant decay were noted as “rejected” and recommended for replacement. No adjustments were made to the ratings based on decay because members slated for replacement were to be restored to original capacity and because of difficulty in estimating section loss for members showing minimal signs of decay.

Pile settlement and/or poor pile spacing were noted on each of the five bridges. Pile settlement may be due to insufficient bearing capacity of the piles, increased rail loads, increased pile load due to poor pile spacing or any combination of the three. Pile spacing is particularly critical due to the fact that the interior piles in the bents were at or near the plan bearing capacity of 25 tons. The effects of the pile spacing noted in the field intensify the load distributed to the interior piles, aggravating an already critical issue.



AREMA Chart for Determining Pile Loads – Note how loads to intermediate piles increase with pile spacing.

Rating of As-Built Timber Trestle Bridges (Continued)

Where gaps exist between pile caps and piles, the inspecting engineer recommended that the piles be cut down and double caps be installed. Double capping affects pile loads by creating a more even load distribution. The stiffer cap is able to “shed” more load to the exterior piles. The typical load distribution for the cap and pile spacing given in the standard plan is 11% of track load on exterior piles, 26.5% on intermediate piles, and 25% on the center pile. This distribution was determined using AREMA methods. Computer analysis shows that by doubling the stiffness of the cap the load distribution changes to 12.5% on exterior piles and 25% on intermediate and center piles. This distribution is used on bridge F-116 where double caps have been installed.

The following ratings show pile loads as high as 42 tons for E 80 load and 32 tons for 286 kip railcar load on 16'-0” spans. Even with the greater load distribution of double caps, pile settlement may not cease to occur. Double capping will have a greater effect on the 14'-0” spans as shown by bridge F-116 where pile loads are less than 25 tons. Further discussion of the effects of double capping is included under the section *Recommended Maintenance and Repairs*.

RATING SUMMARY - AS-BUILT TIMBER TRESTLE BRIDGES

Bridge F-52

East of Hanover, WI

Monroe Subdivision, Milepost: 16.63

CMSt.P&P Standard: Open Deck Pile Trestle w/16' Spans - Drawing H-6160

Overall Rating

Normal Cooper E Rating =	E 53	<i>Bending</i>
Maximum Cooper E Rating =	E 63	<i>Bending</i>

A Cooper **E 55.5** load will create the same load effect as a 286 kip Railcar.

Normal 286 kip Railcar Rating =	273	kip
Maximum 286 kip Railcar Rating =	326	kip

Timber Stringer Ratings

No stringer deterioration noted in Preliminary Inspection Report.

Timber Piles - Load Capacity Calculations at the Pier Bent

Interior pile spacing for all bents varies from 36" to 46". This is an increase from the standard pile spacing of 30". Pile load distributions based on AREMA methods give a load increase of 20% on the center pile and a decrease of 5 to 10% on the exterior piles. Center pile loads for the 286 kip railcar increase from 23.01 tons to 32.21 tons. Adjusted pile loads and ratings are as follows:

Based on AREMA Figures for 5 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	30.28	tons
Exterior Pile Load =	9.08	tons
Center Pile Load =	42.39	tons

For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	23.01	tons
Exterior Pile Load =	6.90	tons
Center Pile Load =	32.21	tons

Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 82
Maximum Cooper E Rating =	E 98

Normal 286 kip Railcar Rating =	394	Kip
Maximum 286 kip Railcar Rating =	472	Kip

Bridge F-62 East of Orfordville, WI Monroe Subdivision, Milepost: 19.76

CMSt.P&P Standard: Open Deck Pile Trestle w/16' Spans - Drawing H-6160

Timber Stringer Ratings

Significant deterioration was noted in many of the stringers. Five stringers were rejected due to visual and mechanical inspection. The inspecting engineer recommended that the stringers be replaced over the full length of the bridge.

Timber Piles - Load Capacity Calculations at the Pier Bent

A washout condition was noted at the east bridge abutment. The inspecting engineer recommended investigating the bridge for replacement so that greater flow area is provided.

At the time of this report, Wisconsin & Southern had replaced the structure.

Bridge F-68

West of Orfordville, WI

Monroe Subdivision, Milepost: 22.28

CMSt.P&P Standard: Open Deck Pile Trestle w/14' Spans - Drawing H-6140

Overall Rating

Normal Cooper E Rating =	E 70	<i>Bending</i>
Maximum Cooper E Rating =	E 84	<i>Bending</i>

A Cooper **E 58.4** load will create the same load effect as a 286 kip Railcar.

Normal 286 kip Railcar Rating =	321	kip
Maximum 286 kip Railcar Rating =	383	kip

Timber Stringer Ratings

No stringer deterioration noted in Preliminary Inspection Report.

Timber Piles - Load Capacity Calculations at the Pier Bent

Bridge F-68 is a single span bridge. Therefore, no pier load conditions exist as they do with multi-span bridges. Interior pile spacing increased from 30" to 41" changing the pile load distribution. Adjusted pile loads and ratings are as follows:

Based on AREMA Figures for 5 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	20.89	tons
Exterior Pile Load =	5.22	tons
Center Pile Load =	28.12	tons
For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	16.20	tons
Exterior Pile Load =	4.05	tons
Center Pile Load =	21.81	tons

Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 122	
Maximum Cooper E Rating =	E 145	
Normal 286 kip Railcar Rating =	570	Kip
Maximum 286 kip Railcar Rating =	677	Kip

Bridge F-108

East of Juda, WI

Monroe Subdivision, Milepost: 33.44

CMSt.P&P Standard: Open Deck Pile Trestle w/16' Spans - Drawing H-6160

Overall Rating

Normal Cooper E Rating =	E 53	<i>Bending</i>
Maximum Cooper E Rating =	E 63	<i>Bending</i>

A Cooper **E 55.5** load will create the same load effect as a 286 kip Railcar.

Normal 286 kip Railcar Rating =	273	kip
Maximum 286 kip Railcar Rating =	326	kip

Timber Stringer Ratings

No stringer deterioration noted in Preliminary Inspection Report. Ratings do not change from standard plans. Stringers cantilever 22" to 23" over the centerline of the east abutment bent. The inspecting engineer recommended that the cantilever portions be cut and the east headwall be rebuilt.

Timber Piles - Load Capacity Calculations at the Pier Bent

Gaps were noted between the bottom of the cap and the top of the piles at three of the four bents, indicating pile settlement. Interior pile spacing increased from 30" to as much as 44" changing the pile load distribution. Center pile loads for the 286 kip railcar increase from 23.01 tons to 32.21 tons. Adjusted pile loads and ratings are as follows:

Based on AREMA Figures for 5 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	30.28	Tons
Exterior Pile Load =	9.08	Tons
Center Pile Load =	42.39	Tons
For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	23.01	Tons
Exterior Pile Load =	6.90	Tons
Center Pile Load =	32.21	Tons

Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 82	
Maximum Cooper E Rating =	E 98	
Normal 286 kip Railcar Rating =	394	Kip
Maximum 286 kip Railcar Rating =	472	Kip

To improve pile to cap bearing, the inspecting engineer recommended that the pile tops be cut down and double caps installed on all four bents.

Bridge F-116

West of Juda, WI

Monroe Subdivision, Milepost: 35.54

CMSt.P&P Standard: Open Deck Pile Trestle w/14' Spans - Drawing H-6140

Overall Rating

Normal Cooper E Rating =	E 70	<i>Bending</i>
Maximum Cooper E Rating =	E 84	<i>Bending</i>

A Cooper **E 58.4** load will create the same load effect as a 286 kip Railcar.

Normal 286 kip Railcar Rating =	321	kip
Maximum 286 kip Railcar Rating =	383	kip

Timber Stringer Ratings

No stringer deterioration noted in Preliminary Inspection Report. Ratings do not change from standard plans. The bridge had been rehabilitated recently and newer stringers were noted in the inspection.

Timber Piles - Load Capacity Calculations at the Pier Bent

Interior pile spacing was greater than the standard plans, but not as significant as previous bridges. Also, double caps were installed during the last rehabilitation. The following adjusted pile loads and ratings use the pile load distribution for double caps stated above.

Based on AREMA Figures for 5 Pile Bents

For Cooper E80 Loading		
Intermediate Pile Load =	27.67	Tons
Exterior Pile Load =	13.84	Tons
Center Pile Load =	27.67	Tons

For 286 Kip WSOR Railcar Loading		
Intermediate Pile Load =	20.69	Tons
Exterior Pile Load =	10.34	Tons
Center Pile Load =	20.69	Tons

Bearing between Timber Cap and Pile Ends

Normal Cooper E Rating =	E 93	
Maximum Cooper E Rating =	E 110	
Normal 286 kip Railcar Rating =	452	Kip
Maximum 286 kip Railcar Rating =	538	Kip

RATING OF AS-BUILT STEEL AND CONCRETE BRIDGES

The six steel and concrete bridges rated are adequate for carrying 286 kip railcar traffic. In terms of standard Cooper E rating, all of the bridges rated below E80 at normal levels. Most rated above normal level for carrying 286 kip railcar traffic, with bridge F-84 rating slightly below normal levels for 286 kip railcar loading. The condition of steel in the girder and truss bridges was good to fair. Section loss due to corrosion was minimal. Bridges D-58, D-125.5 and F-84 were rated using a reduced impact load according to current track speed. Those speeds are as indicated in the inspection report. The remaining bridges were rated using full impact regardless of track speed. With regular maintenance and inspection all six concrete and steel bridges will continue to remain in service. A summary of the steel and concrete bridge ratings is shown in table 5 followed by a discussion of each bridge.

Table 5 – Summary of Steel and Concrete Bridge Ratings

Bridge #	Cooper E Rating		Eq. Cooper E load for WSOR 286k Railcar	286k Railcar Rating	
	Normal	Maximum		Normal	Maximum
D-58 ¹	E 66	E 99	E 56.5	336	506
D-64	E 77	E 117	E 62.5	351	585
D-88	E 67	E 91	E 53.5	358	491
D-125.5 ¹	E 68	E 113	E 58.0	336	560
F-28	E 77	E 119	E 60.0	371	566
F-84 ¹	E 56	E 88	E 59.5	268	418

1. Rating values include a reduction in impact load based on current maximum track speed.

Bridge D-58

Bridge D-58 is an open deck plate girder span over the Rubicon River in Hartford with two 46'-1" girders making a single span. The girders were not originally built for the current location. Odd stiffener spacing and newer cross bracing suggests they were cut down and spread apart to fit the new location. Minor corrosion was noted on the web and top flange angles. An overall section loss of 5% was used to determine structural capacity. The bridge rates E 66 for normal load levels and E 99 for maximum load levels. Both ratings include a reduction in impact load based on the current maximum track speed of 25 mph for FRA Class 2 track. Both are greater than the equivalent Cooper E load of E 56.5. Bridge D-58 is adequate to carry 286 kip railcar traffic at current track speed. For a Class 3 track operating at 40 mph, the ratings would reduce to E 61 for normal load level and E 92 for maximum load level.

Bridge D-64

Bridge D-64 is an open deck plate girder span over a creek north of Hartford with two 25'-0" girders making a single span. No significant section loss was observed. The bridge rates E 77 for normal load levels and E 117 for maximum load levels without any reduction for track speed. Both are greater than the equivalent Cooper E load of E 62.5. Bridge D-64 is adequate to carry 286 kip railcar traffic and no retrofit is necessary.

Rating of As-Built Steel and Concrete Bridges (Continued)

Bridge D-88

Bridge D-88 consists of four ballasted deck timber stringer spans and two ballasted deck plate girder spans over the Rock River in Horicon. The plate girder spans consist of four different girders, each recycled from a different bridge. The girders were erected at their current location in 1911, and at least one of the girders was originally fabricated in 1888. Girder steel properties for rating were based on Bessemer steel rather than Open-Hearth steel assumed for all others. AREMA specifies lesser rating coefficients for Bessemer steel. No significant section loss was noted. Overall ratings for the two spans are E 67 at normal load level and E 91 at maximum load level without any reduction for track speed. Both are greater than the equivalent Cooper E load of E 53.5. The plate girder spans are adequate to carry 286 kip railcar traffic, however the spans should be regularly inspected given their age and nature of construction.

The remaining timber spans consist of two 18'-0" spans and two 15'-0" spans, each with nine 10"x18" stringers. The timber spans rest on concrete masonry piers and stone abutments. For the 18'-0" spans, the overall Cooper ratings are E 53 at normal level and E 65 at maximum level based on stringer bending. The 15'-0" spans rate E 89 at normal level and E 109 at maximum level based on horizontal shear. For the 18'-0" Spans, stresses due to 286 kip railcar traffic will exceed AREMA normal rating stresses but are not high enough to cause significant damage. The stringers will be able to carry 286 kip railcar traffic at the cost of a reduction in the remaining useful service life.

Bridge D-125½

Bridge D-125 ½ is a ballasted slab span over CTH S in Iron Ridge carrying two tracks. The three-part slab varies in thickness with the outer slabs having monolithic fascia beams. No section loss was assumed for rating, however values for deteriorated concrete were considered as specified in AREMA Chapter 8, Section 19.4.1 - Concrete. The bridge rates E 68 for normal load level and E 113 for maximum load level. Both ratings include a reduction in impact load based on the current maximum track speed of 15 mph for FRA Class 1 track. Both ratings are greater than the equivalent Cooper E load of E 58.0; therefore bridge D-125 ½ is adequate to carry 286 kip railcar traffic at current track speed. For a Class 3 track operating at 40 mph, the ratings would reduce to E 57 for normal load level and E 95 for maximum load level.

Bridge F-28

Bridge F-28 consists of three ballasted deck plate girder spans over a creek west of Janesville. Spans 1 and 3 are 35'-0" long and span 2 is 40'-0" long. Each span has four girders. No significant section loss was observed. The bridge rates E 77 for normal load level and E 119 for maximum load level without any reduction for track speed. The equivalent Cooper E load for the bridge is E 60.0, and therefore is adequate to carry 286 kip railcar traffic aside from deck repair noted in the inspection.

Rating of As-Built Steel and Concrete Bridges (Continued)

Bridge F-84

Bridge F-84 consists of a 35'-0" open deck plate girder span, a 105'-0" pony truss span, and 11 timber spans at the west approach. The timber spans conform to standard design H-6140. See previous discussion for rating information. The condition of the steel is good with no significant section loss. No existing plans were found for either span, so the superstructures were measured and recorded for rating purposes. Overall ratings for the girder span and truss are E 56 for normal load level and E 88 for maximum load level. Both ratings include a reduction in impact load based on the current maximum track speed of 25 mph for FRA Class 2 track. The equivalent Cooper E load for the bridge is E 59.5, and therefore 286 kip railcar loading will exceed normal rating capacity. In terms of percent capacity, 286 kip railcar loading is 107% of normal carrying capacity and 68% of maximum carrying capacity. Given the margin between normal and maximum levels and considering that the percentage over normal level is relatively small, no significant damage or loss of service life is anticipated. However, no increase above the current 25 mph track speed is recommended. For a Class 3 track operating at 40 mph, the ratings would reduce to E 53 for normal load level and E 83 for maximum load level.

The inspection report noted that pier 2 at the west end of the pony truss has settled and that the stone has deteriorated at the south bearing. The differential settlement of the pier opened a large crack in the masonry at the north end of the pier. See photo below. A 1971 railroad survey noted both the stone deterioration at the bearing and the settlement crack. The size of the crack in the 1971 survey is approximately the same as it is today. This indicates that the pier is stable and may continue to carry load. However, measures should be taken to repair the crack and the deteriorated stone. See the section *Inspection Findings* for further discussion and the section *Recommended Maintenance and Repairs*.



Bridge F-84, Pier 2 – Differential settlement of masonry pier.

RATING SUMMARY - AS-BUILT STEEL AND CONCRETE BRIDGES

Bridge D-58

Hartford, WI

Milwaukee Subdivision, Milepost: 121.5

Description: 46'-1" Open Deck Plate Girder Span
Two (2) girders, 60" deep. 5% approximate section loss.
No existing plans, all data obtained by inspection.

Rating Speed = 25 MPH

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 66	<i>Bending</i>
Maximum Cooper E Rating =	E 99	<i>Bending</i>

Equivalent Cooper E Load for 286 kip Railcar

A Cooper **E 56.5** load will create the same load effect as a 286 kip Railcar.

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	336	Kip
Maximum 286 kip Railcar Rating =	506	Kip

Increased Speed for Class 3 Track

Rating Speed = 40 MPH

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 61	<i>Bending</i>
Maximum Cooper E Rating =	E 92	<i>Bending</i>

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	312	Kip
Maximum 286 kip Railcar Rating =	466	Kip

Bridge D-64

North of Hartford, WI

Milwaukee Subdivision,
Milepost: 124.4

Description: 25'-0" Open Deck Plate Girder Span
Two (2) girders, 40" deep. 2% approximate section loss.
No existing plans, all data obtained by inspection.

Rating Speed = 60 MPH

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 77	<i>Shear</i>
Maximum Cooper E Rating =	E 117	<i>Bending</i>

Equivalent Cooper E Load for 286 kip Railcar

A Cooper **E 62.5** load will create the same load effect as a 286 kip Railcar.

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	351	kip
Maximum 286 kip Railcar Rating =	585	kip

Bridge D-88

Horicon, WI

Milwaukee Subdivision, Milepost: 138.6

Description: Ballasted Deck Plate Girder Spans 3 & 4
Span 3 - Two (2) 55'-0" Girders & Two (2) 53'-10 1/2" Girders
Span 4 - Two (2) 67'-1 1/2" Girders & One (1) 66'-4" Girder
2% approximate section loss - all girders.
Rated from existing plans and inspection notes.

Rating Speed = 60 MPH

Overall Rating**Cooper E Rating**

Normal Cooper E Rating = E 67 *Bending*
Maximum Cooper E Rating = E 91 *Bending*

Equivalent Cooper E Load for 286 kip Railcar

A Cooper E 53.5 load will create the same load effect as a 286 kip Railcar.

286 Kip Railcar Rating

Normal 286 kip Railcar Rating = 358 Kip
Maximum 286 kip Railcar Rating = 491 Kip

67'-1 1/2" Girder Rating (Girder 1)

Normal Cooper E Rating = E 94 *Bending*
Maximum Cooper E Rating = E 126 *Bending*

66'-4" Girder Rating (Girder 2)

Normal Cooper E Rating = E 67 *Bending*
Maximum Cooper E Rating = E 91 *Bending*

53'-10 1/2" Girder Rating (Girder 3)

Normal Cooper E Rating = E 85 *Bending*
Maximum Cooper E Rating = E 113 *Bending*

55'-0" Girder Rating (Girder 4)

Normal Cooper E Rating = E 74 *Shear*
Maximum Cooper E Rating = E 100 *Bending*

Bridge D-88 Timber Spans

Spans 1 & 2 - 18'-0" Spans, 9 Timber Stringers, Ballasted Deck

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 53	<i>Bending</i>
Maximum Cooper E Rating =	E 65	<i>Bending</i>

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	262	kip
Maximum 286 kip Railcar Rating =	323	kip

Spans 5 & 6 - 15'-0" Spans, 9 Timber Stringers, Ballasted Deck

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 89	<i>H. Shear</i>
Maximum Cooper E Rating =	E 109	<i>H. Shear</i>

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	398	kip
Maximum 286 kip Railcar Rating =	487	kip

Increased Speed for Class 3 Track

Rating Speed = 40 MPH

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 57	<i>Bending</i>
Maximum Cooper E Rating =	E 95	<i>Bending</i>

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	283	kip
Maximum 286 kip Railcar Rating =	472	kip

Middle Slab

Normal Cooper E Rating =	E 59	<i>Bending</i>
Maximum Cooper E Rating =	E 99	<i>Bending</i>

Side Slabs

Normal Cooper E Rating =	E 57	<i>Bending</i>
Maximum Cooper E Rating =	E 95	<i>Bending</i>

Edge Beams

Normal Cooper E Rating =	E 66	<i>Bending</i>
Maximum Cooper E Rating =	E 111	<i>Bending</i>

Bridge F-28

West of Janesville, WI

Monroe Subdivision, Milepost: 11.5

Description: Two 35'-0" Ballasted Deck Plate Girder Spans
One 40'-0" Ballasted Deck Plate Girder Span
Four (4) girders, 36" deep, spans 1 & 3. Four (4) girders, 40" deep, span 2.
2% approximate section loss – all girders.
No existing plans, all data obtained by inspection.

Rating Speed = 60 MPH

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 77	<i>Bending</i>
Maximum Cooper E Rating =	E 119	<i>Bending</i>

Equivalent Cooper E Load for 286 kip Railcar

A Cooper **E 60.0** load will create the same load effect as a 286 kip Railcar.

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	371	kip
Maximum 286 kip Railcar Rating =	566	kip

35'-0" Span Rating

Normal Cooper E Rating =	E 78	<i>Bending</i>
Maximum Cooper E Rating =	E 121	<i>Bending</i>

40'-0" Span Rating

Normal Cooper E Rating =	E 77	<i>Bending</i>
Maximum Cooper E Rating =	E 119	<i>Bending</i>

Bridge F-84

West of Brodhead, WI

Monroe Subdivision, Milepost: 28.90

Description: One 35'-0" Open Deck Plate Girder Span
One 105'-0" Pony Truss Span
2% approximate section loss – all steel.
No existing plans, all data obtained by inspection.

Rating Speed = 25 MPH

Overall Rating**Cooper E Rating**

Normal Cooper E Rating =	E 56	<i>Axial Tens.</i>
Maximum Cooper E Rating =	E 88	<i>Axial Tens.</i>

Equivalent Cooper E Load for 286 kip Railcar

A Cooper E 59.5 load will create the same load effect as a 286 kip Railcar.

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	268	Kip
Maximum 286 kip Railcar Rating =	418	Kip

35'-0" Span Rating

Normal Cooper E Rating* =	E 84	<i>Bending</i>
Maximum Cooper E Rating* =	E 125	<i>Bending</i>

105'-0" Pony Truss Rating

Normal Cooper E Rating =	E 56	<i>Axial Tens.</i>
Maximum Cooper E Rating =	E 88	<i>Axial Tens.</i>

Pony Truss Floorbeam Rating

Normal Cooper E Rating =	E 80	<i>Bending</i>
Maximum Cooper E Rating =	E 119	<i>Bending</i>

Pony Truss Stringer Rating

Normal Cooper E Rating =	E 74	<i>Bending</i>
Maximum Cooper E Rating =	E 110	<i>Bending</i>

Increased Speed for Class 3 Track

Rating Speed = 40 MPH

Overall Rating

Cooper E Rating

Normal Cooper E Rating =	E 53	<i>Axial Tens.</i>
Maximum Cooper E Rating =	E 83	<i>Axial Tens.</i>

286 Kip Railcar Rating

Normal 286 kip Railcar Rating =	254	Kip
Maximum 286 kip Railcar Rating =	396	Kip

35'-0" Span Rating

Normal Cooper E Rating* =	E 78	<i>Bending</i>
Maximum Cooper E Rating* =	E 116	<i>Bending</i>

105'-0" Pony Truss Rating

Normal Cooper E Rating =	E 53	<i>Axial Tens.</i>
Maximum Cooper E Rating =	E 83	<i>Axial Tens.</i>

Pony Truss Floorbeam Rating

Normal Cooper E Rating =	E 74	<i>Bending</i>
Maximum Cooper E Rating =	E 110	<i>Bending</i>

Pony Truss Stringer Rating

Normal Cooper E Rating =	E 69	<i>Bending</i>
Maximum Cooper E Rating =	E 101	<i>Bending</i>

BRIDGE INSPECTION FINDINGS & RECOMMENDATIONS

Wisconsin & Southern Railroad

Milwaukee Subdivision

Monroe Subdivision

August 2006



INSPECTION FINDINGS

A professional engineer licensed in the State of Wisconsin conducted the inspection of the bridges covered in this report. On timber bridges the piles, caps, and stringers in each bridge were hammer sounded to locate the presence of internal decay. A 3/8" diameter hole was drilled in those areas that were deemed suspect by hammer sounding, and the internal decay was measured with a void indicator. A thorough visual inspection of the primary structural members was conducted to note any checking, splitting, or mechanical damage that could affect the member's capacity. Each timber bridge was measured to determine what Milwaukee Road standard bridge plan the structure conformed to, and how well the bridge conformed to that standard.

On steel and concrete structures a thorough visual inspection was conducted of the substructure and superstructure. The steel superstructures were measured and recorded so that ratings calculations could be performed. Concrete structures showing visible signs of surface deterioration were hammer sounded to determine the depth of deterioration.

The deck ties, bracing, walkways, and headwalls were all inspected visually. Care was taken to note any instances of erosion or scour that may affect the bridge capacity or the adjacent right-of-way.

The inspection findings, dimensions, and other technical data for each bridge were then compiled in the bridge inspection report.

General Condition of Bridges

The condition of all the bridges inspected is generally fair to poor, with the exception of four bridges that were recently rehabilitated (D-58, D-64, F-68, & F-116). In general, the condition of the timber bridges is poor, the condition of the lone concrete bridge is good, and the condition of the steel bridges is good to fair. It is readily apparent that the bridges inspected, especially those on the Monroe Subdivision, have had minimal maintenance over the last two or three decades. Despite recent repairs to a limited number of bridges, several severe defects were noted during this inspection.

Timber Bridges

The two primary items of concern with the timber bridges inspected is decay deterioration and timber pile settlement. Other than the two bridges that were recently rehabilitated, defects due to decay deterioration are present in all of the timber structures inspected. The decay is most extensive in the ties, stringers, and caps of the timber bridges, and several of these timber components were found to be defective. The most serious decay defects were found in Bridges F-50, F-76, F-92, and F-134 on the Monroe Subdivision. All of these bridges contain failing caps or stringers that should be replaced within the next year.

The condition of the other bridges outside of these four bridges is not dramatically better. The tie decks on ten bridges of the Monroe Subdivision are in very poor condition. Over two dozen caps have been called out for replacement in the next 2-3 years and several spans of stringers have been called out for replacement.

Inspection Findings (Continued)

The second area of concern with the timber bridges, pile settlement, was noted in several bridges on the Monroe Subdivision. Nine bridges display active pile settlement, most likely the result of the inability of the piling to transfer the present loads to the ground. All of the bridges on the Monroe Subdivision contain bents that were driven with poor pile spacing. This poor pile spacing results in poor distribution of the loads to the piles and overloading of the center pile of the bent. In nearly all instances of pile settlement noted, it is the center pile that shows the greatest amount of settlement.

Analysis of the existing bent design shows that with proper pile spacing, the E60 bent design utilized for the bridges of the Monroe Subdivision is theoretically sufficient to support 286 kip cars. However, there are two reasons contrary to this assertion. First, when the actual pile spacing is considered in the analysis, the load from a 286 kip car on the center pile is greater than the design load. Second, the stated design capacity of the piling may be greater than the actual capacity. It is likely that both these factors contribute to pile settlement.

Steel and Concrete Bridges

The primary item of concern with the steel and concrete bridges inspected is the settlement of Pier 2 at Bridge F-84 of the Monroe Subdivision. This masonry pier was constructed in 1882, and a 1971 survey indicated much the same deterioration. This differential settlement has opened the joints in the masonry, and has broken some stones in the pier. Overall the pier appears to have settled around 2". Without an existing plan or record of construction it is difficult to assess the reasons for settlement. The most likely cause is an increase in footing bearing pressure due to increased traffic loads and/or differential stiffness of the supporting soil.

RECOMMENDATIONS

The extensive list of recommendations for the bridges of the Milwaukee and Monroe subdivisions can be divided into three categories; Maintenance Repairs, Capital Construction, and Regular Inspection. Maintenance repairs are intended to correct capacity reducing defects in bridges with sufficient capacity and return those bridges back to their original design capacity. Capital construction is intended to replace those bridges that lack the capacity to support the sustained operation of 286 kip cars within the next five years. In the case of the four bridges included in the capital construction recommendations, this lack of capacity is due to severe and extensive pile settlement defects.

Additional capital outlays will be required in the future to replace bridges that are affected by increased pile settlement. The ratings data suggests that the timber bridges with 16' spans are more likely to experience increased settlement prior to those timber bridges with 14' spans. For this reason the estimated service life of these bridges has been reduced and these bridges are more likely to require capital replacement within the next 20 years. However, because the actual pile capacities of the bridges are unknown and the available capital budget is small, we have chosen not to recommend a program of blanket replacement for timber bridges with 16' spans. In some cases the actual pile capacities of 16' span bridges will be greater than the design specification, and in other cases the pile capacities of 14' span bridges will be less than the design specification. As a result of this variation there will be situations where 14' span bridges display active settlement and will require replacement before some 16' span bridges.

The maintenance and capital recommendations allow for safe 286 kip operations, but it is the final recommendation category, Regular Inspection, that will allow for sustainable 286 kip operations. By instituting a regular inspection program, defects that arise after the commencement of 286 kip operations can be identified and corrected before failures occur.

Altogether the maintenance and capital recommendations in this report outline \$2,927,000 of maintenance and capital work over the next five years to address the defects located during the inspection. The cost to institute a regular inspection program is difficult to estimate, but the value of this program is tremendous when the cost of a major bridge failure is considered.

Maintenance Repairs

To return the timber bridges to their design capacity an extensive list of recommended maintenance repairs with an estimated cost of \$827,250 has been compiled. These recommended maintenance repairs include the replacement of all the stringers in five bridges, the replacement of the tie decks on fourteen bridges, and the replacement of 36 caps. The remaining timber work includes headwall repairs, bracing replacement and installation, and shim work.

Recommendations (Continued)

On timber bridges where decay deterioration is present without severe pile settlement we have recommended replacing defective members with a new timber member of similar dimensions to maintain the existing capacity. No attempt was made to increase the capacity of the timber bridge by increasing the dimensions or number of stringers because the results of the bridge ratings indicate that the pile capacity is often the controlling factor in rated bridge capacity.

To return the concrete and steel bridges to their design capacity, a list of recommended maintenance repairs with an estimated cost of \$620,000 has been compiled. A majority of this estimated cost is to address the settlement of Pier 2 at Bridge F-84. Among the bridges studied, most of the maintenance repairs to the concrete and steel bridges are of a lower priority when compared to the recommended repairs for timber bridges. Conditions do vary and the sample of steel bridges within this project is small so this may not be the case for the remainder of the railroad.

Capital Construction

Bridges F-60, F-80, F-84 West Approach, F-90, and F-108 have been recommended for reconstruction to address severe and extensive pile settlement that was observed at those bridges. At Bridge F-90, active pile settlement was present along with a visible line swing in the structure, for this reason we have assigned this bridge the highest reconstruction priority.

Overall, the estimated cost to replace all four of these bridges is \$1,479,750. The estimated costs were based on replacing all four bridges with an open deck steel trestle of similar length to the existing bridge. It was assumed that soil conditions at each site would make a pile driven structure feasible. The example replacement structure is based on design recommendations established by the 2005 AREMA Manual for Railway Engineering.

The decision to recommend reconstructing a bridge was heavily dependent on how widespread and severe the observed pile settlement was at a bridge. In the case of the four bridges noted above, the pile settlement was both severe and widespread throughout the bridge. Pile settlement is a persistent failure that will worsen over time and ultimately leads to further defects in the caps, stringers, and line and surface of bridge. Generally, the only effective way to eliminate extensive pile settlement is to re-drive and completely replace the bridge substructure. The four bridges called out for reconstruction also have several decay defects, so in no case is a bridge that is otherwise in good structural condition being recommended for replacement due to pile settlement.

Recommendations (Continued)



Capital Improvement – A new steel trestle bridge.

In a limited number of cases it may be possible to address severe pile settlement by re-driving the substructure of the bridge while retaining the existing timber superstructure. The primary advantage of this approach is that it will postpone the costs associated with superstructure replacement and allow the service life of the existing timber superstructure to be fully realized. The costs associated with superstructure re-construction typically represent 15-25% of the total project cost for bridges with 20' or shorter open deck steel spans. This cost could be postponed by retaining the existing superstructure.

However, there are some additional future costs that limit the effectiveness of this approach. First, an additional mobilization and demobilization charge will be incurred when forces are brought back to install the superstructure at a later date. If the site is in a remote location, these mobilization costs could be significant. Second, the new substructure will need to match the varied lengths of the existing timber spans and this varied spacing will lead to additional engineering and fabrication costs to install a superstructure in the future. To overcome these additional future costs, the existing superstructure needs to be in good condition and able to provide 10-20 years of service life. Also, partial reconstruction is less cost effective on shorter bridges (less than 75') because there is less structure length to distribute the fixed re-mobilization costs. For the reasons stated above, the partial reconstruction approach will only be appropriate to address pile settlement on easily accessible, longer bridges (greater than 75') with timber superstructures that are in good or excellent condition. While some bridges elsewhere on the Wisconsin & Southern system may qualify for this approach, there were no bridges within the study group that would meet these conditions.

Recommendations (Continued)

In cases where there was limited or minor pile settlement we have recommended cutting down the piling and installing a stiffer cap section in lieu of re-driving the bridge. While this will not offer a long-term solution to the observed pile settlement, hopefully installing a stiffer cap section will delay the replacement of the bridge so the more critical bridges can be addressed first.

Based on the results of the rating analysis, the open deck timber bridges with 16' spans are more likely to see increased pile settlement and other capacity related defects with the introduction of regular 286 kip traffic. All things being equal, these bridges should be subject to capital replacement before the 14' span bridges. However, the decision to replace a timber bridge in the future should be based on bridge condition, extent of decay, presence of active pile settlement, and rated capacity - not on rated capacity alone.

Regular Inspection

The recommendations section for every bridge covered in this report includes a recommendation to conduct an annual bridge inspection. We strongly suggest that a bridge inspection program be established by the railroad or the state to cover not only bridges of the Monroe and Milwaukee Subdivision, but the entire railroad. The program should call for the annual inspection of all bridges; creation of written bridge inspection records including bridge data, observed defects, and prioritized recommendations; centralized storage of those records; and the designation of individual responsible for bridge inspection and management.

Overall the Wisconsin and Southern operates across 275 state-owned bridges, not including bridges on other leased lines, and most of those bridges have been subject to deferred maintenance for the last 20-30 years. The bridges covered by this study represent only 10% of the bridges on the railroad and yet within this small sample there are five bridges with severe defects that warrant repairs within one year. While the condition of the railroad's subdivisions does vary, simple extrapolation of these numbers implies there may be 50 bridges located on the Wisconsin & Southern system with severe defects requiring repairs within one year. The actual number of bridges with severe defects may be more or less, but this number will remain unknown until an inspection program is in place. Instituting an effective program will allow the railroad to locate severe defects that may exist before they become a threat to the safe operation of trains.

An organized and well-managed annual bridge inspection program will be particularly important as the state and the railroad begin to invest a limited amount of funds in needed capital construction. With the number of bridges that will require replacement in the next 20 years and the limited budget available it is imperative that data regarding the condition of the bridges throughout the railroad is routinely updated and current. An up to date bridge inspection record for the railroad will allow funds to be directed more effectively to the most critical bridges first.

RECOMMENDED MAINTENANCE AND REPAIRS

Based on the inspection findings, the following lists of recommendations are provided for the bridges of the Monroe and Milwaukee Subdivisions. The list of recommendations has been presented in two formats. The first list of recommendations is formatted in the order of priority, with the recommendations of the same priority category for all bridges listed together. The second list is formatted by bridge, with all the recommendations for each bridge listed together.

The following repair priorities are recommendations only. They are based on the information gathered during the inspection procedure previously described and the professional judgment of the inspecting engineer. The eventual failure of a structure or structural component may be linked to numerous factors, including but not limited to, rail traffic, rail capacity, loading, speed and weather. Specific traffic patterns, speeds, capacities or loads for each structure were not analyzed and are not included in making repair priority recommendations. Repair priority recommendations are based on: (1) the structure's condition as of the date of inspection; and (2) information provided by WSOR regarding rail traffic, capacity, loads and speed.

At this time, the repair recommendations have been assigned one of the following priorities:

- **1st Priority (Emergency):** recommend that the Owner undertake repairs to the structure immediately and prior to the structure being subjected to additional live loads. Structure failure is imminent.
- **2nd Priority:** recommend that the Owner undertake repairs to the structure within the next year and that the structure be monitored on a monthly basis for signs of additional deterioration or impending failure.
- **3rd Priority:** recommend that the Owner undertake repairs to the structure within the next two to three (2-3) years and that the structure be monitored on a semi-annual basis for signs of additional deterioration or impending failure.
- **4th Priority:** recommend that the Owner undertake repairs to the structure within the next three to five (3-5) years and that the structure be monitored on an annual basis for additional deterioration.
- **5th Priority (Regular Maintenance):** recommend that the Owner undertake repairs as part of its routine maintenance plan so as to prevent additional deterioration and potentially extend the life of the structure.

RECOMMENDED MAINTENANCE AND REPAIRS

Listed in Order of Priority.

1st Priority EMERGENCY Repair Recommendations

There are no emergency repair recommendations.

2nd Priority Repair Recommendations

Bridge F-50 – Monroe Subdivision:

1. Replace cap on Bent 3.

Bridge F-62 – Monroe Subdivision:

1. Replace the stringers across the full length of the bridge.

Bridge F-76 – Monroe Subdivision:

1. Replace all stringers in bridge.

Bridge F-92 – Monroe Subdivision:

1. Replace caps on Bents 2, 3, & 4.

Bridge F-134 – Monroe Subdivision:

1. Cut down pile tops and replace cap on Bent 6 with a double cap.

3rd Priority Repair Recommendations

Bridge D-78 – Milwaukee Subdivision:

1. Replace cap on Bent 3.

Bridge D-88 – Milwaukee Subdivision:

1. Replace the subcap on Pier 5.
2. Rebuild walkways on both side of deck.

Bridge F-28 – Monroe Subdivision:

1. Replace timber ballast deck over all three spans.

Bridge F-30 – Monroe Subdivision:

1. Replace entire tie deck.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
3rd Priority (Continued)

Bridge F-40 – Monroe Subdivision:

1. Replace all stringers in bridge.
2. Replace entire tie deck.
3. Replace the cap on Bent 1.

Or:

1. Investigate replacing bridge with pipe and fill.

Bridge F-50 – Monroe Subdivision:

1. Replace entire tie deck.

Bridge F-52 – Monroe Subdivision:

1. Replace entire tie deck.
2. Replace the caps on Bents 4, 6, & 7.
3. Double cap Bent 2 and 3 to slow pile settlement.

Bridge F-60 – Monroe Subdivision:

1. Place bridge in rebuild program.
2. Spot replace most severely deteriorated ties.

Bridge F-76 – Monroe Subdivision:

1. Replace entire tie deck.
2. Replace the cap on Bent 1.

Bridge F-80 – Monroe Subdivision:

1. Install helper stringers on all spans.
2. Place bridge in rebuild program.

Bridge F-82 – Monroe Subdivision:

1. Cut down piles and replace the caps on Bents 1, 3, 6, & 8 with 16” deep caps.
2. Install sway bracing on Bents 3-7.

Bridge F-84 Main Span – Monroe Subdivision:

1. Survey bridge to determine the amount of settlement at Pier 2.
2. Raise the west end of Span 2 so the pony truss is resting at the proper elevation.
3. Install #8 pins across and pressure grout crack on north end of Pier 2.
4. Clean masonry joints in Pier 2.
5. Remove deteriorated stones from Pier 2 bearing areas, install precast blocks, and encase pier with reinforced concrete.
6. Replace ties on Spans 1 & 2.
7. Tamp up east approach.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
3rd Priority (Continued)

Bridge F-84 West Approach – Monroe Subdivision:

1. Cut down piles and replace the cap on Bent 7 with a 16” deep cap.
2. Replace rejected stringers in Spans 1-6.
3. Place bridge in rebuild program.

Bridge F-90 – Monroe Subdivision:

1. Rebuild bridge to address active pile settlement, poor stringer condition, line swing in bridge, and timber decay.

Bridge F-92 – Monroe Subdivision:

1. Replace entire tie deck.

Bridge F-108 – Monroe Subdivision:

1. Place bridge in rebuild program.
2. Spot replace most severely deteriorated ties.

Bridge F-114 – Monroe Subdivision:

1. Cut down piles and replace caps on all bents with double caps.
2. Replace entire tie deck.
3. Tamp up approaches.
4. Shim under stringers at Bent 3.
5. Replace rejected shim on Bent 1.

Or

1. Investigate replacing the structure with a pipe and fill.

Bridge F-122 – Monroe Subdivision:

1. Replace caps on Bents 2 & 3.

Bridge F-134 – Monroe Subdivision:

1. Replace entire tie deck.
2. Replace all stringers in all spans.
3. Rebuild west headwall and extend deeper.

4th Priority Repair Recommendations

Bridge D-64 – Milwaukee Subdivision:

1. Install anchors securing headwall timbers to the concrete abutments.

Bridge D-78 – Milwaukee Subdivision:

1. Replace headwall timbers damaged by regulator.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
4th Priority (Continued)

Bridge D-125½ – Milwaukee Subdivision:

1. Epoxy inject 1/8” structural cracks in both abutments.
2. Remove tree growing out of northwest corner of span.
3. Chip deteriorated concrete from the east face of span and ballast curb and cast back to original lines.

Bridge D-88 – Milwaukee Subdivision:

1. Chip deteriorated concrete from bearing area of Pier 2 riser and cast back with polymer concrete.
2. Epoxy inject 1/8” structural crack in Pier 3.
3. Chip deteriorated concrete from bearing area of Pier 4 riser and cast back with polymer concrete.
4. Chip delaminated concrete from the south face of Pier 5 and patch back to original lines.
5. Pin and grout structural crack in the North abutment shaft.

Bridge F-28 – Monroe Subdivision:

1. Remove deteriorated concrete from east abutment and cast back to original lines with cast-in-place concrete.
2. Remove deteriorated concrete from top of Pier 1 and add a 6” reinforced concrete encasement around the top of the pier. Waterproof bearing seat.
3. Chip deteriorated concrete from base of Pier 1 and cast back to original lines with cast-in-place concrete.

Bridge F-30 – Monroe Subdivision:

1. Replace the east sway brace on Bent 2.

Bridge F-34 – Monroe Subdivision:

1. Replace the west sway brace on Bent 2.
2. Replace the cap on Bent 3.
3. Replace Stringer 1 in Spans 2 & 3.
4. Replace entire tie deck.

Bridge F-40 – Monroe Subdivision:

1. Replace the cap on Bent 2.

Bridge F-50 – Monroe Subdivision:

1. Replace the cap on Bent 2.

Bridge F-52 – Monroe Subdivision:

1. Replace the cap on Bent 1.
2. Replace missing brace bolts in Bents 5 and 6.
3. Install sway bracing on Bent 7.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
4th Priority (Continued)

Bridge F-60 – Monroe Subdivision:

1. Rebuild bridge to address pile settlement concerns.

Bridge F-62 – Monroe Subdivision:

1. Investigate rebuilding or extending structure so that greater flow area is provided at the east end of the bridge.
2. Spot replace defective ties.
3. Post Pile 2 of Bent 3.

Bridge F-76 – Monroe Subdivision:

1. Cut down piles and install double cap on Bent 2, 5 & 6 to address pile settlement.

Bridge F-80 – Monroe Subdivision:

1. Rebuild bridge to address pile settlement and timber condition.

Bridge F-82 – Monroe Subdivision:

1. Cut down piles and replace the caps on Bents 2, 4, 5, & 9 with 16” deep caps.
2. Replace 41 defective ties in deck, or replace entire tie deck.
3. Address pile settlement by cutting down piles and installing stiffer cap section.

Bridge F-84 Main Span – Monroe Subdivision:

1. Reset expansion bearings on the east end on Span 2.
2. Remove deteriorated concrete from the south end of the East Abutment and cast back to original lines.

Bridge F-84 West Approach – Monroe Subdivision:

1. Rebuild bridge to address pile settlement and penetration concerns.

Bridge F-92 – Monroe Subdivision:

1. Replace all stringers in bridge.

Bridge F-108 – Monroe Subdivision:

1. Rebuild bridge to address pile settlement concerns and timber condition.

Bridge F-114 – Monroe Subdivision:

1. Replace all stringers in all spans.

Bridge F-120 – Monroe Subdivision:

1. Replace Stringer 6 in Spans 1 & 2, and Stringer 1 in Span 3.
2. Replace entire tie deck.

Bridge F-122 – Monroe Subdivision:

1. Replace entire tie deck.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
4th Priority (Continued)

Bridge F-134 – Monroe Subdivision:

1. Replace sway bracing on Bents 2-5.
2. Post Pile 1 of Bent 1.
3. Replace the cap on Bent 4.
4. Cut down pile tops and replace cap on Bent 2 with a double cap.

5th Priority (Regular Maintenance) Recommendations

Bridge D-58 – Milwaukee Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor corrosion to span.
4. Monitor spalling on wingwalls of both abutments.

Bridge D-64 – Milwaukee Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor spalled concrete at the base of the south abutment.
4. Monitor spalling on wingwalls of both abutments.

Bridge D-78 – Milwaukee Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of deck.
4. Monitor condition of Stringer 1 in Span 1.

Bridge D-125½ – Milwaukee Subdivision:

1. Perform annual bridge inspection.
2. Monitor spalling and pattern cracking on both abutments.
3. Monitor movement of east wingwall on south abutment.
4. Monitor condition of concrete on underside of span.

Bridge D-88 – Milwaukee Subdivision:

1. Perform annual bridge inspection.
2. Monitor condition of timber stringers.
3. Monitor spalling at waterline on Piers 2 & 3.

Bridge F-28 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Monitor spalling on the west abutment.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
5th Priority (Continued)

Bridge F-30 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the cap on Bent 3 and Stringer 6 of Span 3.

Bridge F-34 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the cap on Bent 1.

Bridge F-40 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the cap on Bent 4.
4. Monitor piling for settlement.

Bridge F-50 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor piling for settlement.

Bridge F-52 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the piling in Bents 2, 3, & 7 for settlement.
4. Shim tight any gaps between piles and caps.

Bridge F-60 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of deck and stringers.
4. Monitor piling for settlement.
5. Monitor cap on Bent 4.
6. Monitor scour that is occurring under the bridge and mitigate any contributing factors when the bridge is rebuilt.

Bridge F-62 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the east headwall for ballast loss or rotation.

Bridge F-68 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
5th Priority (Continued)

Bridge F-76 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for settlement.
5. Monitor cap on Bent 4.

Bridge F-80 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for continued settlement.
5. Monitor cap on Bent 2.
6. Monitor condition of east headwall.

Bridge F-82 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for increased settlement.
5. Monitor condition of stringers.

Bridge F-84 Main Span – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor Pier for increased settlement.
5. Monitor concrete condition on east abutment and Pier 1.

Bridge F-84 West Approach – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for increased settlement.
5. Monitor condition of stringers.

Bridge F-90 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for increased settlement.
5. Monitor condition of stringers.
6. Monitor condition of caps.

Recommended Maintenance and Repairs Listed in Order of Priority (Continued)
5th Priority (Continued)

Bridge F-92 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor condition of stringers.
5. Monitor condition of caps.

Bridge F-108 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor settlement and shim as necessary until bridge is rebuilt.

Bridge F-114 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of caps.

Bridge F-116 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.

Bridge F-120 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of cap on Bent 4.

Bridge F-122 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor bridge for possible wash-out during high water events, if wash-outs are a problem, excavate bridge.

Bridge F-134 – Monroe Subdivision:

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Clear brush from under bridge to reduce fire risk.
4. Shim piles as required.

RECOMMENDED MAINTENANCE AND REPAIRS

Listed by Bridge.

MILWAUKEE SUBDIVISION

Bridge D-58 – Hartford, WI

5th Priority (Annual Maintenance):

5. Perform annual bridge inspection.
6. Tamp up bridge approaches.
7. Monitor corrosion to span.
8. Monitor spalling on wingwalls of both abutments.

Bridge D-64 – Hartford, WI

4th Priority:

1. Install anchors securing headwall timbers to the concrete abutments.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor spalled concrete at the base of the south abutment.
4. Monitor spalling on wingwalls of both abutments.

Bridge D-78 – Woodland, WI

3rd Priority

1. Replace cap on Bent 3.

4th Priority

1. Replace headwall timbers damaged by regulator.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of deck.
4. Monitor condition of Stringer 1 in Span 1.

Bridge D-125½ – Iron Ridge, WI

4th Priority:

1. Epoxy inject 1/8" structural cracks in both abutments.
2. Remove tree growing out of northwest corner of span.
3. Chip deteriorated concrete from the east face of span and ballast curb and cast back to original lines.

Recommended Maintenance and Repairs Listed by Bridge (Continued)
Bridge D-125½ (Continued)

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Monitor spalling and pattern cracking on both abutments.
3. Monitor movement of east wingwall on south abutment.
4. Monitor condition of concrete on underside of span.

Bridge D-88 – Horicon, WI

3rd Priority:

1. Replace the subcap on Pier 5.
2. Rebuild walkways on both side of deck.

4th Priority:

1. Chip deteriorated concrete from bearing area of Pier 2 riser and cast back with polymer concrete.
2. Epoxy inject 1/8" structural crack in Pier 3.
3. Chip deteriorated concrete from bearing area of Pier 4 riser and cast back with polymer concrete.
4. Chip delaminated concrete from the south face of Pier 5 and patch back to original lines.
5. Pin and grout structural crack in the North abutment shaft.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Monitor condition of timber stringers.
3. Monitor spalling at waterline on Piers 2 & 3.

MONROE SUBDIVISION

Bridge F-28 – Janesville, WI

3rd Priority

1. Replace timber ballast deck over all three spans.

4th Priority

1. Remove deteriorated concrete from east abutment and cast back to original lines with cast-in-place concrete.
2. Remove deteriorated concrete from top of Pier 1 and add a 6" reinforced concrete encasement around the top of the pier. Waterproof bearing seat.
3. Chip deteriorated concrete from base of Pier 1 and cast back to original lines with cast-in-place concrete.

Recommended Maintenance and Repairs Listed by Bridge (Continued)
Bridge F-28 (Continued)

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Monitor spalling on the west abutment.

Bridge F-30 – Janesville, WI

3rd Priority

1. Replace entire tie deck.

4th Priority

1. Replace the east sway brace on Bent 2.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the cap on Bent 3 and Stringer 6 of Span 3.

Bridge F-34 – Janesville, WI

4th Priority

1. Replace the west sway brace on Bent 2.
2. Replace the cap on Bent 3.
3. Replace Stringer 1 in Spans 2 & 3.
4. Replace entire tie deck.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the cap on Bent 1.

Bridge F-40 – Hanover, WI

3rd Priority

1. Replace all stringers in bridge.
2. Replace entire tie deck.
3. Replace the cap on Bent 1.

Or:

1. Investigate replacing bridge with pipe and fill.

4th Priority

1. Replace the cap on Bent 2.

Recommended Maintenance and Repairs Listed by Bridge (Continued)
Bridge F-40 (Continued)

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the cap on Bent 4.
4. Monitor piling for settlement.

Bridge F-50 – Hanover, WI

2nd Priority

1. Replace cap on Bent 3.

3rd Priority

1. Replace entire tie deck.

4th Priority

1. Replace the cap on Bent 2.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor piling for settlement.

Bridge F-52 – Hanover, WI

3rd Priority

1. Replace entire tie deck.
2. Replace the caps on Bents 4, 6, & 7.
3. Double cap Bent 2 and 3 to slow pile settlement.

4th Priority

1. Replace the cap on Bent 1.
2. Replace missing brace bolts in Bents 5 and 6.
3. Install sway bracing on Bent 7.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the piling in Bents 2, 3, & 7 for settlement.
4. Shim tight any gaps between piles and caps.

Recommended Maintenance and Repairs Listed by Bridge (Continued)

Bridge F-60 – Hanover, WI

3rd Priority

1. Place bridge in rebuild program.
2. Spot replace most severely deteriorated ties.

4th Priority

1. Rebuild bridge to address pile settlement concerns.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of deck and stringers.
4. Monitor piling for settlement.
5. Monitor cap on Bent 4.
6. Monitor scour that is occurring under the bridge and mitigate any contributing factors when the bridge is rebuilt.

Bridge F-62 – Orfordville, WI

2nd Priority*

1. Replace the stringers across the full length of the bridge.

4th Priority*

1. Investigate rebuilding or extending structure so that greater flow area is provided at the east end of the bridge.
2. Spot replace defective ties.
3. Post Pile 2 of Bent 3.

5th Priority (Annual Maintenance):*

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor the east headwall for ballast loss or rotation.

**Note: Bridge rebuilt in early 2006, these recommendations no longer apply.*

Bridge F-68 – Orfordville, WI

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.

Recommended Maintenance and Repairs Listed by Bridge (Continued)

Bridge F-76 – Brodhead, WI

2nd Priority

1. Replace all stringers in bridge.

3rd Priority

1. Replace entire tie deck.
2. Replace the cap on Bent 1.

3rd Priority

1. Cut down piles and install double caps on Bents 2, 5 & 6 to address pile settlement.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for settlement.
5. Monitor cap on Bent 4.

Bridge F-80 – Brodhead, WI

3rd Priority

1. Install helper stringers on all spans.

4th Priority

1. Rebuild bridge to address pile settlement and timber condition.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for continued settlement.
5. Monitor cap on Bent 2.
6. Monitor condition of east headwall.

Bridge F-82 – Brodhead, WI

3rd Priority

1. Cut down piles and replace the caps on Bents 1, 3, 6, & 8 with 16” deep caps.
2. Install sway bracing on Bents 3-7.

Recommended Maintenance and Repairs Listed by Bridge (Continued)
Bridge F-82 (Continued)

4th Priority

1. Cut down piles and replace the caps on Bents 2, 4, 5, & 9 with 16” deep caps.
2. Replace 41 defective ties in deck, or replace entire tie deck.
3. Address pile settlement by cutting down piles and installing stiffer cap section.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for increased settlement.
5. Monitor condition of stringers.

Bridge F-84 Main Span – Brodhead, WI

3rd Priority

1. Survey bridge to determine the amount of settlement at Pier 2.
2. Raise the west end of Span 2 so the pony truss is resting at the proper elevation.
3. Install #8 pins across and pressure grout crack on north end of Pier 2.
4. Clean masonry joints in Pier 2.
5. Remove deteriorated stones from Pier 2 bearing areas, install precast blocks, and encase pier with reinforced concrete.
6. Replace ties on Spans 1 & 2.
7. Tamp up east approach.

4th Priority

1. Reset expansion bearings on the east end on Span 2.
2. Remove deteriorated concrete from the south end of the East Abutment and cast back to original lines.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor Pier for increased settlement.
5. Monitor concrete condition on east abutment and Pier 1.

Bridge F-84 West Approach – Brodhead, WI

3rd Priority

1. Cut down piles and replace the cap on Bent 7 with a 16” deep cap.
2. Replace rejected stringers in Spans 1-6.
3. Place bridge in rebuild program.

Recommended Maintenance and Repairs Listed by Bridge (Continued)
Bridge F-84 West Approach (Continued)

4th Priority

1. Rebuild bridge to address pile settlement and penetration concerns.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for increased settlement.
5. Monitor condition of stringers.

Bridge F-90 – Brodhead, WI

3rd Priority

1. Rebuild bridge to address active pile settlement, poor stringer condition, line swing in bridge, and timber decay.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor piling for increased settlement.
5. Monitor condition of stringers.
6. Monitor condition of caps.

Bridge F-92 – Brodhead, WI

2nd Priority

1. Replace caps on Bents 2, 3, & 4.

3rd Priority

1. Replace entire tie deck.

4th Priority

1. Replace all stringers in bridge.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Shim piles as required.
4. Monitor condition of stringers.
5. Monitor condition of caps.

Recommended Maintenance and Repairs Listed by Bridge (Continued)

Bridge F-108 – Juda, WI

3rd Priority

1. Place bridge in rebuild program.
2. Spot replace most severely deteriorated ties.

4th Priority

1. Rebuild bridge to address pile settlement concerns.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor settlement and shim as necessary until bridge is rebuilt.

Bridge F-114 – Juda, WI

3rd Priority

1. Cut down piles and replace caps on all bents with double caps.
2. Replace entire tie deck.
3. Tamp up approaches.
4. Shim under stringers at Bent 3.
5. Replace rejected shim on Bent 1.

Or

1. Investigate replacing structure with a pipe and fill.

4th Priority

1. Replace all stringers in all spans.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of caps.

Bridge F-116 – Juda, WI

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.

Bridge F-120 – Juda, WI

4th Priority

1. Replace Stringer 6 in Spans 1 & 2, and Stringer 1 in Span 3.
2. Replace entire tie deck.

Recommended Maintenance and Repairs Listed by Bridge (Continued)
Bridge F-120 (Continued)

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor condition of cap on Bent 4.

Bridge F-122 – Juda, WI

3rd Priority

1. Replace caps on Bents 2 & 3.

4th Priority

1. Replace entire tie deck.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Monitor bridge for possible wash-out during high water events, if wash-outs are a problem, excavate bridge.

Bridge F-134 – Juda, WI

2nd Priority

1. Cut down pile tops and replace cap on Bent 6 with a double cap.

3rd Priority

1. Replace entire tie deck.
2. Replace all stringers in bridge.
3. Rebuild west headwall and extend deeper.

4th Priority

1. Replace sway bracing on Bents 2-5.
2. Post Pile 1 of Bent 1.
3. Replace the cap on Bent 4.
4. Cut down pile tops and replace cap on Bent 2 with a double cap.

5th Priority (Annual Maintenance):

1. Perform annual bridge inspection.
2. Tamp up bridge approaches.
3. Clear brush from under bridge to reduce fire risk.
4. Shim piles as required.

Recommended Maintenance and Repairs (Continued)

Note Regarding Double Capping Bents

In cases where a bridge has little decay deterioration but there is some limited pile settlement present we have recommended that the caps on the affected bents be replaced with a stiffer cap section. A stiffer cap will not increase the capacity of the piling, but it does improve the distribution of load to the piles. Installing a stiffer cap section will not provide a long-term solution to settlement problems. However, stiffer caps may delay the reconstruction of low priority, less decayed structures so that funds can be directed towards reconstructing higher priority, heavily decayed bridges.

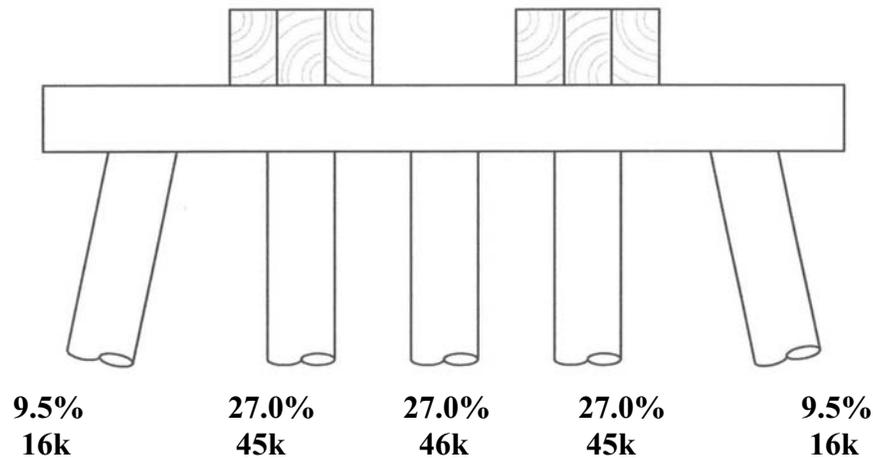
There is conjectural evidence that railroads have had success at slowing pile settlement by cutting down the piles and installing a double pile cap at each bent. However, there is no published study that our team is aware of that has investigated the effectiveness of installing a stiffer cap section to slow pile settlement, or determined what section would be most effective. For this reason, we recommend closely monitoring the bents that receive double caps to evaluate the effectiveness of this approach to limit pile settlement. As well as monitoring the proposed double caps, it may be advantageous to investigate other configurations of stiffer cap sections. Possible alternatives include deeper concrete caps, double caps with provisions for shear transfer between the two timbers, or reinforced bent bracing to improve load distribution.



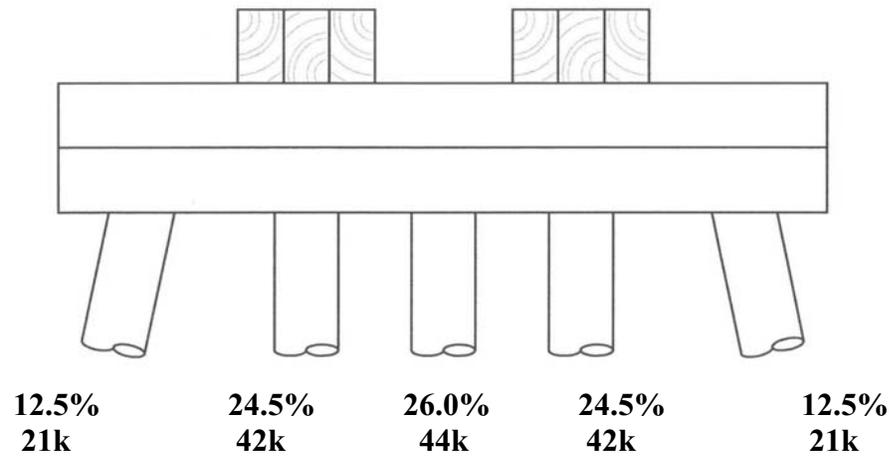
Double Pile Cap – Pile settlement may continue to occur.

Recommended Maintenance and Repairs (Continued)

The effects of double capping timber pile bents can be estimated based on the increased stiffness of the caps. Estimated pile load distributions are shown below, given as a percentage of the total track reaction. A computer model was set up to match as closely as possible the AREMA distribution for a single cap bent. That same model was then changed to incorporate the stiffness of a double cap and a double cap with shear connectors (thus making a composite section). The results indicate that load on the interior piles may be reduced by four to five percent. The distributions shown in the following figures were determined for the design pile spacings shown on standard drawing H-6160: 2'-9" | 2'-6" | 2'-6" | 2'-9".

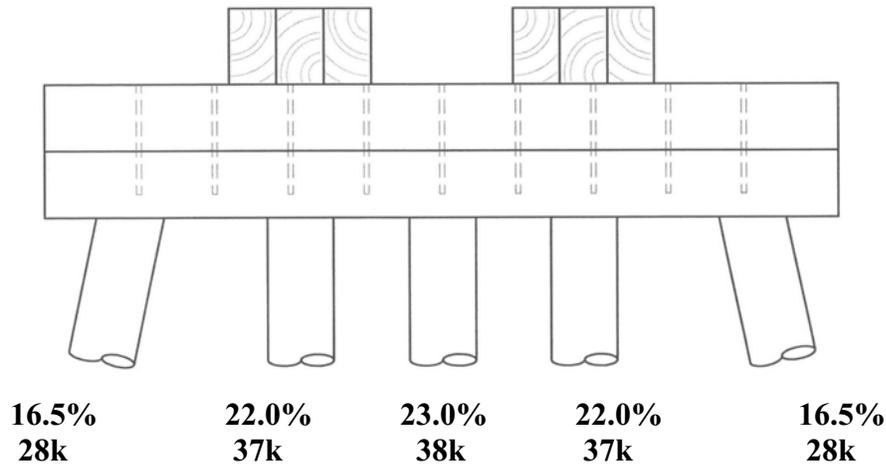


Single Cap - Pile Load Distribution for 286 kip Railcar Load, 16'-0" Span.



Double Cap - Pile Load Distribution for 286 kip Railcar Load, 16'-0" Span.

Recommended Maintenance and Repairs (Continued)



Double Cap Composite - Pile Load Distribution for 286 kip Railcar Load, 16'-0" Span.

Further analysis has shown that double capping may be more beneficial for bents with poor pile spacing, see Table 6. In this situation, a composite cap would reduce the load on the interior piles with greater effect – from five to seven percent of the total track reaction. Creating the composite double cap may be achieved using fiber reinforced polymer (FRP) shear spikes. Research has shown that FRP shear spikes bonded to the wood with an epoxy resin increased the effective stiffness of timber bridge members (Burgers, Gutkowski, Radford, and Balogh. *Composite Repair of Full-Scale Timber Bridge Chord Members Through the Process of Shear Spiking*).

Table 6 – Pile Load Distributions for Bents with Poor Pile Spacing:

Pile Spacing: 2'-3" | 3'-0" | 3'-0" | 2'-3"
 286 kip railcar load, 16'-0" span.

Cap	Pile Load (%)				
	1	2	3	4	5
Single	13k (8.0%)	45k (26.5%)	53k (31.0%)	45k (26.5%)	13k (8.0%)
Double	19k (11.5%)	41k (24.0%)	48k (29.0%)	41k (24.0%)	19k (11.5%)
Double Composite	28k (16.5%)	37k (21.5%)	40k (24.0%)	37k (21.5%)	28k (16.5%)

ENGINEER'S ESTIMATE & REMAINING SERVICE LIFE

Wisconsin & Southern Railroad

Milwaukee Subdivision

Monroe Subdivision

August 2006



ENGINEER'S ESTIMATE

Over the next five years the total estimated cost to conduct all the recommended repairs to restore the bridges to their original design capacity is \$2,927,000. This estimate includes \$1,479,750 of capital costs to rebuild Bridges F-60, F-80, F-84 West Approach, F-90, and F-108. The estimated maintenance cost to perform the recommended repairs on the remaining structures is \$1,447,250.

Over the next year it is estimated that approximated \$105,000 of maintenance repairs will be required to address those items of greatest concern. This cost includes \$29,750 of repairs to Bridge F-62 that was rebuilt this spring, so the estimate for remaining work required within the next year for maintenance repairs stands at \$75,250.

Over the next five years it is estimated that an additional \$2,822,000 of capital and maintenance work will be required. If only the 2nd Priority repairs were addressed in the next year, this total sum equates to roughly \$705,500 of bridge construction costs per year over the following four years for the bridges inspected.

Table 7 – Summary of Estimated Costs per Bridge:

Bridge #	2 nd Priority (1st year)	3 rd Priority (2-3 years)	4 th Priority (3-5 years)	TOTAL
D-58	N/A	N/A	N/A	0.00
D-64	N/A	N/A	\$5,000	\$5,000
D-78	N/A	\$12,500	\$4,500	\$17,000
D-125½	N/A	N/A	\$37,750	\$37,750
D-88	N/A	\$50,250	\$54,500	\$104,750
F-28	N/A	\$145,250	\$97,250	\$242,500
F-30	N/A	\$18,750	\$2,000	\$20,750
F-34	N/A	N/A	\$28,750	\$28,750
F-40	N/A	\$50,750	\$5,000	\$55,750
F-50	\$5,000	\$14,250	\$5,000	\$24,250
F-52	N/A	\$68,250	\$10,000	\$78,250
F-60	N/A	N/A	\$226,500 ¹	\$226,500
F-62	\$29,750 ²	N/A	\$9,250 ²	\$39,000 ²
F-68	N/A	N/A	N/A	0.00
F-76	\$47,000	\$32,000	N/A	\$79,000
F-80	N/A	\$11,000	\$226,500 ¹	\$237,500
F-82	N/A	\$24,500	\$65,500	\$90,000
F-84 MS	N/A	\$203,500	\$26,500	\$230,000
F-84 WA	N/A	\$19,500	\$469,000 ¹	\$488,500
F-90	N/A	\$331,250 ¹	N/A	\$331,250
F-92	\$14,250	\$19,750	\$38,500	\$72,500
F-108	N/A	N/A	\$226,500 ¹	\$226,500
F-114	N/A	\$41,750	\$26,500	\$68,250
F-116	N/A	N/A	N/A	0.00
F-120	N/A	N/A	\$26,750	\$26,750
F-122	N/A	\$10,750	\$19,250	\$30,000
F-134	\$9,000	\$86,750	\$20,750	\$116,500
TOTAL	\$105,000	\$1,194,000	\$1,578,000	\$2,927,000

1. These estimated costs are for complete reconstruction of the bridge and would be considered capital expenses.
2. Bridge F-62 has been rebuilt, this estimated cost would no longer be applicable.

Engineer's Estimate (Continued)

The preceding estimates are based on prevailing labor, material, and equipment rates at the time that this report was drafted in the spring of 2006. Construction rates are subject to change due to several factors including inflation, material shortages, as well as labor and equipment availability. For this reason the following estimated repair costs are subject to change.

The estimates above are for those repairs that will restore capacity lost to deterioration of the bridge. These repairs will not increase the capacity of the bridges beyond their original design capacity, except in the cases that a bridge has been recommended for complete reconstruction. In the case of those bridges with 16' spans but no active or severe pile settlement, the estimated cost to repair the bridges has been provided. However, these bridges are more likely to experience increased settlement with the introduction of regular 286 kip traffic and may require reconstruction sooner than other structures. The need to replace a bridge is dependent of several factors, including condition, presence of active settlement, decay deterioration and rated capacity.

Please note that the cost to conduct 5th Priority work items has not been included above. 5th Priority work items are typically low cost maintenance and inspection items that are intended to monitor existing conditions or prevent new defects from developing.

The Rest of the WSOR System

This study included twenty timber trestles, and six concrete or steel structures. Overall, 1354 feet of timber bridges and 477 feet of concrete or steel bridges were inspected. Of these bridges, \$827,250 is estimated for maintenance of timber bridges, \$1,479,750 is estimated for the replacement of timber bridges, and \$620,000 is estimated for maintenance of concrete and steel bridges.

Based on these figures, over the next five years the existing timber bridges on the lines inspected will require an average of \$610/ foot of maintenance repairs, and \$1100/ foot of capital construction. The sample of timber bridges is nearly large enough that these per foot costs could, within reason, be used to provide a rough estimate of maintenance and capital costs on other WSOR lines that lack detailed inspection information. By simple extrapolation, the 14,420 lineal feet of timber bridges on the lines owned by the State of Wisconsin and operated by WSOR may require approximately \$8.8 million in maintenance repairs and \$15.9 million in capital construction over the next 5 years for sustained 286 kip operations without accelerated structural deterioration due to increased axle loads.

The estimated maintenance cost of the steel and concrete bridges is \$1,300/foot, however the sample of bridges is so small that extrapolation of this data would be of limited use.

Engineer's Estimate (Continued)

When applying these per foot prices it is important to consider the variables that affect the estimated costs including bridge condition, access, and fluctuation of construction costs. The condition of bridges on a particular rail line can vary based on dozens of factors, including gross tonnage, speed, age, quality and frequency of previous maintenance, and quality of original construction. Access costs can vary dramatically from bridge to bridge, while fluctuation of construction costs will vary over time with a general upward trend. Lacking detailed inspection data on all of the bridges on the WSOR lines, the accuracy of any estimate based on a limited number of inspections will be suspect.

ESTIMATED SERVICE LIFE

The following table provides estimated service life remaining in the structures in years from the date of this report. This table is based on the assumption that car weights will not increase beyond the proposed 286 kip cars during the next twenty years. The service life estimates consider only the present condition of the bridge, the age of the bridge, and the deterioration that will occur during normal use. No consideration was made for catastrophic events, a dramatic increase in the frequency or weight of traffic, or non-defect driven factors that may result in the bridge becoming unserviceable.

The service life estimates are divided into three categories; Service Life in Present Condition, Service Life with Recommended Repairs, Service Life with Future Repairs.

Service Life in Present Condition

Present condition service life is defined as approximately how long until a failure renders a bridge unserviceable if none of the recommended work is conducted. In the cases where maintenance repairs are required, the out of service condition will be isolated to individual components and the bridge will be salvageable with repairs. In the cases where capital construction is required, pile settlement has diminished the long-term effectiveness of any repairs and rendered the structure unsalvageable.

Service Life with Recommended Repairs

Service life with recommended repairs is defined as approximately how long until a failure renders a bridge unserviceable if all of the recommended repairs are performed, but no further work is done after the repairs are completed. In the cases where maintenance repairs were performed, an out of service condition in the next 10 to 20 years will be isolated to individual components that are currently not called out for repair but will continue to deteriorate and may require replacement in the future. The components of some bridges are still in serviceable condition at present but are likely to develop serious defects in the next 10 to 20 years. Without future repairs these bridges will be unserviceable after the failure of these components, though the bridge may still be salvageable with future repairs.

Service Life with Future Repairs

Service life with future repairs is defined as approximately how long a bridge remains useable if all future required maintenance is performed. This could also be defined as the ultimate service life of the bridge.

For steel and concrete bridges the ultimate service life can be reached when the proposed car weights exceed the rating of the bridge, the fatigue life of the steel is reached, or the cost of repairing the structure exceeds the replacement value of the bridge. Overall the condition of the steel and concrete bridges that were inspected is good, and both the Milwaukee and Monroe Subdivision have been low density lines for most of their existence. For these two reasons, car weight will probably be the driving factor behind the replacement of the steel and concrete bridges on the Milwaukee and Monroe Subdivisions.

Estimated Service Life (Continued)

For timber bridges the ultimate service life is most likely to be driven by the pile capacity of the bridge. Creosote treated timber bridges are generally easy and inexpensive to maintain, and can be upgraded for heavier cars relatively cheaply as long as the piling have sufficient capacity. Unfortunately, the piling in the bridges of the Milwaukee and Monroe Subdivisions are near capacity for 286 kip cars. For this reason the estimated remaining service life of timber bridges has been capped at 20 years for bridges with 14’ spans, and 15 years with 16’ spans. Given that these structures are already 40-60 years old and that car weights tend to increase every 20 years it is difficult to predict what timber bridges, if any, will still be in service after this point.

Table 8 – Summary of Estimated Service Life per Bridge:

All values are in years.

Bridge #	Present Condition	With Recommended Repairs	With Future Repairs
D-58	20+	20+	20+
D-64	20+	20+	20+
D-78	< 10	< 20	20
D-125½	< 20	20+	20+
D-88	< 5	20	20+
F-28	< 5	20+	20+
F-30	< 10	< 15	20
F-34	< 10	< 10	15
F-40	< 5	< 10	15
F-50	< 2	< 15	20
F-52	< 5	< 10 ¹	10 ¹
F-60	< 5	(50+) ²	(50+) ²
F-62	< 2	(50+) ³	(50+) ³
F-68	20	20	20
F-76	< 2	< 20 ¹	20 ¹
F-80	< 5	(50+) ²	(50+) ²
F-82	< 5	< 10 ¹	< 10 ¹
F-84 MS	< 5	20+ ⁴	20+
F-84 WA	< 5	(50+) ²	(50+) ²
F-90	< 4	(50+) ²	(50+) ²
F-92	< 2	< 10	15
F-108	< 5	(50+) ²	(50+) ²
F-114	< 5	< 20	20
F-116	< 20	< 20	20
F-120	< 10	< 10	15
F-122	< 5	< 15	20
F-134	< 2	< 20	20

1. Remaining service life is dependent on rate of settlement under 286k traffic. Service life will be reduced if rate increases after introduction of 286k traffic.
2. Service life in parentheses is for the proposed replacement bridge.
3. Bridge has been rebuilt. Service life in parentheses is for replacement bridge.
4. Remaining service life is dependent on the effectiveness of proposed repairs at slowing the settlement of Pier 2.



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