U.S. Department of Transportation
Federal Highway Administration

Massachusetts Division
March 21, 2011

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In Reply Refer To:

Theodore Keon, Director of Coastal Resources
Town of Chatham
549 Main Street
Chatham, MA 02633

Subject: Chatham, MA – Mitchell River Bridge Project
Bridge Repair/Rehabilitation Feasibility Study

Dear Mr. Keon:

The Massachusetts Department of Transportation (MassDOT), Highway Division, has completed their review and finalized the Repair/Rehabilitation Feasibility Report for the Bridge Street over the Mitchell River in Chatham. As discussed in the Consulting Parties meeting in January 25, 2011, MassDOT and FHWA agreed to provide this report as part of our on-going commitment to consult with interested parties under Section 106 of the National Historic Preservation Act.

MassDOT is in the process of reviewing and finalizing an alternatives evaluation and life cycle cost report. Upon completion, this report will also be provided to the consulting parties. We anticipate having a meeting with all consulting parties after transmittal of the second report.

Enclosed please find one copy in CD format of the entire report and appendices. If you would like a hard copy, please forward a request in writing to me and I will provide a copy. In addition, if you would like to provide written comments in advance of our next meeting, please forward all comments to Damaris Santiago of my staff.

Sincerely yours,

Pamela Stephenson
Division Administrator

By: Damaris Santiago
Damaris Santiago
Environmental Engineer

cc: Kevin Walsh, Director of Environmental Services, MassDOT-Highway Division
Joseph Pavao, Jr, ABP Project Manager, MassDOT-Highway Division

BRIDGE REPAIR/REHABILITATION FEASIBILITY STUDY

for

BRIDGE STREET

over

MITCHELL RIVER

BRIDGE NO. C-07-001 (437)

DISTRICT 5

CHATHAM

MASSACHUSETTS

Prepared for:

Commonwealth of Massachusetts

Mass DOT

10 Park Plaza, Boston, MA 02116

Prepared by:

URS Corporation

260 Franklin Street, Boston, MA 02110

URS

MARCH 10, 2011

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1.0 EXECUTIVE SUMMARY

The existing Mitchell River Bridge (Bridge Number C-07-001 (437)) in Chatham, Massachusetts, which is owned and maintained by the Town of Chatham, was planned for replacement under the Massachusetts Department of Transportation (MassDOT) Accelerated Bridge Program. This project will be supported in part with Federal funding through the Federal Highway Administration (FHWA) and, therefore, is subject to review under Section 106 of the National Historic Preservation Act of 1966, as amended [36 CFR 800].

As part of the Section 106 process, FHWA and MassDOT submitted documentation to the Keeper of the National Register of Historic Places in September 2010 requesting formal determination of the Mitchell River Bridge's eligibility for listing in the National Register. The Keeper subsequently determined in October 2010 that the bridge is eligible for listing in the National Register. The Keeper found that the existing Mitchell River Bridge was a "rare example" and "of exceptional significance as the last remaining single-leaf wooden drawbridge in Massachusetts (and perhaps the entire United States)" and "an exceptionally important part of the community's historic identity." The Keeper's finding overturned a series of earlier findings by the Massachusetts State Historic Preservation Officer in 1981, 1985, and more recently in January, February and July 2010 that the bridge was not eligible for listing in the National Register.

This study develops and evaluates repair and rehabilitation alternatives for the undertaking that could avoid, minimize or mitigate adverse effects to the National Register eligible Mitchell River Bridge, as required under 36 CFR 800.6(a). The results of this evaluation are as follows.

The bridge currently has a National Bridge Inventory (NBI) Sufficiency Rating of 45.9 out of 100 and the bridge is currently classified as "Structurally Deficient" primarily due to the poor condition of the substructure. The current condition of the timber throughout the bridge varies from "satisfactory" to "poor" and conditions are conducive to continuing deterioration. Doing nothing or performing only normal maintenance will not correct the conditions that cause the bridge to deteriorate. Furthermore, currently available maintenance and repair techniques will not extend the service life of the timber elements a reasonable duration in this environment.

Although the bridge is currently considered safe, anticipated deterioration in the near future is expected to reduce the load carrying capacity to a threshold where load restrictions will be required. Two timber elements already have load carrying capacities less than the required load capacity and many other timber elements have load carrying capacities only slightly above the required capacity. Without corrective action, the condition of the timber is ultimately expected to reach a level where the bridge will be unsafe to carry traffic. Doing nothing or performing only normal maintenance will not correct the load carrying capacity concerns.

In addition to the current deficiencies in the structural condition, there are functional and safety concerns that need to be addressed. The bridge would be classified as "Functionally Obsolete" due to the substandard roadway width, if it were not for the current "Structurally Deficient" classification. Other functional and safety concerns include substandard curbs and bridge railings, substandard guardrails and associated end treatments and transitions, substandard sidewalk widths that do not meet accessibility requirements and substandard pedestrian railings. The bridge does not operate reliably and the operating equipment does not meet standards for safety and maintainability. The current navigation opening is also inadequate to serve the needs of the boating community. Doing nothing or performing only normal maintenance will not correct the functional and safety concerns.

Although technically feasible to repair or rehabilitate the existing bridge, all feasible schemes have significant consequences or leave significant deficiencies. Although some of the consequences and deficiencies individually may be considered minor, the cumulative impact of these is significant. Specific consequences of maintaining, repairing or rehabilitating the existing timber bridge include the following:

- The effort to maintain the existing timber bridge will continue to be a significant effort and a burden to the Town of Chatham in terms of maintenance cost and disruptions to the traveling public with continual piecemeal replacement and/or repair of timber members.
- Although not all timber elements of the bridge currently need to be replaced, it is not cost effective or technically feasible to repair, strengthen or replace certain elements without removing other elements. Although certain timber members can be replaced on an individual basis (e.g. wearing surface, railing, curbs, bracing, fender system, sheave poles and lifting beam) other major elements (e.g. structural deck, stringers, cap beams, and piles) cannot be replaced without removal of a significant number of other elements.
- Continued replacement, repair and strengthening of the timber cannot be sustained indefinitely as this work will eventually weaken members and create conditions that promote further decay. As such, all timber members will eventually need to be replaced.
- Modern strengthening methods such as fiber reinforced polymer (FRP) sheets or pile jackets are expensive relative to the cost of the timber, do not have a long-term performance history for use in salt water environments, and may introduce visual impacts.
- Extending the service life of the existing timber members using in-place preservative treatments is not prudent due to the need for frequent reapplication of the treatment and because of significant environmental and human health concerns. The currently available treatment techniques and chemical preservatives have limited effectiveness and require frequent reapplication (every 5 to 10 years). Some of the treatment would require removal of significant portions of the bridge to provide access for the retreatment. Because of the human health and environmental contamination risks, there is a risk that this treatment will not be permitted for use in this environment.
- Repair or rehabilitation will not fully address the limited navigation opening. Navigation through the bridge continues to be a challenge and a safety concern for the boating community. As such, the boating community has requested improvements to the navigation opening with a preferable minimum horizontal clear opening width with unlimited vertical clearance of 25’-0”. Evaluation of the existing bascule span geometry confirmed, with the existing constraints, modifications to the bascule span would at best yield only a 19’-4” wide navigation opening with unlimited vertical clearance. A major repair or rehabilitation effort that replaces the majority of timber components throughout the bridge may be viewed by the US Coast Guard as more of a bridge replacement and as

such there is a risk that the project may not be permitted unless the navigation channel is improved to adequately address the concerns of the boating community.

- Although rehabilitation can correct some of the functional and safety concerns, it is not feasible to significantly improve the narrow roadway width on the bridge. With the narrow roadway width, it is advisable to maintain low traffic speed across the bridge. The current significant wear of timber wearing surface promotes lower traffic speeds, which reduces the likelihood of crashes. However, with the replacement of the timber wearing surface and corresponding improvement in the smoothness of the riding surface, traffic speeds are anticipated to increase, which increases the concerns with the narrow roadway width.
- Although MassDOT has confirmed that a rehabilitation project would still be funded under the Accelerated Bridge Program, the funds only cover the cost of the initial project (i.e. the Town of Chatham will be responsible for the cost of the maintenance and any future repairs and/or replacement.) As a rehabilitation project will result in a bridge with a relatively short service life (i.e. only 20 to 30 years) the Town will be responsible for programming funds for replacement much sooner than a bridge with a 75 year service life. Furthermore, a rehabilitated bridge is anticipated to have higher maintenance costs than a new bridge. As these future costs are the responsibility of the Town, the Town will have a greater overall financial responsibility (i.e. a greater proportion of the overall life cycle costs) following a rehabilitation project than a bridge replacement project.

Based on the above listed consequences of maintaining, repairing, or rehabilitating the existing bridge and the scope, cost and life expectancy for each alternative, it can be concluded that maintenance and repair are not prudent cost effective alternatives compared to the rehabilitation alternative. Furthermore, because the rehabilitation alternative includes replacement of a majority of the bridge elements, and yet still results in functional and safety deficiencies (i.e. narrow roadway and navigation width), has a relatively short service life and requires greater maintenance than other bridge replacement alternatives, complete replacement of the bridge is a more prudent alternative. Complete replacement will provide a more cost effective long-term solution that better addresses future maintenance, functional and safety concerns including navigation that can also address the historical significance of the bridge.

2.0 INTRODUCTION

The existing Mitchell River Bridge (Bridge Number C-07-001 (437)) in Chatham, Massachusetts, which is owned and maintained by the Town of Chatham, was planned for replacement under the Massachusetts Department of Transportation (MassDOT) Accelerated Bridge Program. This project will be supported in part with Federal funding through the Federal Highway Administration (FHWA) and, therefore, is subject to review under Section 106 of the National Historic Preservation Act of 1966, as amended [36 CFR 800].

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This study develops and evaluates repair and rehabilitation alternatives for the undertaking that could avoid, minimize or mitigate adverse effects to the National Register eligible Mitchell River Bridge, as required under 36 CFR 800.6(a).

This report makes the following distinction between rehabilitation and repair:

Repair of an existing bridge is generally defined as work needed to restore a bridge to original condition and does not correct major safety defects or upgrade a bridge to current design standards.

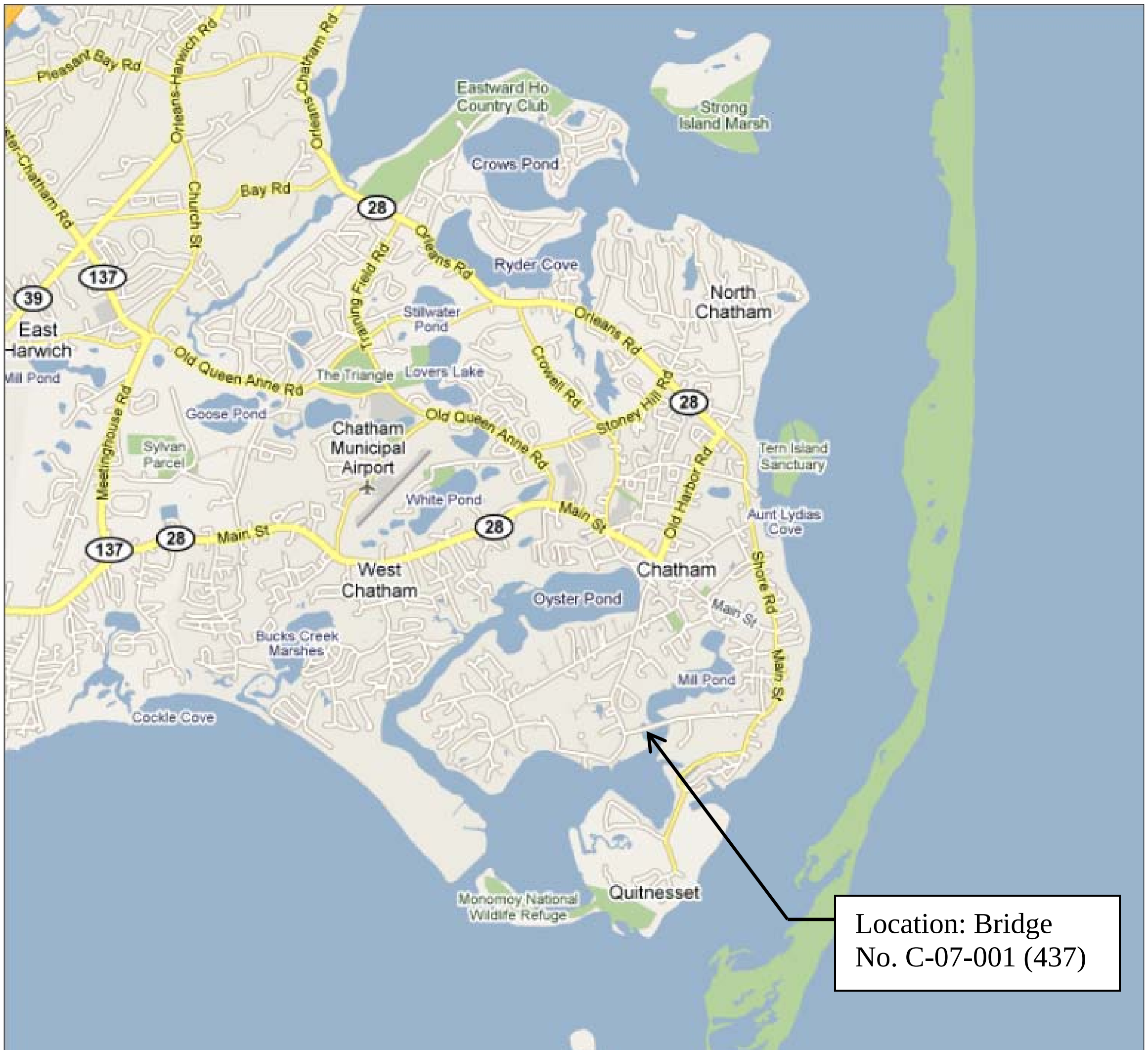
Rehabilitation of an existing bridge is generally defined as work including modifications and repairs needed to correct major safety defects and to preferably upgrade the bridge to meet current design standards.

Evaluation of bridge replacement alternatives is not considered in this study.

3.0 BRIDGE DESCRIPTION

Bridge Number C-07-001 (437) carries Bridge Street over the Mitchell River between Stage Harbor Road and the intersection of Main Street and Morris Island Road in the Town of Chatham. Bridge Street is a two-lane local road with two-way traffic and is classified as an Urban Collector with Average Daily Traffic of 2,100 vehicles of which approximately 6% are trucks. The bridge is approximately 192 feet long and consists of a twelve span timber trestle structure including a single-leaf timber bascule type lift span.

There has been a timber drawbridge at this location continually since 1858. However, the bridge has been replaced, reconstructed and modified numerous times since the first bridge was initially constructed. The known history of the bridge generally is as follows:



Location Map

- The original 1858 bridge included a timber double-leaf bascule span and timber approach spans that were significantly longer than the present bridge.

- The bridge was completely replaced in 1925 with a shorter twelve-span timber bridge with a single-leaf timber bascule span. The overall width of the 1925 bridge was 15’-4”. The bridge included an all timber superstructure with steel pipe railings on both sides and all timber substructure and foundations except for concrete abutments.
- The bridge was widened in 1949 to the north to provide 24’-0” clear roadway width and 3’-0” raised sidewalks on both sides with an overall width of 30’-0”. During the widening, Bent 5 was removed and steel beams were installed in Spans 5 and 6 to support the timber superstructure including an intermediate steel hanger beam where Bent 5 was previously located. The steel beams were supported on two new pile bents, Bent 4A and Bent 6A. The steel pipe railings were relocated to the back of the new raised sidewalks. Additional piles were added to supplement the existing piles for the widened configuration. The widened bridge included an all timber superstructure except for the steel framing in Spans 5 and 6 and all timber substructure and foundations except for concrete abutments.
- In 1980, the bridge superstructure was completely replaced to its current configuration retaining only the existing timber piles and concrete abutments. In the new configuration, wider sidewalks were provided in all but the first, last and bascule spans and the sidewalks were placed at deck level behind timber curbs. The pivot for the bascule span was relocated to the opposite side of the channel and a new Bent 7A constructed, while the existing Bent 7 was removed. Additional piles were added to supplement the existing piles and timber pile caps and bracing replaced. The steel framing in Spans 5 and 6 was removed and Bent 5 was reconstructed.
- Periodic minor repairs to the bridge have been performed since the bridge was reconstructed in 1980 including replacement of portions of the timber wearing surface, replacement of the lifting beam, installation of plastic wrap on some of the timber piles, and other miscellaneous minor repairs.

Photo 1 - Present Mitchell River Bridge - South Elevation

Photo 2 - Present Mitchell River Bridge - Roadway Section Looking East

The bridge currently has a clear roadway width of 24’-0” and carries one lane of traffic in each direction with sidewalks located each side of the roadway behind timber curbs and with timber bridge railings at the back of sidewalk. In Spans 2 thru 7 and Spans 9 thru 11 the sidewalks are 5’-9” wide with an overall bridge width of 37’-6”. In Spans 1, 8 and 12, the sidewalks are 2’-9” wide with an overall bridge width of 31’-6”. There is a tapered transition in sidewalk width in Spans 2 and 11 (see Appendix A.)

The superstructure includes a 3x8 sawn lumber plank timber wearing surface with the planks oriented at 60 degrees to the roadway centerline and which extends the width of the roadway. The timber wearing surface is supported on and nailed to 4x8 sawn lumber plank timber structural deck with the planks oriented perpendicular to the roadway centerline and that extends the full width of the bridge. The timber deck is supported on 6x16 sawn lumber stringers at 15½” on center. The timber curbs consist of 8x8 sawn lumber members elevated on top of 6x8 spacers at 6 feet on center. The timber bridge railing consists of 8x8 posts, 6x6 top rails, 10x5 intermediate rails and 6x4 bottom rails/curbs. The timber for the bridge structural members was specified as pressure treated Dense Select Douglas Fir-larch with waterborne preservatives. The deck planks were specified as No. 2 Grade Douglas Fir-larch without pressure treating. The timber piles contain creosote preservative.

The substructure at the ends of the bridge consists of concrete abutments supported on timber piles. The abutments include integral concrete wing walls (retaining walls) that extend along the approach roadway at the back of sidewalk that retain the roadway embankment. The retaining walls extend beyond the bridge ends approximately 16 feet at the NW quadrant, 84 feet at the SW quadrant, 16 feet at the NE quadrant and 60 feet at the SE quadrant. The embankments adjacent to the abutments and retaining walls along the waterway contain rubble rip rap slope protection. The substructure over the waterway consist of pile bents with timber piles and 16x14 sawn lumber caps and 6x12 sawn lumber lateral and longitudinal timber bracing members.

The bascule span provides 19'-4" of horizontal clearance between fenders and approximately 7'-4" of vertical clearance above mean high water with the bascule leaf in the lowered position. The pivot for the bascule leaf is located on the west side of the navigation channel. The bascule leaf is approximately 23'-8" from pivot to tip and rotates to a maximum angle of approximately 75 degrees from the horizontal position in the fully raised position. With the bascule leaf in the fully raised position, the bascule leaf overhangs the west fender and provides unlimited vertical clearance for a width of approximately 15'-2" between leaf tip and east fender.

The timber stringers for the bascule leaf are located in between the timber stringers of the approach spans. The bascule leaf superstructure pivots about a 1" diameter stainless steel rod that passes through 1¼" diameter stainless steel pipe sleeves with threaded flanges inserted through and secured to each of the bascule leaf and approach span timber stringers. A manually operated 1'-8" wide hinged portion of the deck (deck flap) above the pivot provides clearance between the timber stringers and deck when the bridge operates. The reconstructed bridge was originally provided with steel pins driven through guides and receivers attached to the top of the timber curb on each side of the joint between the bascule span and approach spans to secure the leaf in the lowered position. Padlocks were specified on the pins to prevent unauthorized operation. The pins have been removed, but padlocks are still used.

In order to reduce the loads on the operating machinery, the bascule leaf is balanced with a counterweight hung from the underside of an extension of bascule leaf timber stringers that extends under the approach span deck a length of 9'-2" from the pivot. The counterweight consists of a galvanized steel box filled with concrete and steel ballast.

The bascule span is operated by a pair of electric winches, one located in each sidewalk on the approach spans west of the bascule span. Each winch draws in and pays out 5/8" wire operating rope attached to a pulley system for additional mechanical advantage. The pulley system is attached to a 7/8" wire rope attached to the ends of a lifting beam under the bascule leaf deck near the tip ends of the leaf that deflects over a 15" diameter deflector sheave located at the top of a sheave pole. Each sheave pole consists of a 12x12 sawn lumber mast with 5/8" guy wire attached near the top of the mast and to the bridge superstructure. The wire rope, pulleys and deflector sheaves are all stainless steel. The operating equipment was specified to open or close the bascule leaf in approximately 120 seconds at a maximum pull in each 7/8" wire rope of 5,000 pounds. An electrical control cabinet is located on the northwest quadrant of the bridge. Traffic is controlled during bridge operations using electrically operated horizontally pivoting warning gates and post mounted traffic signals located along the roadway approaching the bridge.

4.0 ELEMENT CONDITION & REHABILITATION/REPAIR SCOPE

The following discussion summarizes the current condition of the bridge along with required repair and rehabilitation work. The condition evaluation is based on review of the available Massachusetts Department of Transportation - Structures Inspection Field Reports and limited field reviews to verify conditions described in these reports. The inspection of the timber structure used in preparation of Structures Inspection Field Reports included routine visual and tactile (sounding and probing) inspection and does not include more in-depth inspection techniques such as moisture meters, drilling and coring, sonic testing, x-rays or tomography scanning. The following discussion also considers function and safety, load capacity, service life, future maintenance, and potential environment and visual impacts.

4.1 Overall Condition

4.1.1 Sufficiency Rating:

The current Sufficiency Rating for the bridge is 45.9. Sufficiency ratings are based on a scale of 0 to 100, where 100 is excellent and 0 is very poor. In accordance with the Code of Federal Regulations, Title 23 Part 650D (23 CFR 650D), the sufficiency rating is a method of evaluating highway bridge data by calculating factors to obtain a numeric value, which is indicative of bridge sufficiency to remain in service.

The sufficiency rating includes the following applicable primary factors:

1. Structural Adequacy and Safety including:
    a. Superstructure Condition
    b. Substructure Condition
    c. Load Carrying Capacity
2. Serviceability and Functional Obsolescence including:
    a. Deck Condition
    b. Overall Structural Condition
    c. Roadway Geometry
    d. Traffic Volume
3. Essentiality for Public Use Including:
    a. Traffic Volume
    b. Detour Length
    c. Probability of Bridge Closure

Sufficiency Ratings are used in part to determine whether a bridge is eligible for Federal Highway Bridge Program replacement funds. A bridge with a Sufficiency Rating less than 50 and that is classified as “Structurally Deficient” is eligible for bridge replacement or bridge rehabilitation funds.

4.1.2 General Condition Ratings:

The Massachusetts Department of Transportation - Structures Inspection Field Reports document the National Bridge Inspection Standards (NBIS) Condition Ratings. (See Appendix B.) The NBIS Condition Ratings, which consist of a numerical code (based on a scale of 0 to 9, where 0 describes a "Failed Condition" and 9 describes an "Excellent Condition") provide a uniform standard for bridge inspectors and describe the overall general characterization of the physical condition of the entire deck, superstructure and substructure components of the bridge. The NBIS Condition Ratings reported in the 2004, 2006, 2008 and 2010 Structures Inspection Field Reports were as follows:

SUMMARY OF NBIS CONDITION RATINGS				
ITEM	2004	2006	2008	2010
Deck	6 (Satisfactory)	6 (Satisfactory)	6 (Satisfactory)	5 (Fair)
Superstructure	6 (Satisfactory)	5 (Fair)	6 (Satisfactory)	6 (Satisfactory)
Substructure	4 (Poor)	4 (Poor)	4 (Poor)	4 (Poor)

- *Satisfactory* denotes that structural elements show some minor deterioration.
- *Fair* denotes that all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
- *Poor* denotes advance section loss, deterioration, spalling or scour.

The Structures Inspection Field Reports indicate a continuing gradual reduction in the overall physical condition of the bridge. The increase in the NBIS Condition Rating of the Superstructure between 2006 and 2008 reflects slight improvements following the repairs to the superstructure performed in 2007.

Due to an NBIS Condition Rating of 4 (Poor) for the Substructure, the bridge is classified as "Structurally Deficient". This does not signify that a bridge is unsafe; rather it signifies that significant structural members are in need of repair.

4.1.3 Load Capacity/Restrictions:

According to the 1980 bridge reconstruction plans, the design live loading for the existing bridge was the AASHTO H20-44 truck loading which has a 20 ton gross vehicle weight and two axles (8,000 pounds and 32,000 pounds separated by a distance of 14 feet). This design loading is lighter than both the AASHTO HS20-44 design live load and the current AASHTO LRFD HL-93 design live load. Live load capacity calculations for the bridge were last performed in 1997 for both the Inventory and Operating Levels. The Inventory Level is considered the load level at which the structure can be subjected to indefinitely and is consistent with design level loading for new bridges. The Operating Level is considered the maximum load level that the structure can safely withstand and is consistent with current overload provisions and is the level at which Massachusetts Department of Transportation (MassDOT) establishes load restrictions and weight posting.

Based on the 1997 load rating analysis, all members of the bridge have capacities in excess of Operating Level capacities (see Appendix C.) As such, load restrictions and weight posting were previously waived. Although the bridge does not currently require load restrictions, the load rating analyses revealed that two elements of the bridge have load carrying capacities less than the Inventory Level capacities. These elements are the shear capacity of the bascule span timber stringers and the shear capacity of the Bent 7A timber bent cap that supports the bascule span. Load capacities less than the Inventory Level capacities indicate that the structural member may not have adequate capacity to carry current loading indefinitely and that degradation of the elements under loading is eventually expected. Furthermore, in accordance with FHWA guidelines, if the existing bridge was to remain and was rehabilitated, a design exception would need to be granted to allow the members with substandard Inventory Level capacity to remain. Otherwise the substandard members would need to be strengthened or replaced with stronger members. According to the 2010 Structures Inspection Field Report, the condition of the bridge has not changed sufficiently to warrant a new load rating evaluation.

4.1.4 Functional Evaluation and Roadway Safety

The existing bridge contains geometry that is considered substandard (i.e. the geometry does not meet current design standards.) Specifically, the narrow 24’-0” clear roadway width between curbs for two travel lanes is considered substandard. Because of the geometry, the bridge has a Deck Geometry Rating of 2 (Intolerable with a High Priority of Replacement) and as such, the bridge qualifies as “Functionally Obsolete”. In accordance with FHWA guidelines, as the bridge is also currently classified as “Structurally Deficient” it cannot also be classified as “Functionally Obsolete”. Bridges that qualify as both “Structurally Deficient” and “Functionally Obsolete” are classified as “Structurally Deficient”. If sufficient improvements were made to the deficient structural members without corresponding improvements to the geometric features, the existing bridge would then be classified as “Functionally Obsolete”.

Photo 3 - Approach Sidewalk and Guardrails

The existing bridge does not contain traffic railings that are crash tested in accordance with NCHRP 350 as required by current design standards. Low-level curbs, such as the existing 1’-1” high timber curbs, have a history of causing errant vehicles that strike the curb to lose control and rollover. The traffic railings are required to meet Test Level 2 (TL-2) crash testing criteria as a minimum, which are appropriate for use on local collector roads, with favorable site conditions, a small number of heavier trucks and reduced speeds. Based on the relatively high volumes of pedestrians that use the bridge for activities such as fishing, it is recommended that a crash tested traffic railing separate the sidewalk from the roadway to better protect pedestrians from vehicular traffic.

The guardrail approaching the bridge including the guardrail end terminations and guardrail transitions to the bridge do not meet current design standards.

In January 2011, the Town reduced the posted speed across the bridge to 15 mph.

4.1.5 Accessibility and Pedestrian Safety

The sidewalks do not meet current safety and accessibility requirements per the Code of Federal Regulations, Title 28 Part 36 (28 CFR 36) pertaining to the Americans with Disabilities Act of 1990. The 2'-9" sidewalk width in Spans 1, 8 and 12 and the sidewalks approaching the bridge do not provide the required minimum clear width of 3'-0" for an accessible route. In addition, the operating equipment (winches) is mounted on the sidewalks within Span 7 and reduces the sidewalk width to less than 3'-0" for a short distance.

The bridge railing contains openings between horizontal rail elements of 8" where as the NFPA Life Safety Code specifies that the openings in guards protecting drop-off hazards should not permit a 4 inch diameter sphere to pass.

The steel guardrails along the abutment wing walls also do not meet standards of safety for protecting drop-off hazards. The guardrail is less than the required minimum height of 42" and includes openings greater than 4".

4.2 Deck

4.2.1 Wearing Surface

NBIS Condition Rating: 5 (Fair)

Condition Description: The top surface of the timber wearing surface typically exhibits significant wear with knots and nails protruding above the top surface. The nails securing the planks to the structural deck have worked loose on numerous planks throughout the deck allowing the planks to move as traffic crosses the bridge. Numerous planks have been replaced at random locations throughout the deck and are not flush with the older planks. Overall the condition creates a non-uniform surface that is very rough for motorists crossing the bridge and creates a potentially unsafe condition for vehicles travelling at higher speeds.

Older timber planks exhibit moderate deterioration with early signs of decay and widespread splits and checks throughout. The splits and checks in the top (horizontal surface) of the wood contribute to increased water absorption by providing easier access of the moisture to interior grains of the wood. The increased water absorption results in greater volumetric expansion of the wood when it is wet and increased shrinkage of the wood as it dries. The increased shrinkage promotes growth in the number and size of splits and checks in the wood, which further increases moisture absorption and provides an avenue for fungal spores to enter the wood. The significant volumetric change in the wood also acts to work nails loose. Increased water absorption also promotes decay by providing the required source of moisture required by fungi that feed on the wood. Larger splits and checks retain a greater amount of moisture. Water retained in the checks in splits freezes during winter months increasing damage to the wood. Timber planks with significant checks and splits eventually splinter under traffic loading.

Photo 4 - Timber Wearing Surface

Small gaps between the wearing surface planks, which increase in width as the wood dries and shrinks, act to retain moisture between the planks. Movement of the wearing surface planks, where nails have worked loose, permits moisture between the wearing surface planks and the structural deck planks. Sand on the deck has typically filled the small gaps between the wearing surface planks, which increases water retention. The retained moisture acts to promote decay.

The cut ends of the wearing surface planks adjacent to the timber curbs and sidewalks are not sealed. This permits moisture to more easily enter the end grains of the planks. Because the wearing surface planks terminate at the back of the curbs, water that ponds on the sidewalks will be readily absorbed by the end grains of the wood. This increase in moisture retention in the ends of the planks increases decay at the ends of the planks.

Based on the above conditions, it is expected that the wear, deterioration and decay of the timber wearing surface will continue and may accelerate.

Repair Scope: With the significant wear and deterioration, the existing timber wearing surface has reached the end of its useful service life and thus it is recommended that it be replaced in entirety.

If the deck is replaced, it is recommended that the new timber planks be oriented parallel to the roadway centerline in lieu of the current 60 degree skew. This will reduce the number of joints in the deck surface that tires contact as vehicles cross the bridge, which will reduce abrasion and wear to the deck surface and improve the smoothness of the riding surface.

In-place preservative treatments (see 4.3.1 below) are inconsequential as replacement of the timber wearing surface is recommended for other reasons. However, the timber wearing surface would not otherwise be a good candidate for in-place preservative treatments.

Rehabilitation Scope: The Rehabilitation Scope would be the same as that above for the Repair Scope (i.e. no upgrades are required to meet current design standards.)

Functionality and Safety: Replacing the timber wearing surface would improve certain aspects of the functionality and safety by providing a smoother riding surface. However, as a smoother riding surface will be conducive to faster travel speeds, the substandard roadway width and safety features become a more significant concern.

Load Capacity: The timber wearing surface is not considered to contribute to the load carrying capacity of the deck. As such, there is no reduction in load carrying capacity due to the deteriorated condition of this element.

Maintenance: Replacing the timber wearing surface would reduce maintenance in the short-term by reducing the need to periodically replace the existing deteriorating timber planks. However, the timber wearing surface is still expected to wear under abrasion from traffic loading, which will require that the timber wearing surface to be periodically replaced. Furthermore, it is not possible to completely eliminate small gaps between the wearing surface planks and thus there will still be small gaps between the planks that retain moisture, which promotes decay. Details that facilitate future replacement of the timber wearing surface may extend the service life of the supporting timber structural deck including reuse of predrilled holes in the timber structural deck that can be reused when the wearing surface planks are periodically replaced. Sealing or treating the cut ends of the planks may also reduce moisture absorption. A smoother riding surface will reduce vibrations that also act to work fasteners loose.

Visual Impacts: It is not anticipated that replacing the timber wearing surface would introduce a visual impact as the timber wearing surface can be replaced in-kind.

4.2.2 Deck

NBIS Condition Rating: 5 (Fair)

Condition Description: The timber structural deck planks, which include the sidewalk areas, exhibit visual evidence of moisture retention and decay with staining and mildew on the underside between the timber stringers. Much of the preservative chemicals in the deck planks appear to have leeched from the timber and thus do not provide significant protection from decay. Although, the top surface of the structural deck beneath the timber wearing surface and the underside of the deck above the stringers is not accessible for visual inspection, the timber structural deck has experienced structural failure at one location in Span 4, which indicates that deterioration of the structural deck may be more significant than the visual evidence reveals.

As described above for the timber wearing surface, moisture enters the small gaps between the timber wearing surface planks and is retained between the top of the structural deck and underside of the wearing surface, especially where the nails for the wearing surface planks have loosened. The underside of the deck exhibits signs of moisture retention and decay in varying severity throughout. Open nail holes in the top of the structural deck from attachment of timber wearing surface planks previously replaced, as well as splits and checks, provide opportunities for moisture and fungal spores to enter the structural deck planks to a depth beyond the preservatives, which promotes decay. As the top surface of the structural deck beneath the wearing surface and the underside of the structural deck above the stringers is not visible, it is not possible to visually confirm the condition of these areas. However, based on the observed condition of the accessible surfaces, it is likely that the condition of the non-visible surfaces is likely to be more severe due to the greater potential for retained moisture.

The top surface of the structural deck in the sidewalks is visible and exhibits moderate deterioration with early signs of decay and significant splits and checks throughout. Similar to the timber wearing surface, the splits and checks in the top (horizontal surface) of the wood contribute to increased water absorption by providing easier access of the moisture to enter grains of the wood. The increased water absorption results in greater volumetric expansion of the wood when it is wet and increased shrinkage of the wood as it dries. The increased shrinkage promotes growth in the number and size of splits and checks in the wood, which further increases moisture absorption and provides an avenue for fungal spores to enter the wood. The significant volumetric change in the wood also acts to work nails loose. Increased water absorption also promotes decay by providing the source of moisture required by fungi that feed on the wood. Larger splits and checks will retain a greater amount of moisture.

The ends of the timber structural deck planks exhibit early signs of decay. The cut ends of the structural deck are not sealed, and although the cut ends are not located where water typically ponds, water on the sidewalks drains over the cut ends as it drains through the openings in the pedestrian railing curbs, which permits water to absorb into the ends of the planks. Water absorption in the cut ends of the structural planks promotes decay near the ends of the planks.

Based on the above conditions, it is expected that the deterioration and decay of the timber structural deck will continue and may accelerate.

Repair Scope: With the significant deterioration, including one reported structural failure, and due to the significant potential for more severe conditions than that known based on visual observation, the structural deck likely has limited remaining service life without corrective action. As such, it is recommended that the timber structural deck be completely replaced.

Even if it were shown that the condition of the structural deck was not critical, it is not a good candidate for in-place preservative treatments (see 4.3.1 below) to extend the service life. The 4x8 timber planks are too small for internal treatments. The surface treatments have limited service life (approximately 5 years) requiring frequent reapplication, which is a concern due to the limited access to the top of the deck that is covered by the timber wearing surface. Removal of the timber wearing surface every 5 years to reapply the preservative treatment is not a practical solution. Many of the more effective preservatives include toxic chemicals that may be a concern for human contact and that may be an environmental concern due to the potential contamination from spills or excess preservative chemicals that leech out of the deck.

Rehabilitation Scope: The Rehabilitation Scope would be the same as that above for the Repair Scope (i.e. no upgrades are required to meet current design standards.)

Functionality and Safety: The proposed work has no significant impact on functionality and safety.

Load Capacity: The current load rating does not identify a substandard load carrying capacity for the structural deck. However, the single structural failure indicates that the deteriorated condition of the deck has introduced localized areas with reduced load carrying capacity. Replacement of the structural deck planks will restore any loss in load carrying capacity.

Maintenance: Replacing the timber structural deck would reduce maintenance in the short-term by reducing the need to perform repairs to the existing deck or to reapply in-place preservative treatments. Details that facilitate future replacement of the timber wearing surface may extend the service life of the timber structural deck including use of predrilled holes in the timber structural deck that can be reused when the wearing surface planks are periodically replaced. Sealing or treating the cut ends of the planks may also reduce moisture absorption.

Visual Impacts: It is not anticipated that replacing the timber structural deck would introduce visual impacts as the structural deck can be replaced in-kind.

4.2.3 Sidewalks

NBIS Condition Rating: 6 (Satisfactory)

Condition Description: The timber sidewalks are part of the timber structural deck (see 4.2.2 above.)

Repair Scope: See 4.2.2 above for details.

Rehabilitation Scope: In order to meet accessibility standards, the sidewalk in Spans 1, 8 and 12 would need to be widened 1'-7" to provide a minimum clear sidewalk width of 3'-0" in those spans and the other sidewalks would need to be widened 7" to provide a clear sidewalk width of 5'-0" behind the new crash tested timber traffic railings (see 4.1.5 above and 4.2.4 below.)

Functionality and Safety: Wider sidewalks that meet accessibility standards proposed under the Rehabilitation Scope would improve accessibility, while the current sidewalk width does not provide this access.

Maintenance: See 4.2.2 above for details.

Visual Impacts: See 4.2.2 above for details. Minor widening of the sidewalk to meet accessibility standards is not anticipated to introduce a visual impact.

4.2.4 Curbs

NBIS Condition Rating: 5 (Fair)

Condition Description: The timber curbs are generally sound, but contain widespread minor to moderate splits and checks of varying severity throughout. In addition there is severe decay of a 3 foot length of the south curb near the bascule span. Similar to other timber members, the splits and checks in the top (horizontal surface) of the wood contribute to increased water absorption by providing easier access of the moisture to interior grains of the wood. The increased water absorption results in greater volumetric expansion of the wood when it is wet and increased shrinkage of the wood as it dries. The increased shrinkage promotes growth in the number and size of splits and checks in the wood, which further increases moisture absorption and provides an avenue for fungal spores to enter the wood. Increased water absorption promotes decay by providing the required source of moisture required by fungi that feed on the wood. Larger splits and checks will retain a greater amount of moisture. Most of the preservative treatment in the curbs has leeched out of the members and thus no longer protects the timber from decay.

The cut ends of the curbs are not sealed, and although the cut ends are not located where water typically ponds, some of the water on top of the curb drains over the cut ends, which permits water to absorb into the ends of the curbs. Water absorption in the cut ends of the curbs promotes decay near the ends of the curbs.

As discussed above, neither the bridge railing nor the timber curbs meet current standards for safety. Low level brush curbs, such as the 1'-1" high curbs on this bridge, have a history of causing errant vehicles that strike the curb to lose control and rollover. The timber curbs are constructed of a series of individual 8x8 timber members in 12 to 18 feet lengths. The curb segments are misaligned as much as 1½" in some locations creating potential snag hazards for passing vehicles.

Repair Scope: The presence of significant splits and checks, the lack of remaining preservative treatment, untreated end cuts, opportunities for retained moisture and exposure introduce conditions conducive to continuing decay. Although the existing bridge curb members currently exhibit only minor decay, the remaining service life of the curbs is likely limited without corrective action. In addition, as it is recommended that the timber wearing surface and timber structural deck be replaced, it is recommended that the timber curbs also be replaced.

In-place preservative treatments (see 4.3.1 below) of the timber curbs are not recommended. Many of the more effective preservatives for both internal and surface treatment include toxic chemicals that may be a concern for human contact and that may be an environmental concern due to the potential contamination from spills or excess preservative chemicals that leech out of the curbs.

Rehabilitation Scope: The Rehabilitation Scope would be the same as that above for the Repair Scope with the exception that the timber curbs would be replaced with traffic railings located in the same location as the curbs and that meet the crash testing criteria of NCHRP 350. Crash tested timber traffic railings would better protect pedestrians from vehicular traffic. There are available timber traffic railings that meet the crash testing criteria of NCHRP 350 that can be implemented. The timber posts for the traffic railing would need to be mounted to the sides of the timber stringers with adequate bracing diaphragms between the stringers. The timber stringers will need to be relocated and spaced to accommodate the new traffic railings. As the available crash tested timber traffic railings are wider than the existing curbs, the sidewalks and overall bridge width would need to be widened by approximately 1'-7" in Spans 1, 8 and 12 to provide a minimum sidewalk width of 3'-0" to meet accessibility standards and 7" throughout the remainder of the bridge to maintain a minimum sidewalk width of 5'-0".

Use of crash tested traffic railings permits use of the existing bridge railings as pedestrian railings (see 4.2.5 below for additional discussion.)

Functionality and Safety: The Repair Scope would not address the safety concerns.

Replacement of the low-level timber curbs with crash tested timber traffic railings proposed under the Rehabilitation Scope would improve the safety for both motorists and pedestrians.

Load Capacity: The timber curb is not considered to contribute to the load carrying capacity of the bridge. As such, there is no reduction in load carrying capacity due to the deteriorated condition of this element. Similarly, a crash tested timber traffic railing would not be considered to contribute to the load carrying capacity of the bridge.

Maintenance: Replacing the timber curbs now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating curb members or to reapply in-place preservative treatments.

Visual Impacts: Replacing the timber curbs in-kind would not be considered a visual impact.

Replacing the timber curbs with crash tested timber traffic railings, which are higher and have a more massive appearance than the existing timber curbs, may have a visual impact.

4.2.5 Railings

NBIS Condition Rating: 6 (Satisfactory)

Condition Description: The timber bridge railing members are generally sound, but contain splits and checks in the vertical posts, horizontal rails and curbs in isolated railing members throughout the bridge. These checks and splits retain moisture and provide an avenue for fungal spores to enter the wood, which promotes decay. Most of the preservative treatment in the timber railing members has leeched out of the members and thus no longer protects the timber from decay.

The cut ends of the railings and curbs are not sealed, and although the cut ends for the railings are not located where water typically ponds, some of the water on top of the rails drains over the cut ends, which permits water to absorb into the ends of the rails. As the curbs rest on the sidewalk, they are located where water that ponds on the deck and will absorb into the ends of the curbs. Water absorption in the cut ends of the rails and curbs promotes decay near the ends. The cut ends of the top of the posts are capped with copper sheeting to prevent moisture from entering through the end grains.

As noted above, water absorption results in volumetric expansion of the wood when it is wet and increased shrinkage of the wood as it dries. Significant volumetric change in the wood can act to work fasteners loose. Loose bolts securing the horizontal rails to the posts and curbs to the posts and sidewalk deck, would permit water retention in the small gaps between these elements, which promotes decay.

As noted above, the bridge railings contain openings between horizontal rail elements of 8" where the NFPA Life Safety Code specifies that the openings in guards protecting drop-off hazards should not permit a 4 inch diameter sphere to pass.

Repair Scope: The presence of splits and checks, the lack of remaining preservative treatment, untreated end cuts, opportunities for retained moisture and exposure introduce conditions conducive to continuing decay. Although the existing bridge railing members currently exhibit minimal decay, the remaining service life of the railing will be limited without corrective action. In-place preservative treatments (see 4.3.1 below) of the timber railing are not recommended. The railing members are too small for internal treatments. Many of the more effective preservatives used in surface treatments include toxic chemicals that may be a concern for human contact and that may be an environmental concern due to the potential contamination from spills or excess preservative chemicals that leech out of the railings.

As the existing railing elements have some remaining service life, it is possible to reuse portions of the railing, at least until deterioration has advanced to the point at which the railings are unsafe. Eventually the railing elements will need to be replaced in entirety.

Rehabilitation Scope: The Rehabilitation Scope would be the same as that above for the Repair Scope with the exception that it is recommended that the pedestrian railing be modified such that the maximum opening between the horizontal rail elements not permit a 4" sphere to pass in accordance with the NFPA Life Safety Code. This can be accomplished with the introduction of additional horizontal timber railing members or stainless steel cables located in between the timber rail elements.

Functionality and Safety: The addition of horizontal timber railing members or intermediate cable rails between the horizontal timber rails proposed under the Rehabilitation Scope would increase the safety for pedestrians.

Load Capacity: The bridge railings are not considered to contribute to the load carrying capacity of the bridge. As such, there is no reduction in load carrying capacity due to the condition of this element.

Maintenance: Replacing the timber railings now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating railing members or to reapply in-place preservative treatments.

Visual Impacts: Replacing the timber railings in-kind would not introduce a visual impact. The addition of horizontal railing members or intermediate cable rails between the horizontal rail elements is not anticipated to introduce a significant visual impact.

4.2.6 Deck Joints:

NBIS Condition Rating: 4 (Poor)

Condition Description: The timber deck joints between the bascule leaf and approach spans are currently a concern due to the tight contact between these elements that cause the bascule leaf to periodically become stuck during bridge operation and/or to not seat properly and thus create a discontinuity (typically as much as ½") in the roadway and sidewalk surfaces. The magnitude of this tight fit varies based on the ambient temperature and moisture content of the deck. It is also possible that the substructure and timber piles are slowly shifting slightly toward the channel as vehicles decelerate and brake while on the bridge, as often found on movable bridges, although this cannot be confirmed.

Repair Scope: It is recommended that a wider joint opening be provided between the tip of the bascule leaf and approach span if the timber wearing surface and structural deck are replaced.

Rehabilitation Scope: The Rehabilitation Scope would be the same as that above for the Repair Scope (i.e. no upgrades are required to meet current design standards.)

The hinged flap in the deck that provides clearance during operation of the bascule span may need to be modified if the location of the pivot is shifted to improve the navigation opening. The length of the flap may need to be increased if the opening angle is increased. A larger flap will likely be heavier and may require a longer lever arm for the operator to lift the flap.

Functionality and Safety: Eliminating the tight fit of the deck will improve the reliability of the bridge operation and correct the discontinuity in the deck surface, which will improve the smoothness of the ride and safety for motorists.

Load Capacity: The bridge joints do not contribute to the load carrying capacity of the bridge. As such, there is no reduction in load carrying capacity due to the condition of this element.

Maintenance: Eliminating the tight fit will reduce maintenance by eliminating the need for maintenance personnel to periodically visit the site to address the stuck bridge. It will also increase the service life of the operating equipment, by reducing the load on the equipment.

Visual Impacts: Small adjustments in the deck joints to eliminate the tight fit are not anticipated to introduce a visual impact.

4.3 Superstructure

4.3.1 Stringers

NBIS Condition Rating: 6 (Satisfactory)

Condition Description: The timber stringers are typically sound with no apparent significant decay, although a number of stringers contain splits and checks in varying severity (up to 1/8” in width with varying lengths.) The splits and checks in several isolated stringers are larger and up to 5/16” in width. The larger splits and checks are of a depth that permits fungal spores to access the center of the stringers, where there are no preservatives, which increases the risk for decay. Much of the preservatives have leeched from the surfaces of the stringers increasing the risk of surface decay as well. In general, the timber wearing surface and structural deck minimizes the amount of moisture that accesses the sides and bottom surface of the timber stringers. However, moisture that leaks through the joints between the timber wearing surface and structural deck is likely retained on the top of the stringers, which promotes fungal decay, especially if there are checks and splits in the top surface. With the structural deck bearing directly on top of the stringers, the top surface of the stringers is not accessible for visual inspection, and thus the condition of these surfaces cannot be verified.

There is minor impact damage to the underside of the stringers in the bascule span.

Photo 5 - Stringer and Diaphragms

Repair Scope: Although the timber stringers currently do not exhibit significant deterioration, the size and depth of the current splits and checks, the limited remaining preservatives in the wood, and the current exposure introduce conditions conducive for fungal decay. As such, the remaining service life of the existing timber stringers may be limited without corrective action.

There are options for in-place preservative treatment of large timber members including both internal treatments and surface treatments (see Appendix D.) Internal treatments include use of liquid and solid fumigant or fungicide chemicals inserted into drilled holes in the timber members. Surface treatments include application of preservative chemicals to the exterior face of the members. However, there are limitations and concerns with each treatment that reduces their effectiveness or makes the treatment undesirable for use.

Internal in-place preservative treatments on heavy timber beams typically consist of drilling holes (pairs of holes typically 3/8 inch to 7/8 inch in diameter at a spacing of no greater than 4 feet) from the top to nearly the bottom of the beam, installing the liquid (e.g. chloropicrin) or solid (e.g. methylisothiocyanate) chemical fumigants into the holes in the members, and capping the drilled holes with timber dowels. The chemicals then spread throughout the member by way of gaseous diffusion. Solid fumigants typically require a minimum amount of moisture for the diffusion to take place.

Surface in-place preservative treatments consist of saturating the surface of the timber with liquid oil-based preservative chemicals (e.g. penta or copper naphthenate) by brush or spray application so that all surfaces, cracks and crevices are thoroughly treated.

Although in-place preservative treatments have been effective in extending the service life of certain timber elements and in some locations throughout the United States (e.g. utility poles and railroad ties), there are a number of general concerns with the potential use of in-place preservative treatments on this bridge including the following:

- Use of toxic chemicals that are harmful to humans and marine life that can run off of the surfaces (surface treatment), leech out of splits and checks in the wood (internal treatment) and/or can be spilled during the work with corresponding potential that the work will not be permitted,
- Limited duration of effectiveness (10 years for internal treatment and 5 years for surface treatment) due to leeching of chemicals from the timber with corresponding need for periodic inspection and reapplication,
- Limited effectiveness of treatments due to the poor diffusion and absorption especially when certain conditions needed for proper diffusion and absorption are not present (e.g. specific moisture content), which potentially results in chemicals not diffusing or absorbing to the areas of fungal decay,
- Weakening of smaller structural members due to the need to drill a significant number of holes in the members to install the chemicals (internal treatment),
- Limited initial effectiveness due to slow diffusion and absorption rates, which permits decay to take place before the treatment has become fully effective,
- Limited performance data on certain newer treatments.

In addition, as the timber stringers are of limited thickness (only 6" thick), the drilled holes for internal in-place treatment will likely reduce the load carrying capacity of the members and may require load restrictions. In order to provide access to the top of the timber stringers to perform the work, the deck must be removed. As the preservatives have a limited service life and need to be periodically reapplied, it would be necessary to remove the deck in the future to provide access to the tops of the stringers for reapplication. As the new timber wearing surface and structural deck are anticipated to have a longer service life than the estimated 10-year service life of the preservative treatment, it would be necessary to temporarily remove and reinstall the deck, when this would otherwise not be necessary, which significantly increases the cost of retreatment. It may be possible to drill the holes from the bottom of the beam. However, this introduces a potential environmental concern if one or more dowels that plug the holes were to come loose due to dimensional changes in the timber from changes in moisture content, permitting the chemicals to drop into the water. Water-diffusible fungicides (e.g., boron and sodium fluorides) reduce some of the risks associated with the environment and human contact with the toxic chemicals. However, these chemicals are a recent development with ongoing research. Limited testing results have shown that the effectiveness of these chemicals can vary significantly. With the significant above concerns and risks, in-place internal treatment would not be a prudent alternative for the timber stringers.

(NOTE: If the decision is made to pursue in-place preservative treatment of other larger members that do not have the same access concerns and/or concerns with human contact (e.g. the timber cap beams), it is recommended that a solid fumigant such as methylisothiocyanate (MITC) (available in capsule form) be used as this chemical fumigant would likely provide the best alternative when balancing safety and effectiveness. Minor decay during the slow diffusion process should not pose a significant concern for larger members that do not currently exhibit decay.)

The required saturation of the surfaces of the timber members for in-place surface treatments introduces concerns of run off of the toxic chemicals. Implementation of fully effective containment that ensures that spilled chemicals will not enter the Mitchell River will be a challenge due to the limited clearance beneath the bridge and the limited available space between the pile bents. As such, it may be difficult to obtain a permit for this work. With these concerns and risks, in-place surface treatment would not be a prudent alternative for the timber stringers.

Alternatively, in order to increase the service life of the timber and eliminate the above concerns and risks associated with in-place preservative treatments, the timber stringers and blocking should be replaced.

Rehabilitation Scope: In addition to the work addressed in the Repair Scope, the bascule span stringers should be strengthened or replaced with larger members. One method of strengthening includes attachment of fiber reinforced polymer (FRP) to the sides of the timber members.

Larger members will increase the weight of the bascule span and thus the counterweight will need to be replaced with a heavier counterweight. The steel counterweight box will need to be replaced and a new counterweight box that contains a greater proportion of steel ballast than concrete ballast. If the weight required to balance the span is too great, it may be required to provide material with greater density in the counterweight, such as lead or an all steel counterweight. Alternatively, an all steel counterweight can be used with stacks of stainless steel plate (see 4.3.5 below.)

As noted above, it may be necessary to modify the layout of the timber stringers in order to accommodate mounting of crash tested timber traffic railing (see 4.2.5 above) and to accommodate a shift in the location of the sheave poles (see 4.3.4 below.)

Functionality and Safety: The stringers have no significant impact on functionality and safety.

Load Capacity: As noted above, the 1997 load rating analysis identified that the shear capacity of the bascule span timber stringers are less than the Inventory Level capacities. The shear capacity of the members would need to be increased approximately 20% in order to provide the required capacity. With the substandard capacity, these structural members may not have adequate capacity to carry current loading indefinitely and that degradation of the elements under loading is eventually expected. In accordance with FHWA guidelines, if the existing bridge was to remain and was rehabilitated, a design exception would need to be granted to allow the bascule span members to remain or the substandard members would need to be strengthened or replaced with stronger members.

The impact damage to the underside of the bascule span stringers does not significantly affect the load capacity of the members.

The bascule span timber stringers can be strengthened with the addition of fiber reinforced polymer (FRP) sheets to the exterior faces of the members. However, as FRP is expensive relative to the cost of the timber and a relatively new technology without a long track record of use in extremely aggressive saltwater environments, it may be more economical and prudent to replace the substandard timber members than to strengthen them with FRP sheets. However, larger members will be heavier and thus will require a heavier counterweight to balance the span.

Maintenance: Installation of FRP sheets to the sides of the beams may increase maintenance as it may be necessary to provide minor maintenance including reapplication of protective coatings, repair of adhesives and/or periodic replacement of the carbon fiber.

Replacing the stringers and blocking now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating stringers and blocking or to reapply in-place preservative treatments.

Visual Impacts: Replacing the timber stringers in-kind would not introduce a visual impact.

The addition of FRP sheets to the exterior surfaces of the bascule span timber stringers may introduce a visual impact.

4.3.2 Girders or Beams (Timber Lifting Beam)

NBIS Condition Rating: 7 (Good)

Condition Description: The timber lifting beam was replaced in 2007 and is generally in good condition.

Repair Scope: As the timber lifting beam was replaced in 2007, no significant repairs are required.

Rehabilitation Scope: The size of the lifting beam may need to be increased in conjunction with the new operating equipment and so that the lifting beam has adequate capacity to resist the larger design forces meeting current design standards. In addition, in order to provide the required minimum clear sidewalk width of 3’-0” with the new crash tested timber traffic railings, the operating winches and sheave poles will need to be moved outward approximately 2’-0”. In conjunction with this modification, the lifting beams will need to be lengthened by approximately 2’-0” on each end.

Functionality and Safety: The lifting beam does not have an effect on functionality and safety.

Load Capacity: It was found that the existing operating equipment does not meet current design standards and that more substantial equipment is required to meet the current design standards. As such, a stronger lifting beam will likely be required to meet the larger operating loads.

Maintenance: As the timber lifting beam was recently replaced and may be replaced again under rehabilitation, maintenance in the short-term for the new lifting beam is anticipated to be low.

Visual Impacts: Replacement of the existing lifting beam using a slightly longer and larger beam section would not likely introduce a visual impact.

4.3.3 Diaphragms/Cross Frames:

NBIS Condition Rating: 6 (Satisfactory)

Condition Description: The midspan timber blocking (diaphragms) between the stringers have worked loose and rotated in several locations throughout the bridge. Much of the preservatives have leeched from the surfaces of the timber blocking, thus increasing the risk of surface decay. However, as the timber wearing surface and structural deck generally minimizes the amount of moisture to the timber blocking needed to support fungal decay, the risk is currently low.

Repair Scope: In-place preservative treatment of the timber blocking is not recommended for the same reasons it is not recommended for the timber stringers. As such, the timber blocking should be replaced similar to that recommended for the timber stringers (see 4.3.1 above).

Rehabilitation Scope: As it may be necessary to modify the stringer spacing in conjunction with new crash tested timber railing, it may also be necessary to replace some or all of the timber blocking (diaphragms) to accommodate these modifications and to install additional diaphragms at the location of the traffic railing posts.

Functionality and Safety: The timber blocking has no significant impact on functionality and safety.

Load Capacity: The timber blocking does not contribute directly to the load carrying capacity of the bridge, but is required to brace the timber stringers and thus are considered in the rating of the stringers. The condition of the timber blocking does not significantly reduce the load capacity of the stringers.

Maintenance: See 4.3.1 for similar comments regarding maintenance.

Visual Impacts: See 4.3.1 for similar comments regarding visual impacts.

4.3.4 King Posts (Timber Sheave Pole)

NBIS Condition Rating: 6 (Satisfactory)

Condition Description: The timber masts supporting the deflector sheave for the operating equipment are generally sound, but typically contain significant checks up to 1/4" in width and 4 feet long. The large splits and checks are of a depth that permits fungal spores to access the center of the member where there are no preservatives, which increases the risk for decay. Much of the preservatives have leeched from the surfaces of the masts increasing the risk of surface decay as well. As the masts are vertical members, the exterior surfaces generally do not readily retain moisture.

Repair Scope: Although the timber masts are currently sound with no significant decay, the size and depth of the current splits and checks, the limited remaining preservatives in the wood, and the current exposure introduces conditions conducive to fungal decay. As such, the remaining service life of the existing timber stringers may be limited without corrective action.

Similar to the stringers, there are options for in-place preservative treatment of the masts including both internal and surface treatments (see 4.3.1 above). However, many of the same risks and concerns for in-place preservative treatments exist for the masts with exception that the drilled holes for internal treatment are not likely to significantly reduce the capacity and there are no access concerns. Due to the location of the timber masts along the sidewalks, there are significant concerns with human contact with the toxic chemicals and concerns with environmental contamination from spills or run-off of chemicals that leech from the masts. As such, in-place preservative treatments are not recommended for the masts.

Photo 6 - Sheave Pole (Mast)

Rehabilitation Scope: It may be necessary to increase the size of masts in order to resist larger operating forces meeting current design standards and to accommodate the details of conjunction of the new operating equipment including new larger deflector sheaves (see 4.3.6 below).

Alternatively, the masts can be strengthened with the addition of fiber reinforced polymer (FRP) sheets to the exterior faces of the members. However, as FRP is expensive relative the cost of the timber and a relatively new technology without a long track record of use in extremely aggressive saltwater environments, it may be more economical and prudent to replace the substandard timber members than to strengthen them with FRP.

In order to provide the required minimum clear sidewalk width of 3’-0” with the new crash tested timber traffic railings, the operating winches and sheave poles will need to be moved outward approximately 2’-0”. In conjunction with this modification, the lifting beams will need to be lengthened by approximately 2’-0” on each end.

Functionality and Safety: The timber masts have no significant affect on functionality and safety. Shifting the masts in conjunction with the replacement of the operating equipment will improve accessibility.

Load Capacity: The timber masts may be undersized for operating forces meeting current design standards (see 4.3.6 below). Replacing the masts with a larger members or strengthening the masts with carbon fiber can be used to address this potential concern.

Maintenance: Installation of FRP sheets to the sides of the masts may increase maintenance as it may be necessary to provide minor maintenance including reapplication of protective coatings, repair of adhesives and/or periodic replacement of the carbon fiber.

Replacing the masts now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating masts or to reapply in-place preservative treatments.

Visual Impacts: Replacing the timber masts in-kind would not introduce a visual impact.

The addition of FRP sheets to the exterior surfaces of the timber masts may introduce a visual impact.

4.3.5 Paint/Coating (Steel Counterweight Box)

NBIS Condition Rating: 5 (Fair)

Condition Description: The rear third of the steel counterweight box that contains the concrete and steel ballast exhibits moderate to heavy surface corrosion with minor overall corrosive deterioration and localized areas with moderate section loss. The bolts used to secure the counterweight to the underside of the timber stringers also exhibit moderate to heavy corrosion with minor overall section loss. The galvanized coating on the steel box and mounting bolts no longer adequately protects the steel from corrosion as much of the zinc that cathodically protects the steel has been consumed. The corrosion of the steel is largely attributed to the dipping of the rear end of the counterweight box into the saltwater each time the bridge is raised at high tide and low clearance above the saltwater.

Repair Scope: As a minimum, the steel counterweight box should be sand-blasted and recoated. It is recommended that the new coating also contain zinc (similar to that of the previous galvanizing.) Zinc can be field applied as either a paint coating or by way of hot spray application (metalizing). Metalizing has a higher initial cost but is known to have a longer service life than zinc paint coatings. In addition, it is recommended that the portion of the counterweight that dips into the water also be sealed with a coal tar epoxy or polyurea coating that limits exposure of the counterweight to the saltwater. The corroded mounting bolts for the counterweight should be replaced.

Alternatively, the counterweight can be replaced with a new counterweight fabricated using stacks of stainless steel plate (in lieu of a combination of concrete and steel) and stainless steel mounting bolts. This will reduce maintenance and extend the service life of the counterweight.

Use of an all steel counterweight will permit reduction in the length of the counterweight with the potential to prevent the counterweight from dipping in the saltwater.

Rehabilitation Scope: The counterweight may need to be replaced with a new heavier counterweight in conjunction with new heavier timber stringers (see 4.3.1 above.) Similar to the Repair Scope, it is recommended that the counterweight be completely replaced using stacks of stainless steel plate, stainless steel mounting bolts and a shorter counterweight.

Functionality and Safety: The counterweight does not affect the functionality and safety of the bridge.

Load Capacity: The timber stringers will need to be evaluated for the additional weight from a heavier counterweight. The counterweight will be heavier if the counterweight is made shorter and if heavier stringers are provided. Currently, the design of the stringers is not governed by the weight of the counterweight and thus it is not anticipated that larger stringers would be needed due to a heavier counterweight.

Maintenance: Cleaning and painting the existing steel counterweight box will require recurring ongoing maintenance to recoat the steel and to replace mounting bolts. Replacement of the counterweight using stainless steel and using a shorter, heavier counterweight that keeps the counterweight from dipping in the saltwater will further extend the service life and reduce maintenance.

Visual Impacts: Repair or replacement of the counterweight is not anticipated to introduce a visual impact as the proposed modifications do not significantly change the overall configuration of the bascule span or other parts of the bridge.

4.3.6 Operating Equipment

NBIS Condition Rating: N/A

Condition Description: The condition of the bridge operating equipment is not described in the Structures Inspection Field Reports. However, there are numerous reported concerns with the frequent required maintenance and unreliable operation of the bridge.

Photo 7 - Operating Equipment

Boaters requesting that the bridge be raised to the maximum extent possible to maximize the horizontal clearance have reportedly been told by the bridge operator that the bridge cannot be fully raised due to safety concerns. The bridge operating equipment reportedly struggles to raise the bridge and shudders, creaks, and vibrates significantly as the bridge operates. The tight fit between the bascule span and approach spans has reportedly resulted in the bascule leaves to periodically become stuck in the lowered position.

The stainless steel pins and sleeves that the bridge pivots about are not readily accessible for inspection, but is not a reported item of concern.

The electrical conduit throughout the bridge exhibits surface corrosion and the hardware used to secure the conduit to the bridge is severely corroded. There is at least one location where hardware and conduit have failed.

The operating equipment is mounted on the sidewalks, which reduces the clear width of the sidewalks to less than the minimum clear width of 3'-0".

Repair Scope: Based on the reported reliability and safety concerns and the evaluation of the current design of the operating ropes, sheaves, pulleys and winch drums, it is recommended that the operating equipment be replaced with a design that meets current design standards. The new operating equipment would include new winch assemblies, operating ropes, pulleys, deflector sheaves and associated clevises and mounting hardware. It is also recommended that the electrical power and controls be replaced for compatibility with the new operating equipment and to address the deteriorated condition of the conduit.

Rehabilitation Scope: The Rehabilitation Scope is similar to the Repair Scope with the addition that the new operating winches and sheave poles will need to be moved outward approximately 2'-0"in order to provide the required minimum clear sidewalk width of 3'-0" around the operating equipment and to accommodate the new wider crash tested timber traffic railings.

Functionality and Safety: Replacement of the operating equipment will improve the reliability and safety of the bridge operation, but will not address the accessibility concerns. Relocation of the operating winch proposed in the Rehabilitation Scope will improve accessibility.

Load Capacity: The operating winches, cables, pulleys and deflector sheaves do not meet current AASHTO LRFD Movable Highway Bridge Design Specifications (AASHTO Movable) including the following:

- The existing operating equipment was designed for an unbalanced load only and does not consider the force effects of ice load, friction, and wind loads, which are required in AASHTO Movable (Article 5.4.2) and are known to be significant on bascule type movable bridges. The current design of the operating equipment is implied in the 1980 Plans, which specifies that the counterweight be adjusted such as to produce a force of 5,000 pounds in each operating rope. The Plans also specify that the operating ropes be sized for a force of 5,000 pounds. If the operating equipment were designed for the additional force effects, the specified force in the operating ropes would have been larger than the specified imbalanced force in the operating ropes.

- The existing operating ropes do not conform to the type of construction and minimum size of operating ropes specified in AASHTO Movable (Article 6.8.3.3), which requires that the operating ropes utilize improved plow steel (IPS) or extra improved plow steel (EIPS) wire that is preformed and fabricated to 6x19 class wire rope of 6x25 filler wire construction with hard fiber (polypropylene) core. The wire rope construction specified in AASHTO Movable is specifically engineered for use in bridge applications, which considers the tension strength, bending fatigue resistance, wear resistance, and resistance to crushing. The wire rope specified in the 1980 Plans (Mil. Spec W-83420B, Type 304 stainless steel) consist of 7x7 class wire rope around a wire rope strand core. This wire rope was engineered for a different application (i.e. aircraft flight control requiring moderate flexibility) and the wire rope construction does not adequately consider all the above factors. The 7x7 wire rope construction utilizes larger diameter outer wires, which are more susceptible to fatigue failure than smaller diameter outer wires. Furthermore, stainless steel wire rope is more susceptible to fatigue than carbon steel rope. As fatigue of wire ropes is a critical factor in wire rope for movable bridges, this type of wire rope construction and this material is not recommended. Without a hard fiber core, the wire rope is susceptible to crushing failure and flattening, which leads to premature wear. Lastly, the current 5/8" operating ropes are smaller than the minimum wire rope size of 3/4" specified in AASHTO Movable.
- The sizes of the pulleys, deflector sheaves and winch drums do not conform to the minimum sizes specified in AASHTO Movable (Article 6.8.3.1.3), which requires a minimum sheave diameter of 45 times the wire rope diameter and preferably 48 times the wire rope diameter. The existing 15" deflector sheaves are only 17 times the existing 7/8" wire ropes and the existing pulleys and winch drum 24 times the 5/8" wire ropes. As such, the undersized sheaves, pulleys and drums result in excessive bending in the wire rope and corresponding premature wear and fatigue of the wire rope. Although the existing wire ropes have adequate capacity in direct tension to resist the specified loads, they do not provide the specified factor of safety of 3.33 per AASHTO Movable (Article 6.6.5) for combined bending and tension. Even if the wire rope were replaced with the proper wire rope, using the AASHTO design loads, and the current wire rope and sheave sizes, the current factor of safety for combined bending and tension is 1.75 for the 7/8" operating ropes and 2.35 for the 5/8" operating ropes. This indicates that the current design does not provide the specified margin of safety. Without the specified factor of safety, there is greater risk that an operating rope can fail. Furthermore, low factors of safety and lack of redundancy in the current bascule span and operating equipment design could result in the catastrophic collapse of the bascule span should one of the two wire ropes fail with the bridge raised. The bascule span timber framing lacks the lateral strength and stiffness required to permit the span to be supported from one side only. Furthermore, with the current low factors of safety in the operating ropes, a single operating rope lacks sufficient strength to support the span during operation and thus if one operating rope were to fail it is likely that the other operating rope will also fail. The factor of safety for supporting the span with a single operating rope would be only 0.87. A factor of safety less than 1.00 indicates that failure is likely.

The effectiveness of the counterweight to balance the operating forces is lessened when it dips in the water at high tide and becomes somewhat buoyant, which increases the force in the operating ropes when the bascule span is raised.

Maintenance: Replacement of the operating equipment with new operating equipment properly sized and designed to current design standards would reduce the wear and fatigue on the wire ropes, provide greater horsepower to overcome minor increases in load caused by ice, wind and friction. All of these will reduce maintenance requirements. Replacement of the electrical power and control equipment will also reduce the maintenance required to periodically repair the electrical equipment.

Visual Impacts: The minimum recommended size for the new sheaves, pulleys and winch drums is approximately 36" in diameter. The significantly larger sheaves, pulleys and winch drums will be a significant visual departure from the existing equipment and thus may introduce a visual impact. Shifting the operating equipment outward by 1'-0" may also introduce a visual impact.

4.4 Substructure

4.4.1 Concrete Abutments

NBIS Condition Rating: 5 (Fair)

Condition Description: The abutment concrete is generally sound with minimal cracking and spalling that does not significantly reduce the integrity of the abutments. Previously installed 1/8" thick epoxy mortar applied to the exposed concrete surfaces of the abutments has cracked and spalled in isolated areas, primarily at the locations of construction joints where the abutments were previously modified. However, this condition is primarily cosmetic in nature. There is a single large spall, measuring 12"x9"x6", at the top of the East Abutment back wall adjacent to the south sidewalk.

The timber sills (caps) are typically sound with no apparent significant decay, although the sills contain splits and checks of a depth that permits fungal spores to access the center of the timber, where there are no preservatives, which increases the risk for decay. Much of the preservatives have leeched from the surfaces of the timber increasing the risk of surface decay as well. Moisture from the roadway deck joint, as evidenced by the moisture staining, is retained on top of the abutment breast walls adjacent to the sills, which promotes fungal decay. The backside and underside of the timber sills adjacent to the abutment concrete and the top of the sills directly below the timber stringers are not accessible for visual inspection, and thus the condition of these surfaces cannot be verified. The cut ends of the sills are not sealed, and although the cut ends are not located where water typically ponds, water running over the cut ends can absorb in to the ends of the sills, which promotes decay.

The asphalt sidewalks along the wing walls (retaining walls) do not provide the required minimum clear width of 3'-0" and thus to not meet accessibility requirements. The top of the concrete wing walls is above the asphalt sidewalk surface with the height above the sidewalk varying along the length. The steel guardrail attached to the back face of the wing walls is typically loose. The steel guardrail does not meet standards of safety for protecting drop-off hazards.

Repair Scope: The failed epoxy mortar spalls should be repaired.

Although the timber sills are currently sound with no significant apparent decay, the size and depth of the current splits and checks, the limited remaining preservatives in the wood, and the current exposure introduces conditions conducive to fungal decay. As such, the remaining service life of the existing timber sills may be limited without corrective action.

Similar to the timber stringers, there are options for in-place preservative treatment of the timber sills including both internal and surface treatments. However, many of the same risks and concerns for in-place preservative treatments exist for the sills with exception that the drilled holes for internal treatment are not likely to be significant and there are no access concerns. Due to the location of the timber sills adjacent to the waterway, there are significant concerns with the toxic chemicals and the potential for environmental contamination from spills or run-off of chemicals that leech from the sills. As such, in-place preservative treatments are not recommended for the timber sills.

Rehabilitation Scope: In addition, to the Repair Scope, the abutments should be modified to accommodate wider sidewalks needed to satisfy accessibility requirements. This includes lowering the top of the wing walls and casting new concrete sidewalks that are approximately 2'-0 wider, which can be accomplished by cantilevering the sidewalk past the exterior face of the wing walls. This work should be performed in conjunction with recommended improvements to the guardrails and pedestrian railings (see 4.6.1 below.)

Functionality and Safety: The Repair Scope does not improve the functionality and safety. Without modifications and improvements to the abutment wing walls and the adjacent sidewalks, guardrails, curbs and railings, there will continue to be safety concerns for pedestrians and motorists and accessibility concerns.

Proposed improvements to the abutment and approach roadway in the Rehabilitation Scope will improve safety by better protecting pedestrians from the drop-off hazard and motorists of the bridge end hazard. The modifications will also provide the required minimum sidewalk width for accessibility.

Load Capacity: The current abutment deficiencies do not contribute directly to the load carrying capacity of the bridge.

Maintenance: Replacing the timber sills now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating timber or to reapply in-place preservative treatments.

Visual Impacts: Modifications to the abutments to accommodate the wider sidewalks, pedestrian railings and traffic railing are a visual departure from the existing configuration and thus may introduce a visual impact.

4.4.2 Pile Caps

NBIS Condition Rating: 6 (Satisfactory)

Condition Description: The cap beams for the pile bents are typically sound with no apparent significant decay, although the caps typically contain 1/16" wide splits and checks throughout on all surfaces. On Bents 3 and 4, the cap beams contain larger splits and checks up to 1/4" in width with these extending the full height. The larger splits and checks are of a depth that permits fungal spores to access the center of the timber, where there are no preservatives, which increases the risk for decay. Much of the preservatives have leeched from the surfaces of the timber increasing the risk of surface decay as well. Moisture leaking through the deck, as evidenced by the moisture staining, is retained on the horizontal top surface of the cap beams, which promotes fungal decay. The underside of the cap beams over the piles and the top of the cap beams directly below the timber stringers are not accessible for visual inspection, and thus the condition of these surfaces cannot be directly verified. The cut ends of the cap beams are not sealed, and although the cut ends are not located where water typically ponds, water running over the edges of the deck also runs over the cut ends of the members permitting water to absorb into the ends of the members, which promotes decay near the ends. Several of the cap beams exhibit initiation of decay near the ends of the cap.

The cap beams in all but Bents 4A, 6A and 7A were spliced when the bridge was widened in 1949. The galvanized steel bolts used to make the splice exhibit light surface corrosion indicating that most of the zinc coating on the bolts has been consumed.

Repair Scope: Although the timber cap beams are currently sound with no significant apparent decay, the size and depth of the current splits and checks, the limited remaining preservatives in the wood, and the current exposure introduces conditions conducive to fungal decay. As such, the remaining service life of the existing timber cap beams may be limited without corrective action.

Similar to the timber stringers, there are options for in-place preservative treatment of the timber cap beams including both internal and surface treatments. However, many of the same risks and concerns for in-place preservative treatments exist for the cap beams with exception that the drilled holes for internal treatment are not likely to be significant and there are no access concerns. Due to the location of the timber cap beams directly above the waterway, there are significant concerns with the toxic chemicals and the potential for environmental contamination from spills or run-off of chemicals that leech from the cap beams. As such, in-place preservative treatments are not recommended for the timber cap beams.

Rehabilitation Scope: In addition to the work addressed in the Repair Scope replace the cap beams in Bent 7A with larger members. As noted above, the cap beams will need to be made approximately 4'-0" longer (2'-0" on each end) to accommodate the required shift in the operating winches and sheave poles needed to improve accessibility. If the decision is made not to shift the masts, the cap beams at Bent 7A could be strengthened using fiber reinforced polymer (FRP) sheets applied to the exterior faces of the members.

Functionality and Safety: The cap beams do not affect the functionality and safety.

Load Capacity: As noted above, the 1997 load rating analysis identified that the shear capacity of the cap beams at Bent 7A are less than the Inventory Level capacities. The shear capacity of the members would need to be increased approximately 20% in order to provide the required capacity. With the substandard capacity, these structural members may not have adequate capacity to carry current loading indefinitely and that degradation of the elements under loading is eventually expected. In accordance with FHWA guidelines, if the existing bridge was to remain and was rehabilitated, a design exception would need to be granted to allow the deficient members to remain or the substandard members would need to be strengthened or replaced with stronger members.

The deficient cap beam members can be strengthened with the addition of FRP sheets to the exterior faces of the members. However, as carbon fiber is expensive relative to the cost of the timber and a relatively new technology without a long track record of use in extremely aggressive saltwater environments, it may be more economical and prudent to replace the substandard timber members than to strengthen them with FRP.

Maintenance: Replacing the timber cap beams now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating timber or to reapply in-place preservative treatments.

Visual Impacts: Replacement of the cap beams in-kind would not introduce a visual impact.

Installing FRP sheets on the sides of the Bent 7A cap beams could introduce a visual impact. Replacing the Bent 7A cap beams with longer beams of a heavier section would not likely introduce a visual impact.

4.4.3 Piles

NBIS Condition Rating: 4 (Poor)

Condition Description: The timber piles throughout the bridge are of different ages including some piles from the original 1925 construction, some from the 1949 widening, and some from the 1980 reconstruction. The intermediate pile bents include a total of 128 timber piles still being used to support the bridge of which an estimated 30 piles were added in 1949 and 31 piles added in 1980. The other 67 piles appear to be from the original 1925 construction. The piles supporting the abutments are completely buried within the approach embankment and rubble rip rap and thus are not accessible for visual inspection.

Several piles in Bent 10 include addition of a 12x12 timber build-ups at the top of the pile that was spliced in line with the pile. Based on the appearance of these pile build-ups, which is similar to the piles, they are likely the same age as the piles and were likely added when those piles were originally installed to add length to the pile or to replace a damaged section of the tops of the piles.

Photo 8 - Piles and Bracing

Twelve (12) of the piles including six (6) in Bent 1, three (3) in Bent 2, one (1) in Bent 3 and two (2) in Bent 4, all from among the original piles from 1925, were wrapped in plastic from just above the mudline to just above the tidal zone. The plastic was added in 2005 to slow or stop further marine borer attack and further section loss to these piles. The plastic wrap obscures the piles from visual inspection. Tactile inspection (i.e. sounding and probing) is also not recommended on these piles due to the potential of damaging the plastic wrap. As such, there is no practical means to perform routine inspection of these piles and to periodically determine whether the condition is deteriorating beneath the plastic.

The timber piles typically exhibit heavy marine growth extending from the mudline through the tidal zone obscuring some of the surface of the piles from visual inspection and preventing full tactile inspection.

All of the existing piles contain creosote preservatives. However, most of the piles are typically bleached indicating that the creosote has leeched from the older piles and thus no longer protects the piles from surface decay and marine borer attack. The creosote preservative in the newer piles is in greater quantity; however, there is evidence that the quantity has reduced somewhat due to ongoing leeching of the material. The piles typically exhibit evidence of surface decay and marine borer attack at and above the tidal zone of varying severity throughout the bridge.

The surface decay and deterioration is considered minor in 75% of the piles, moderate in 15% of piles and significant in 10% of the piles.

The piles throughout the bridge also contain checks and splits of adequate width and depth to penetrate the outer portion of the piles that contains the preservative treatment. This permits moisture and fungal spores to gain access to the interior of the pile where there is no preservative treatment, which creates conditions conducive for development of internal fungal decay. The checks and splits are considered minor in 75% of the piles, moderate in 15% of piles and severe in 10% of the piles. Two of the piles (one in Bent 4A and one in Bent 6) exhibit extensive splits at the top of the piles where the piles connect to the cap beams.

In general, the tops of the piles are sound. However, there is no evidence that the cut ends of the top of the piles were field treated with preservative or sealed either during the original construction, widening or reconstruction. As such, the cut ends provide opportunities for moisture absorption and decay at the tops of the piles.

There is evidence of active marine borer attack in approximately one-third of the piles throughout the bridge. In addition to the twelve (12) piles wrapped in plastic with previously identified marine borer attack, there are six (6) piles with marine borer attack extending from the mudline through the tidal zone, nineteen (19) piles within the tidal zone and four (4) piles near the mudline only. The most severe deterioration has occurred to a pile in Bent 8, which reportedly includes approximately 80% loss in cross section to the pile. The marine borer attack is primarily from teredo worms that consume the interior of the pile where there are no chemical preservatives. However, there is evidence that limnoria (gribble) has also attacked the exterior surface of the timber. The teredo worms have typically bypassed the chemical preservatives in the surface of the piles and have accessed the interior of the piles through bolt holes in the piles. A number of the holes that were previously used for bolting timber bracing members to the piles, but are no longer used due to changes in the bracing configuration, were left open for a period of time. After the discovery of marine borer attack, bolts were inserted into the open holes to prevent access. However, the bolts have typically failed as a result of corrosive deterioration. Other holes typically became open when the bolts attaching the timber bracing members failed due to corrosive deterioration.

The galvanized steel bolts used to secure battered piles to plumb piles and timber bracing members to the piles typically exhibit severe corrosive deterioration throughout the bridge.

Repair Scope: The creosote preservative in the existing timber piles have contributed to a relatively long service life for piles in this environment. However, significant splits and checks in the piles, significant loss of preservative chemicals in a large number of piles, continued loss of chemical preservatives in the other piles, evidence of surface decay and significant potential for internal decay, and evidence of significant marine borer attack all substantially limit the remaining service life of the piles unless corrective action is taken.

Similar to the other timber elements of the bridge, there are options for in-place preservative treatment of the piles including both internal and surface treatments. However, many of the same risks and concerns for in-place preservative treatments of other elements apply to the piles with the exception that the drilled holes for internal treatment will not significantly reduce the pile capacity. In-place preservative treatments can only be applied above the waterline and as such, they would only be effective in treating the piles above the waterline. The risk of contamination from the toxic chemicals is far greater with the piles than the other elements due to the closer proximity to the water and the potential for the chemicals to leech out through the interconnected network of splits and checks that extend above and below the waterline. As such, in-place preservative treatments are not recommended for the timber piles.

As a number of existing piles contain significant loss in section, the deteriorated sections of the piles should either be strengthened or replaced, or the piles completely replaced.

The piles can be strengthened using fiber reinforced polymer (FRP) composite jackets that completely wrap the piles and then are filled with epoxy grout (see Appendix F.) In addition to restoring the strength of the piles, the jackets provide the additional benefit of preventing decay and marine borer attack by limiting the opportunity for fungal spores and marine borers to access the piles. In order to provide full protection of the piles from both marine borers and decay, the FRP jackets should extend from several feet below the mudline to the top of the piles. The tops of the piles should be adequately sealed with a bituminous coating to prevent moisture from absorbing into the pile from the top.

The current pile arrangement introduces some installation challenges for the jackets. In many bents, there are instances where two piles are immediately adjacent to each other and in other bents there are battered piles that butt into the side of the adjacent plumb piles. The piles may need to be temporarily separated by jacking in order to provide sufficient clearance to install the jackets. In addition, the piles in Bent 10 that contain the 12x12 timber build-up spliced in line to the top of the piles will likely require larger jackets to fully encapsulate the splice and build-up. After the jackets are installed, new holes will need to be drilled through the jackets and piles in order to connect piles together and to attach the new timber bracing members. Previous unused holes will be covered so as not continue to pose a problem. However, precautions will need to be taken to ensure that the new holes do not eventually become open holes including the use of corrosion resistant bolt material.

Although a relatively new technology, the FRP jackets have been successfully used on a number of bridge, pier and wharf foundations with timber piles over the last decade. As it is a relatively new technology, long-term performance data in the extremely aggressive salt water environment is not available and thus the predicted service life of the jackets is somewhat unknown. The FRP material and associated adhesives, grout and coatings are potentially susceptible to wear from abrasion, impact damage, delaminations due to freeze-thaw, and degradation due to ultraviolet light and exposure to the salt water.

Installation of the jackets requires that the piles be thoroughly cleaned to remove barnacles and any decayed timber material. This work will expose the full extent of the deterioration, which will not otherwise be known in detail until the work is performed. It may be found that some of the piles contain too much deterioration to repair with the FRP jackets (i.e. there may be inadequate pile capacity even with the jackets or insufficient sound material in the piles for the jackets to connect.) This scenario is possible given that the marine borer attack is primarily on the interior of the piles where the full extent of the deterioration is not visible. If this occurs, it may be necessary to splice a new section of pile into place prior to installing the jackets. Replacement of a section of pile may or may not require temporary supports and/or jacking to remove load from the pile. The heavily deteriorated section of pile would then be cut-out, the new section of pile inserted in-line with the existing section of pile to remain, and timber or steel plates installed and bolted to splice the pile sections together. Larger FRP jackets will be required with the spliced piles. In addition, the cleaning of the piles may temporarily increase the release of the creosote into the water, which may be an environmental concern.

Due to the high cost, potential limited service life of the FRP jackets, and potential visual impacts, it may be more prudent to completely replace the piles. This will require removal of the existing timber superstructure, complete extraction of the existing piles and installation of new driven timber piles. Due to numerous concerns on the use of timber piles in the marine environment, there are a number of challenges to be overcome including some of the following:

- Tropical timber, such as Greenheart and Basralocus, which both have been used in Massachusetts, is generally considered to have greater resistance to decay and marine borer attack. However, according to *Commercial Timbers of the Caribbean (Agriculture Handbook 207)* by the US Department of Agriculture (see Appendix E) "No timber is known to be entirely resistant to marine borers or teredo. A number of Caribbean timbers do exhibit a high resistance to these marine animals. However, the service life of these timbers is often influenced by local conditions and the particular species of marine borers present. Timbers that show high resistance to teredo in Caribbean waters are sometimes far less resistant along the Atlantic Coast of the United States. Similarly, timbers may vary in their resistance between salt and brackish waters. These differences are considered to be the result of different types and species of marine borers from one place to another."

- The Powder Point Bridge in Duxbury, Massachusetts (a 2200 foot long, 133-span timber bridge over the Back River at Duxbury Bay) illustrates this concern (see Appendix B.) The bridge was reconstructed in 1987 using piles made from Basralocus. Although Basralocus reportedly is considered highly resistant to decay, the piles exhibited significant decay and deterioration after only 25 years of use. Based on the referenced statements above and the disappointing performance on the Powder Point Bridge, there are reasons for concern with the use of these materials. Ultimately, there is insufficient evidence to support that tropical timber can be used to significantly increase the service life of the piles at this site.

Photo 9 - Powder Point Bridge - Pile Condition

- The above referenced article on *Commercial Timbers of the Caribbean*, referring to marine borers, states, “The most practical protection for piling and other timbers used in sea water is heavy treatment with coal-tar creosote or creosote-coal-tar solution.” Currently, the use of creosote preservative treatment of piles is restricted and there is widespread opposition to its use in marine environments in Massachusetts. However, proponents of creosote preservative treatments such as the Western Wood Preservative Institute, the Creosote Council, and others argue that the environmental concerns are unfounded and that there is no scientific evidence to support the concerns. Until these disagreements can be resolved, the restrictions on its use are likely to remain and there is a risk that creosote treated timber piles will not be permitted. As such, the preservatives currently supported for use on timber piles in this environment are less effective water-borne preservative chemicals, which yield a significantly shorter service life for the piles than creosote.

It is recommended that the bolting hardware throughout bridge be replaced with more corrosion resistant material such as Type 316 stainless steel that does not rely on sacrificial material with a limited service life (e.g. zinc coatings) to protect the bolts.

Rehabilitation Scope: The Rehabilitation Scope is the same as that for the Repair Scope.

Functionality and Safety: The piles do not affect the functionality and safety of the bridge.

Load Capacity: The current loss in section of the piles is not currently considered severe enough to reduce the load carrying capacity of the bridge to a capacity less than the other governing members of the bridge. However, if the piles are permitted to continue to deteriorate, it is likely that this condition will eventually be reached.

The foundation capacity of many of the piles is unknown as there are no pile driving records indicating the depth to which the piles were installed or the driving resistance that was achieved. Although it is likely that the piles were driven to dense sandy glacial till material found 40 to 50 feet below the river bed, this cannot be confirmed. There is also no information regarding the design capacity of the 1925 piles. The predicted local scour (approximately 4 feet) will further reduce the load carrying capacity of the piles and the lateral stability. Although there is no reported significant settlement or loss in stability, the factors of safety for both axial capacity and lateral stability are unknown and thus there is a risk that the piles can settle under heavy loads or lose stability due to scour from a major storm event.

Maintenance: Installation of FRP jackets to the piles may increase maintenance as it may be necessary to provide minor maintenance of the jackets. Based on the limited experience with these jackets, it is difficult to fully gauge the maintenance impacts.

Replacing the timber piles now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating timber or to reapply in-place preservative treatments. However, based on the limited anticipated service life of timber piles in this environment, maintenance would likely continue to be a significant long-term concern with the less effective water-borne preservatives. Use of tropical timber may increase the service life slightly and thus reduce maintenance somewhat, but because the durability of this timber is unreliable, the long-term maintenance is still anticipated to be a significant concern.

Visual Impacts: The installation of FRP jackets on the piles may introduce a visual impact, as the timber piles will be completely obscured by the jackets. Furthermore, the jackets will be significantly larger in diameter than the existing piles (approximately 18” to 20” in diameter instead of the current 12” diameter timber piles.) With the FRP jackets installed, the piles will effectively no longer be considered timber piles as they will be considered composite piles (i.e. FRP shell with a timber core.)

4.4.4 Timber Bracing

NBIS Condition Rating: 4 (Poor)

Condition Description: The timber lateral bracing members throughout the bridge were replaced, with the exception of the bracing members in Bents 4A and 6A, when the bridge was reconstructed in 1980. There are diagonal lateral bracing members secured to the piles in every pile bent with the exception of Bent 8 and diagonal longitudinal bracing members attached to the piles at the outside edge of the bridge between Bents 2 and 3, Bents 5 and 6 and Bents 8 and 9. The bracing sometimes include spacer boards to offset the bracing from the piles needed to accommodate misalignment of the piles.

The bracing members typically exhibit moderate to heavy deterioration and corresponding loss in section within the tidal zone due to marine borer attack. The south end of Bent 3, the north end of Bent 5, and the south end of Bent 8 represent the most severe conditions with the lower end of the bracing member exhibiting complete deterioration for a length of 4 to 5 feet.

All of the existing bracing members contain creosote preservatives; however, much of the creosote has leeched from the bracing members in the tidal zone and thus no longer protects the bracing members from surface decay and marine borer attack. The creosote preservative in the upper portion of the bracing is in greater quantity; however, there is evidence that the quantity has reduced somewhat due to ongoing leeching of the material.

The galvanized steel bolts that attach the bracing members to the piles exhibit heavy surface corrosion and moderate section loss in the tidal zones and light surface corrosion at other locations.

Repair Scope: As the bracing members throughout the bridge include significant deterioration from marine borer attack, it is recommended that the timber bracing members including corresponding spacer boards be replaced. As the bracing members are partially submerged in saltwater and creosote preservative treatment of piles is restricted for use in marine environments, the bracing members will need to be replaced with dimensional lumber with water-borne preservative chemicals permitted for use in this environment. As the water-borne preservatives are less effective in protecting the timber, the bracing members are likely to have a limited service life. The use of tropical timber may increase the service life somewhat, but recent experience in similar applications indicates that the service life is still likely to be limited.

It is recommended that the bolting hardware throughout bracing system be replaced with more corrosion resistant material such as Type 316 stainless steel that does not rely on sacrificial material with a limited service life (e.g. zinc coatings) to protect the bolts.

Rehabilitation Scope: The Rehabilitation Scope is the same as that for the Repair Scope.

Functionality and Safety: The bracing members do not affect the functionality and safety of the bridge.

Load Capacity: The bracing members are required for the lateral stability of the structure and to reduce deflections that might make motorists and pedestrians feel uncomfortable. The lateral bracing does not otherwise directly affect the load carrying capacity of the structure.

Maintenance: Replacing the timber bracing now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating timber or to reapply in-place preservative treatments. However, based on the limited anticipated service life of timber piles in this environment, maintenance would likely continue to be a significant long-term concern with the less effective water-borne preservatives. Use of tropical timber may increase the service life slightly and thus reduce maintenance somewhat, but because the durability of this timber is unreliable, the long-term maintenance is still anticipated to be a significant concern.

Visual Impacts: Replacement of the timber bracing is not anticipated to introduce a visual impact.

4.5 Channel & Channel Protection

4.5.1 Timber Fender System

NBIS Condition Rating: 3 (Serious)

Condition Description: The timber members that make up the fender system were replaced when the bridge was reconstructed in 1980. These members consist of a series of 6x12 vertical members and 6x12 horizontal members used to stiffen and mount the fender boards to the pile bents. There are also smaller horizontal members secured to the front of the vertical planks that serve as rub rails.

The vertical planks for the rub rails typically exhibit moderate to heavy deterioration and corresponding complete loss in section within the tidal zone due to marine borer attack and decay.

The existing vertical planks contain water-borne preservatives, much of which has leeched out of the members in the tidal zone. The horizontal members contain creosote preservatives, some of which has leeched out the members making it less effective in protecting the members.

The east fender exhibits impact damage at both ends with several vertical planks that are leaning or that have rotated. The fenders do not include tapered features that help guide vessels approaching the opening.

The galvanized steel bolts that attach the fender members to the pile bents exhibit heavy surface corrosion and moderate section loss.

Repair Scope: As the boards that make up the fender system include significant deterioration from marine borer attack, it is recommended that these members be replaced. As the fender boards are partially submerged in saltwater and creosote preservative treatment of piles is restricted for use in marine environments, these boards will need to be replaced with dimensional lumber with water-borne preservative chemicals permitted for use in this environment. As the water-borne preservatives are less effective in protecting the timber, the fender boards are likely to have a limited service life. The use of tropical timber may increase the service life somewhat, but recent experience in similar applications indicates that the service life is still likely to be limited.

It is recommended that the bolting hardware throughout fender system be replaced with more corrosion resistant material such as Type 316 stainless steel that does not rely on sacrificial material with a limited service life (e.g. zinc coatings) to protect the bolts.

Rehabilitation Scope: The Rehabilitation Scope is the same as that for the Repair Scope.

Functionality and Safety: The fender system helps guide boats through the opening beneath the bascule span. The narrow channel and the significant overhang of the bascule span reportedly make navigation through the bridge a significant challenge. This is reflected in the damage to the fenders. The Repair and Rehabilitation Scope for the fender system will not correct this undesirable condition.

Load Capacity: The fender system does not affect the bridge load carrying capacity.

Maintenance: Replacing the timber fender system members now would reduce maintenance in the short-term by reducing the need to make periodic repairs to the deteriorating timber or to reapply in-place preservative treatments. However, based on the limited anticipated service life of timber in this environment, maintenance would likely continue to be a significant long-term concern with the less effective water-borne preservatives. Use of tropical timber may increase the service life slightly and thus reduce maintenance somewhat, but because the durability of this timber is unreliable, the long-term maintenance is still anticipated to be a significant concern.

Visual Impacts: Replacement of the fender system timbers is not anticipated to introduce a visual impact.

4.5.2 Embankment Slope Protection

NBIS Condition Rating: 7 (Good)

Condition Description: The rubble rip rap slope protection is generally stable with no apparent significant erosion or settlement and appears to be adequately protecting the approach embankments along the abutment wing walls.

Repair Scope: None required.

Rehabilitation Scope: None required.

Functionality and Safety: The rubble rip rap does not affect the functionality and safety of the bridge.

Load Capacity: The rubble rip rap does not affect the load capacity of the bridge.

Maintenance: There are no reported maintenance concerns with the current rubble rip rap and no proposed changes that would affect the maintenance.

Visual Impacts: There are no proposed changes to the rip-rap that would introduce a visual impact.

4.5.3 Waterway Bottom Surface/Scour

NBIS Condition Rating: 7 (Good)

Condition Description: There are currently no reported scour concerns and the NBIS Scour Rating considers the bridge "Stable for Assessed Scour Conditions".

Repair Scope: None required.

Rehabilitation Scope: None required.

Functionality and Safety: The waterway bottom surface does not affect the functionality and safety of the bridge.

Load Capacity: The predicted local pier scour during a major storm event for the pile bents is approximately 4 feet, which will reduce the axial load carrying capacity and lateral stability. The foundation capacity of many of the piles is unknown as there are no pile driving records indicating the depth to which the piles were installed or the driving resistance that was achieved. Although it is likely that the piles were driven to dense sandy glacial till material found 40 to 50 feet below the river bed, this cannot be confirmed. Although there is no reported significant settlement or loss in stability, the factors of safety for both axial capacity and lateral stability are unknown.

Maintenance: There are no reported maintenance concerns with the current waterway bottom surface and no proposed changes that would affect the maintenance.

Visual Impacts: There are no proposed changes that would introduce a visual impact.

4.6 Traffic Safety

4.6.1 Curb/Bridge Railing

NBIS Condition Rating: 5 (Fair)

Condition Description: See 4.2.4 and 4.2.5 above.

Repair Scope: See 4.2.4 and 4.2.5 above.

Rehabilitation Scope: See 4.2.4 and 4.2.5 above.

Functionality and Safety: See 4.2.4 and 4.2.5 above.

Load Capacity: See 4.2.4 and 4.2.5 above.

Maintenance: See 4.2.4 and 4.2.5 above.

Visual Impacts: See 4.2.4 and 4.2.5 above.

4.6.2 Approach Guardrail/Transitions

NBIS Condition Rating: 5 (Fair)

Condition Description: The steel guardrail attached to the back face of the wing walls is typically loose. There is minor impact damage to the north approach guardrail at the west approach to the bridge. The steel guardrail does not meet current design standards and thus does not adequately protect motorists from the bridge end hazards. The steel guardrail does no include proper end treatments and transitions to the bridge.

The steel guardrail is also acting as a pedestrian railing along the sidewalk. The steel guardrail does not meet current design standards for a pedestrian railing protecting a drop-off hazard including railing height and opening width.

Repair Scope: Reattach the loose guardrail attached to the back of the abutment wing walls.

Rehabilitation Scope: See 4.4.1 above for additional discussion.

Provide crash-tested timber guardrail in line with the new traffic railing on the bridge and along the approach roadway for a length of approximately 120 feet to provide the required advancement length required to protect motorists from the bridge end hazard. Provide the required proper end terminations and transitions to the bridge traffic railing.

Replace the guardrail at the back of the sidewalk with new timber pedestrian railings that meet current safety standards for drop-off hazards. This will work will need to be worked with the modifications to the abutment wing walls and new concrete sidewalks.

Functionality and Safety: The Repair Scope does not improve the functionality and safety. Without modifications and improvements to the abutment wing walls and the adjacent sidewalks, guardrails, curbs and railings, there will continue to be safety concerns for pedestrians and motorists and accessibility concerns.

Proposed improvements to the abutment and approach roadway in the Rehabilitation Scope will improve safety by better protecting pedestrians from the drop-off hazard and motorists of the bridge end hazard. The modifications will also provide the required minimum sidewalk width for accessibility.

Load Capacity: The guardrails do not affect the load capacity of the bridge.

Maintenance: The continued use of the existing guardrails is not a significant maintenance concern. New timber guardrails and pedestrian railings are not anticipated to introduce significant additional maintenance requirements in the short-term but may introduce minor additional maintenance in the long-term with additional timber members to be maintained.

Visual Impacts: Modifications to the abutments to accommodate the wider sidewalks, pedestrian railings and traffic railing are a visual departure from the existing configuration.

5.0 OTHER CONSIDERATIONS

5.1 Navigation Opening

As identified above, the bascule span currently provides 19'-4" of horizontal clearance between fenders. The bascule leaf is approximately 23'-8" from pivot to tip and rotates to a maximum angle of approximately 75 degrees from the horizontal position in the fully raised position. With the bascule leaf in the fully raised position, the bascule leaf overhangs the west fender and provides unlimited vertical clearance for a width of approximately 15'-2" between leaf tip and east fender. Reportedly the bridge does not currently open to its originally intended opening angle due to concerns with the bridge operation. Replacement of the operating equipment with new equipment that allows the bridge to pivot to its full intended opening angle will at best only provide the original 15'-2" wide clear opening identified above. Reportedly there are numerous impacts to the east fender system as boaters navigate to clear the raised bascule leaf. Due to the significant challenges of navigating this narrow opening, boating interests have requested for improvements to the navigation opening and have confirmed that a minimum horizontal clear opening with unlimited vertical clearance for a width of 25 feet would meet their needs.

Evaluation of the bascule span geometry confirmed that limited improvements to the navigation width can be gained within the existing constraints. A slight shift of the pivot point to the west will permit the bascule span to be raised to a steeper opening angle. The shift combined with a bascule span opening angle of 82.5 degrees yields a clear width with unlimited vertical clearance of 19'-4", which equals the clear distance between fenders. However, this is still significantly less than the 25'-0" clear opening width requested by the boating interests.

Physical restrictions limit the amount this opening can be improved as follows:

1. A greater shift results in a longer bascule span from pivot to tip, which requires greater amount of counterweight to balance the span. There are two limitations that limit the size of the counterweight. The first is the limitation on the length of the counterweight, which is restricted by the limited underdeck clearance and the requirement that the counterweight not become submerged when the bascule span fully opens at high tide. The second is the limitation on the counterweight thickness, which is restricted by the limited clearance between the underside of the stringers that support the counterweight and the Bent 7A piles with the bascule span fully raised. The limitations on the size of the counterweight govern the amount of shift that can be made.
2. With the bascule span fully raised, the extension of the operating rope past the defector sheave must be of a minimum length in order to meet maximum horizontal deflection angles. The current length of extension of operating rope at the current maximum opening angle is already close to the minimum recommended. In order to improve this, the offset of the sheave pole relative to the pivot needs to increase. This shift is possible with the relocation of the sheave poles from their current location on Bent 7A to Bent 6.

As the recommended repairs and rehabilitation include replacement of significant portion of the bridge, there is a risk that the US Coast Guard may consider and classify the project as a bridge replacement instead of a repair or rehabilitation and as such require improvements to the navigation opening before they will grant a permit, which can lead to delays in the project. There are numerous examples of this that can be found throughout the United States (e.g. 1993-1994, Blackburn Point Swing Bridge Rehabilitation, Nokomis, Florida, a swing bridge listed on the National Register of Historic Places.)

Although it is always possible to identify a different scope of work that minimizes the number of components to be replaced, this potentially reintroduces the numerous other significant concerns such as significantly increased construction cost, increased required maintenance, increased deterioration that can eventually result in load restrictions and/or reduced service life, potential for environmental contamination or human health risks, and reductions in safety.

5.2 Maintenance and Service Life

The current condition of the timber varies throughout the bridge from “satisfactory” to “poor” depending on the element (see Section 4 above.) In addition, the condition of the timber throughout the bridge is of a condition that is conducive to continuing deterioration, and thus it is anticipated that the timber will continue to deteriorate unless corrective action is taken. Continued deterioration will result in loss of section and corresponding loss in load carrying capacity. Although the current deterioration has not reduced the load carrying capacity to a level that requires load restrictions, it is anticipated that the deterioration will eventually reach a level where load restrictions may be necessary. Without corrective action, the deterioration would ultimately expect to reach a level where the bridge would be unsafe to carry traffic.

In consideration of the current conditions, a “do nothing” approach including normal maintenance will not correct the conditions that cause the bridge to deteriorate and make it “Structurally Deficient”. Furthermore, currently available maintenance and repair techniques will not extend the service life of the timber elements of the bridge a reasonable duration in this environment.

As different timber elements of the bridge are in different condition, the service life and maintenance requirements are also different for each element. Due to the wide variety of factors that contribute to deterioration, it is difficult to estimate with accuracy the remaining service life of timber members. However, experience with similar bridges in similar environments in Massachusetts provides some guidance in this area. An estimate of the remaining service life for each of the existing members and an estimate of the overall service life for replacement members is as follows:

SUMMARY OF TIMBER ELEMENT SERVICE LIFE			
Element	Est. Remaining Life (years)	Est. Overall Life (years)	Anticipated Governing Failure Mode
Wearing Surface[1]	0	10-20	Abrasion/Wear
Structural Deck	0-10	30-40	Decay
Curbs	0-10	30-40	Decay
Railings	10-20	40-50	Decay
Sheave Poles/Masts	10-20	40-50	Decay
Lifting Beam[2]	20-30	30-40	Fatigue/Decay
Stringers/Blocking	10-20	40-50	Decay
Cap Beams/Sills	10-20	40-50	Decay
Bracing[3]	0	20-30	Marine Borers/Decay
Piles[4]	0	20-30	Marine Borers/Decay
Fender System[3]	0	20-30	Marine Borers/Decay

1 – The existing wearing surface effectively required replacement 5 – 10 years prior and has required significant repair over this period.
2 – The lifting beam was replaced in 2007 due to fatigue failure.
3 – Many of the existing bracing and fender members required replacement 5 – 10 years prior.
4 – The long service life of many of the existing piles is due to the use of heavy creosote oil-based preservative not permitted for use today.

The above estimates assume that the timber will be replaced with commonly available treated timber and installed following current best management design and construction practices. The estimates do not include the extension of the service life by way of periodic in-place preservative treatment, pile jackets, pile wrapping, etc. Recent use of tropical timber on similar bridges and environments in Massachusetts (e.g. Powder Point Bridge, Duxbury) has not demonstrated a significant improvement in the service life of the timber and thus are not considered here. Similarly, there is insufficient experience with Accoya wood, glass infused wood and other recent advances in timber products to support that this material can provide longer service life on bridges in this environment.

As identified earlier, decay of timber can be slowed and the service life extended with the use of in-place preservative treatments (see Section 4 above.) However, for various reasons, the service life of these treatments is relatively short, typically only 5 to 10 years depending on a number of factors including the type of treatment, chemicals used, timber condition, exposure conditions, type of timber, etc. As such, these treatments require frequent reapplication, which can significantly increase the cost of maintenance. Furthermore, many of the toxic chemicals used in these preservative treatments raise concerns regarding human health. A number of the timber elements are readily accessible to human contact including the bridge railings, sidewalks, curbs, wearing surface and sheave poles and thus certain chemicals are not recommended for these locations. Many of the more effective chemicals in preventing decay are the same products not suitable for direct human contact. There are available preservative chemicals that prevent decay that are suitable for human contact (e.g. boron and sodium fluoride) however, research on the effectiveness of these chemicals is somewhat limited and has shown mixed results. In addition, the potential for spills and leeching of the toxic chemical preservatives into the marine environment raises environmental concerns with significant risk that the use of these treatments may not be permitted.

A program of continuing to extend the service life of the bridge by way of piecemeal replacement of timber members, although technically feasible, is generally not cost-effective. Although it is technically feasible to replace a number of the more readily accessible timber elements on a piecemeal basis (e.g. bridge railing, curbs, timber wearing surface, sheave poles, lifting beams and bracing members) replacement of other timber elements that are not readily accessible requires removal of a significant portion of other elements of the bridge. For example, replacement of the structural deck planks requires removal of the timber wearing surface and curbs, replacement of the stringers requires removal of the structural deck, wearing surface and curbs, replacement of the timber cap beams requires replacement of the stringers, structural deck, wearing surface and curbs, and replacement of the piles requires complete removal of the superstructure and cap beams. It is sometimes possible to strengthen or replace a deteriorated portion of an existing member (e.g. a deteriorated section of a stringer, cap beam or pile.) However, this typically requires the addition of reinforcing plates to the members or temporary support of the structure while the deteriorated portion is removed and a new section inserted and spliced to the existing section to remain. This can introduce significant challenges in some locations due to limited space, interference with other members, limited access to fasteners, submerged connections, etc. Although technically feasible, these approaches to extending the life of the bridge significantly increase the cost to maintain the bridge.

Although there are many examples of timber bridges where the service life has been extended in excess of a 100 years, most of these bridges are covered bridges located in non-coastal locations. Unlike covered bridges, where the roof structure and siding typically protect the main structural timber members, the Mitchell River Bridge is fully exposed to the weather, where the effects of continual exposure to moisture and sunlight accelerates deterioration and decay and reduces the service life of the timber. In addition, most covered bridges are not located in marine environments where timber foundations are subject to marine borer attack. In fact, many of the covered bridges are supported on stone foundations not susceptible to deterioration due to submersion in water.

Although technically feasible, prolonging the service life of a timber bridge beyond 30 years in this environment requires a significant financial investment and maintenance commitment by the community and agreements by permitting agencies to support these efforts. Furthermore, now that it has been determined that the existing bridge is historic, the Town has a responsibility to maintain the bridge in a manner that will prevent the continued deterioration.

5.3 Funding

The project is currently funded through the Massachusetts Department of Transportation Accelerated Bridge Program which includes funding participation from the federal government. Although funding for this project was originally intended for replacement of the bridge, the Accelerated Bridge Program covers both replacement and rehabilitation of structurally deficient bridges.

The Federal Highway Administration (FHWA) currently has a policy that bridges replaced using federal funding be designed with a minimum service life of 75 years. Currently, it is not practical to design a timber bridge in this environment for a minimum 75 year service life. However, as a timber bridge will have a lower initial construction cost than a concrete and steel bridge, it is possible for a timber bridge with a 20 to 30 year minimum service life (following major repair, rehabilitation or replacement) to have an overall life cycle cost that is similar to a concrete and steel bridge with a 75 year service life. However, as a timber bridge will have a service life significantly less than that of a concrete and steel bridge, it is anticipated that the bridge will need to be replaced two or three times over a 75 year life cycle period.

As funding under the Accelerated Bridge Program only covers the cost of initial project (not future construction projects) the Town would be responsible for the cost of future repair, maintenance, rehabilitation and/or replacement work. Even though a timber bridge can have similar overall life cycle costs as a concrete and steel bridge, it is likely that the Town would be responsible for a larger proportion of the life cycle cost.

Funds for the Accelerated Bridge Program are only available through Fall 2016. As such, construction for the bridge must be complete before this date in order for the project to be eligible for these funds.

6.0 SCOPE, COST AND SERVICE LIFE FOR REPAIR & REHABILITATION

The scope of work, estimated construction cost and anticipated service life for recommended repairs and rehabilitation are summarized below.

Costs are reported in 2011 dollars (see Appendix G) and include mobilization, traffic control, milling and resurfacing of the approach roadway pavement within the project limits, and a contingency to cover miscellaneous items not considered and anticipated tolerances in unit costs and quantities. The costs do not include engineering design, permitting and construction inspection and engineering.

Because the factors that determine the rate of deterioration in timber members can vary significantly, it is difficult to accurately estimate the service life of timber components. As such, the anticipated service life associated with each scope of work is shown as a range that envelopes the likely best case to the worst case scenario.

Recommended Repair Scope: As a minimum the existing bridge should be repaired to address those elements that require immediate corrective action. The recommended scope of work for these repairs include replacement of the wearing surface, structural deck, curbs, bracing and fenders; replacement of the operating equipment (i.e. wire ropes, deflector sheaves, pulleys, winches, and associated attachments); replacement of the electrical system; installation of FRP jackets on the piles; repair of the abutment concrete; and reattachment of the guardrail. The estimated cost of the repair work is $ 9,363,000 and is expected to provide a service life of 10 to 20 years before replacement of the bridge will be required.

Recommended Rehabilitation Scope: A Rehabilitation Scope with modifications that correct a number of structural, functional, safety and reliability concerns would be a more cost effective solution compared to the Repair Scope in that it will be less expensive and would provide a longer service life. As such, a Rehabilitation Scope would be recommended over a Repair Scope. The recommended scope of work for major rehabilitation includes complete replacement of the timber structure (i.e. wearing surface, structural deck, railings, curbs, stringers and diaphragms, lifting beam, sheave poles, cap beams, sills, piles, bracing and fenders); replacement of the counterweight; replacement of the operating equipment (i.e. wire ropes, deflector sheaves, pulleys, winches, and associated attachments); replacement of the electrical system; repair of the abutment concrete; and reattachment of the guardrail. If desired, the timber railings could be temporarily removed and reinstalled on the reconstructed bridge. Modifications and improvements include replacement of the curbs with crash tested timber traffic railing including timber guardrail along the approach roadways; minor widening of the sidewalks to address accessibility including shifting the operating equipment and sheave poles, and widening the sidewalks on the roadway approaches; installation of additional horizontal timber railing elements or cable railing elements to the pedestrian railings to meet safety requirements; replacement of the guardrail with pedestrian railing along the abutment wing walls; increasing the capacity of the bascule span stringers and cap beams; increasing the capacity of the operating equipment (i.e. wire rope, deflector sheave, pulley, winch, lifting beam and sheave pole sizes); shortening of the counterweight arm to keep the counterweight from becoming submerged; relocation of the pivot point and sheave poles and increasing the opening angle to improve the navigation opening. The estimated cost of the rehabilitation work is $ 4,781,000 and is expected to provide a service life of 20 to 30 years before complete replacement of the bridge will be required.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The bridge currently has a National Bridge Inventory (NBI) Sufficiency Rating of 45.9 out of 100 and the bridge is currently classified as “Structurally Deficient” primarily due to the poor condition of the substructure. The current condition of the timber throughout the bridge varies from “satisfactory” to “poor” and conditions are conducive to continuing deterioration. Doing nothing or performing only normal maintenance will not correct the conditions that cause the bridge to deteriorate. Furthermore, currently available maintenance and repair techniques will not extend the service life of the timber elements a reasonable duration in this environment.

Although the bridge is currently considered safe, anticipated deterioration in the near future is expected to reduce the load carrying capacity to a threshold where load restrictions will be required. Two timber elements already have load carrying capacities less than the required load capacity and many other timber elements have load carrying capacities only slightly above the required capacity. Without corrective action, the condition of the timber is ultimately expected to reach a level where the bridge will be unsafe to carry traffic. Doing nothing or performing only normal maintenance will not correct the load carrying capacity concerns.

In addition to the current deficiencies in the structural condition, there are functional and safety concerns that also should be addressed. The bridge would be classified as “Functionally Obsolete” due to the substandard roadway width, if it were not for the current “Structurally Deficient” classification. Other functional and safety concerns include substandard curbs and bridge railings, substandard guardrails and associated end treatments and transitions, substandard sidewalk widths that do not meet accessibility requirements and substandard pedestrian railings. The bridge does not operate reliably and the operating equipment does not meet standards for safety and maintainability. The current navigation opening is also inadequate to serve the needs of the boating community. Doing nothing or performing only normal maintenance will not correct the functional and safety concerns.

Although technically feasible to repair or rehabilitate the existing bridge, all feasible schemes have significant consequences or leave significant deficiencies. Although some of the consequences and deficiencies individually may be considered minor, the cumulative impact of these is significant. Specific consequences of maintaining, repairing or rehabilitating the existing timber bridge include the following:

- The effort to maintain the existing timber bridge will continue to be a significant effort and a burden to the Town of Chatham in terms of maintenance cost and disruptions to the traveling public with continual piecemeal replacement and/or repair of timber members.
- Although not all timber elements of the bridge currently need to be replaced, it is not cost effective or technically feasible to repair, strengthen or replace certain elements without removing other elements. Although certain timber members can be replaced on an individual basis (e.g. wearing surface, railing, curbs, bracing, fender system, sheave poles and lifting beam) other major elements (e.g. structural deck, stringers, cap beams, and piles) cannot be replaced without removal of a significant number of other elements.

- Continued replacement, repair and strengthening of the timber cannot be sustained indefinitely as this work will eventually weaken members and create conditions that promote further decay. As such, all timber members will eventually need to be replaced.
- Modern strengthening methods such as fiber reinforced polymer (FRP) sheets or pile jackets are expensive relative to the cost of the timber, do not have a long-term performance history for use in salt water environments, and may introduce visual impacts.
- Extending the service life of the existing timber members using in-place preservative treatments is not prudent due to the need for frequent reapplication of the treatment and because of significant environmental and human health concerns. The currently available treatment techniques and chemical preservatives have limited effectiveness and require frequent reapplication (every 5 to 10 years). Some of the treatment would require removal of significant portions of the bridge to provide access for the retreatment. Because of the human health and environmental contamination risks, there is a risk that this treatment will not be permitted for use in this environment.
- Repair or rehabilitation will not fully address the limited navigation opening. Navigation through the bridge continues to be a challenge and a safety concern for the boating community. As such, the boating community has requested improvements to the navigation opening with a preferable minimum horizontal clear opening width with unlimited vertical clearance of 25'-0". Evaluation of the existing bascule span geometry confirmed, with the existing constraints, modifications to the bascule span would at best yield only a 19'-4" wide navigation opening with unlimited vertical clearance. A major repair or rehabilitation effort that replaces the majority of timber components throughout the bridge may be viewed by the US Coast Guard as more of a bridge replacement and as such there is a risk that the project may not be permitted unless the navigation channel is improved to adequately address the concerns of the boating community.
- Although rehabilitation can correct some of the functional and safety concerns, it is not feasible to significantly improve the narrow roadway width on the bridge. With the narrow roadway width, it is advisable to maintain low traffic speed across the bridge. The current significant wear of timber wearing surface promotes lower traffic speeds, which reduces the likelihood of crashes. However, with the replacement of the timber wearing surface and corresponding improvement in the smoothness of the riding surface, traffic speeds are anticipated to increase, which increases the concerns with the narrow roadway width.
- Although MassDOT has confirmed that a rehabilitation project would still be funded under the Accelerated Bridge Program, the funds only cover the cost of the initial project (i.e. the Town of Chatham will be responsible for the cost of the maintenance and any future repairs and/or replacement.) As a rehabilitation project will result in a bridge with a relatively short service life (i.e. only 20 to 30 years) the Town will be responsible for programming funds for replacement much sooner than a bridge with a 75 year service life. Furthermore, a rehabilitated bridge is anticipated to have higher maintenance costs than a new bridge. As these future costs are the responsibility of the Town, the Town will have a greater overall financial responsibility (i.e. a greater proportion of the overall life cycle costs) following a rehabilitation project than a bridge replacement project.

Based on the above listed consequences of maintaining, repairing, or rehabilitating the existing bridge and the scope, cost and life expectancy for each alternative (see Section 6.0 above), it can be concluded that maintenance and repair are not prudent cost effective alternatives compared to the rehabilitation alternative. Furthermore, because the rehabilitation alternative includes replacement of a majority of the bridge elements, and yet still results in functional and safety deficiencies (i.e. narrow roadway and navigation width), has a relatively short service life and requires greater maintenance than other bridge replacement alternatives, complete replacement of the bridge is a more prudent alternative. Complete replacement will provide a more cost effective long-term solution that better addresses future maintenance, functional and safety concerns including navigation that can also address the historical significance of the bridge.

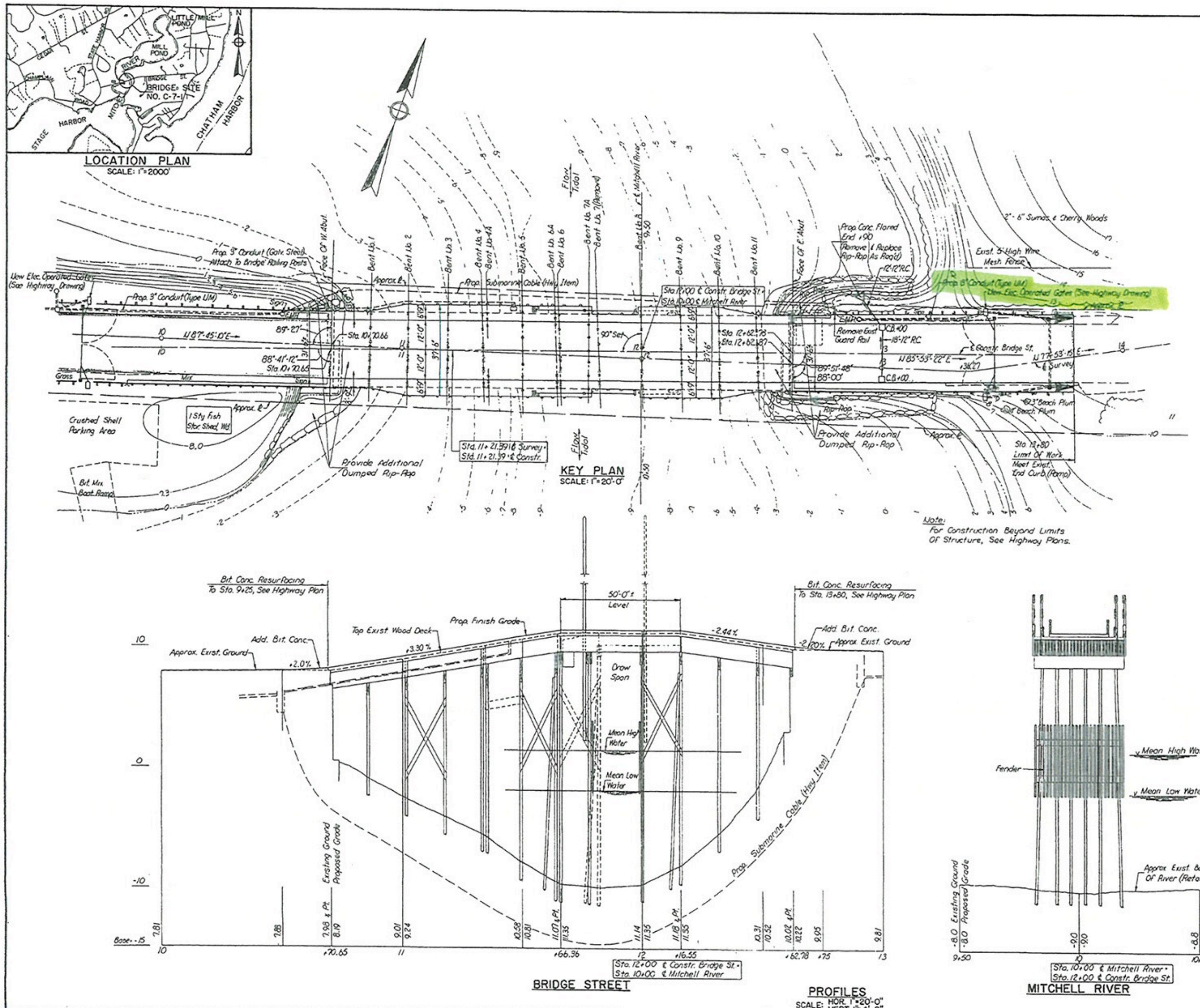
APPENDICES

A. Existing Bridge Plans
B. Structures Field Inspection Reports
    - 2004 Routine
    - 2006 Routine
    - 2008 Routine
    - 2010 Routine
    - 2010 Underwater
    - 2010 Powder Point Bridge (Duxbury)
C. Load Rating Summary (1997)
D. In-place Preservative Treatments
E. Commercial Timbers of the Caribbean
F. FRP Pile Jackets
G. Cost Estimates
H. Operating Equipment Evaluation
I. Correspondence

APPENDIX A

Existing Bridge Plans

PUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
1	MASS.	BH-Z-0707(014)	197	6	16



GENERAL NOTES

FOUNDATIONS

Existing foundations are to remain undisturbed except for modifications to abutment seats and parapets as shown on the contract drawings.

TIMBER PILES

New piles shall be treated timber with 12" min. butt dia. driven to a minimum capacity of 25 tons.

DESIGN

In accordance with current specifications of the American Association of State Highway and Transportation officials 1977 Edition amended to date for H20-44 loading.

BENCH MARK

T.P. square cut top of concrete retaining wall sta. 10+69.4, 76.8 ft. right El. 8.78.

TIMBER

Deck planks: shall be No. 2 Douglas Fir-Larch F_b=1250 psi E=1,700,000 Fv=95 psi

BEAMS, STRINGERS & OTHER STRUCTURAL TIMBER

Dense select structural Douglas Fir-Larch: F_b=1900 psi E=1,700,000 Fv=85 psi
All timber shall be pressure treated in accordance with American Wood Preserves Association Standards P-5. Apply two coats of preservative to all field cuts and holes and to all reused timber.

STEEL RODS, PLATES & SHAPES

shall be A-36 steel galvanized or stainless steel as noted on plans. Machine bolts, drift bolts and pins, lag screws, nuts and washers and nails shall be galvanized steel.

RAILING

Shall be timber, F_b=1900psi E=1,700,000 Fv=85psi. See details contract drawings.

SURVEY NOTEBOOKS

For survey information see Survey Book No's: 21900 & 31633.

BORING NOTES

For boring logs see plan sheet no. 2.

SCALES

Scales noted on plans are not applicable to reduced size prints. Divide scales by 2 for 1/4 size prints.

HYDRAULIC DATA

Not applicable: Tidal Basin.

NOTES

1. Contractor to maintain existing quantity and quality of water at all times.
2. No debris or construction materials shall be spilled or dumped in the existing stream during construction.
3. All existing conditions and dimensions shall be verified in the field by the Contractor prior to fabrication or construction.

ESTIMATED QUANTITIES (Not Guaranteed)
Bridge No. C-7-1

Demolition of Bridge No. C-7-1	1 L.S.
Bridge Excavation	10 C.Y.
Gravel Borrow	10 C.Y.
Drilling Dowel Holes	90 L.F.
Treated Timber Piles	1400 L.F.
Epoxy Mortar for Patching	1200 Lbs.
Dumped Rip-Rap	230 Tons
Bridge Structure No. C-7-1	1 L.S.

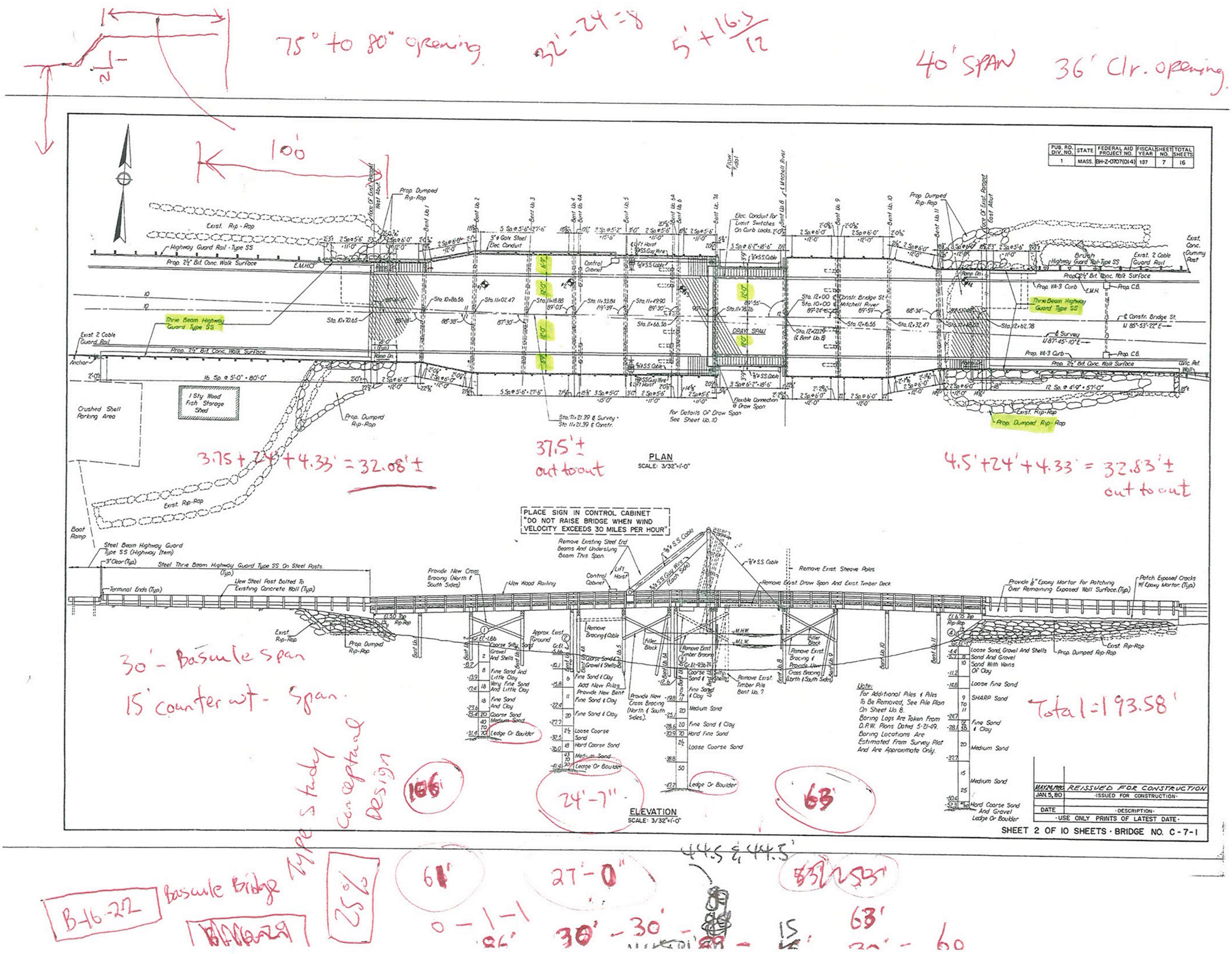
BAYSIDE ENGINEERING ASSOC., INC.
BOSTON, MASS.

DATE	DESCRIPTION
MAY 24, 1980	REISSUED FOR CONSTRUCTION
JAN. 5, 1980	ISSUED FOR CONSTRUCTION

THE COMMONWEALTH OF MASSACHUSETTS
PROPOSED BRIDGE
CHATHAM
BRIDGE STREET
OVER
MITCHELL RIVER
SCALE AS NOTED
OFFICE OF
DEPARTMENT OF PUBLIC WORKS
100 NASHUA ST., BOSTON, MASS.

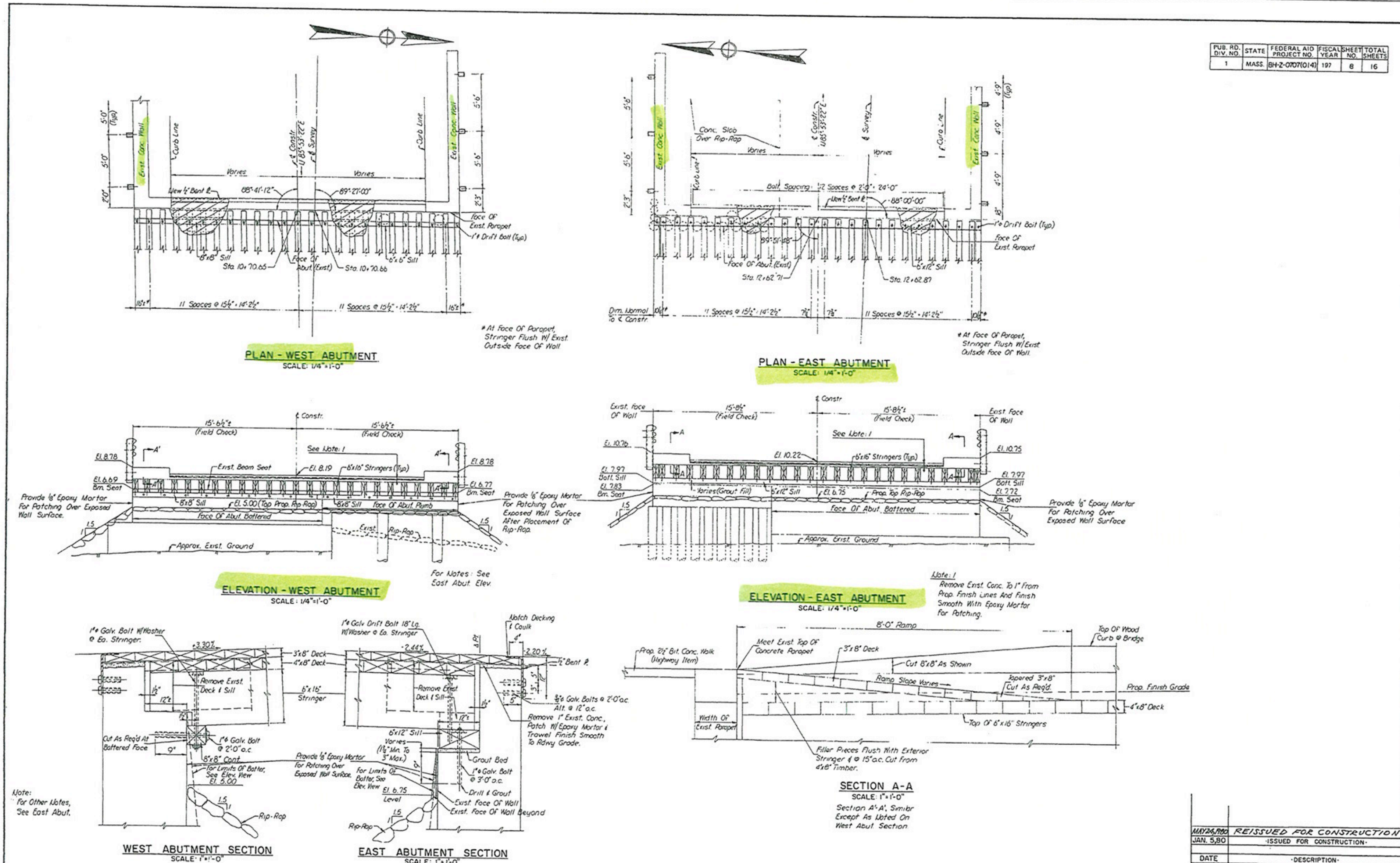
BRIDGE ENGINEER P.E. — CHIEF ENGINEER P.E.

SHEET 1 OF 10 SHEETS · BRIDGE NO. C-7-1



75° to 80° opening
32'-24'=8
40' SPAN
36' Clr. opening
100'
PUB. RD. DIV. NO. | STATE | FEDERAL AID PROJECT NO. | FISCAL YEAR | SHEET NO. | TOTAL SHEETS
1 | MASS. | BH-Z-0707(014) | 197 | 7 | 16
Prop. Dumped Rip-Rap
Exist. Rip-Rap
Highway Guard Rail - Type SS
Prop. 2½" Bit. Conc. Walk Surface
Control Cabinet
Thrie Beam Highway Guard Type SS
Exist. 2 Cable Guard Rail
DRAW SPAN
16 Sp. @ 5'-0" = 80'-0"
1 Sty. Wood Fish Storage Shed
Crushed Shell Parking Area
For Details Of Draw Span See Sheet No. 10
Sta. 11+21.39 ⊈ Survey - Sta. 11+21.39 ⊈ Constr.
⊈ Constr. Bridge St. N 85°-53'-22" E
⊈ Survey N 87°-45'-10" E
Prop. VA-3 Curb
12 Sp. @ 4'-9" = 57'-0"
Boat Ramp
3.75'+24'+4.33' = 32.08'±
37.5'± out to out
PLAN
SCALE: 3/32"=1'-0"
4.5'+24'+4.33' = 32.83'± out to out
PLACE SIGN IN CONTROL CABINET "DO NOT RAISE BRIDGE WHEN WIND VELOCITY EXCEEDS 30 MILES PER HOUR"
Steel Beam Highway Guard Type SS (Highway Item)
Steel Thrie Beam Highway Guard Type SS On Steel Posts (Typ.)
Terminal Ends (Typ.)
New Steel Post Bolted To Existing Concrete Wall (Typ.)
Provide New Cross Bracing (North & South Sides)
New Wood Railing
Remove Existing Steel End Beams And Underslung Beam This Span
Remove Exist. Sheave Poles
Remove Exist. Draw Span And Exist. Timber Deck
Provide ⅛" Epoxy Mortar For Patching Over Remaining Exposed Wall Surface (Typ.)
Patch Exposed Cracks W/ Epoxy Mortar (Typ.)
M.H.W.
M.L.W.
Remove Exist. Timber Pile Bent No. 7
Note:
For Additional Piles & Piles To Be Removed, See Pile Plan On Sheet No. 8.
Boring Logs Are Taken From D.P.W. Plans Dated 5-21-49.
Boring Locations Are Estimated From Survey Plat And Are Approximate Only.
30' - Basule Span
15' counter wt. - Span.
Total = 193.58'
Type study
Conceptual Design
24'-7"
63'
REISSUED FOR CONSTRUCTION
JAN. 5, 80 ISSUED FOR CONSTRUCTION
DATE | DESCRIPTION
USE ONLY PRINTS OF LATEST DATE
ELEVATION
SCALE: 3/32"=1'-0"
SHEET 2 OF 10 SHEETS - BRIDGE NO. C-7-1
44.5 & 44.5'
B-16-22
Basule Bridge
25%
27'-0"
0-1-1
30'-30'
15
63'
60

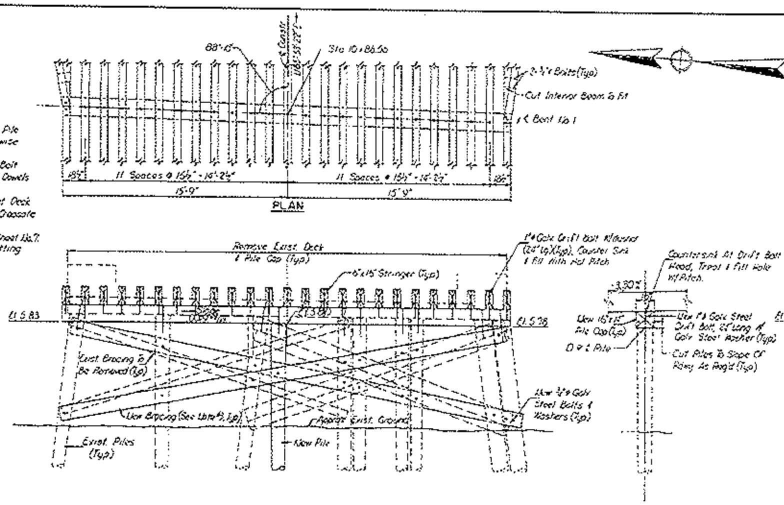
PUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
1	MASS.	BH-Z-0707(014)	197	8	16



SHEET 3 OF 10 SHEETS · BRIDGE NO. C-7-1

PUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
1	MASS.	BH-Z-070R(014)	197	9	16

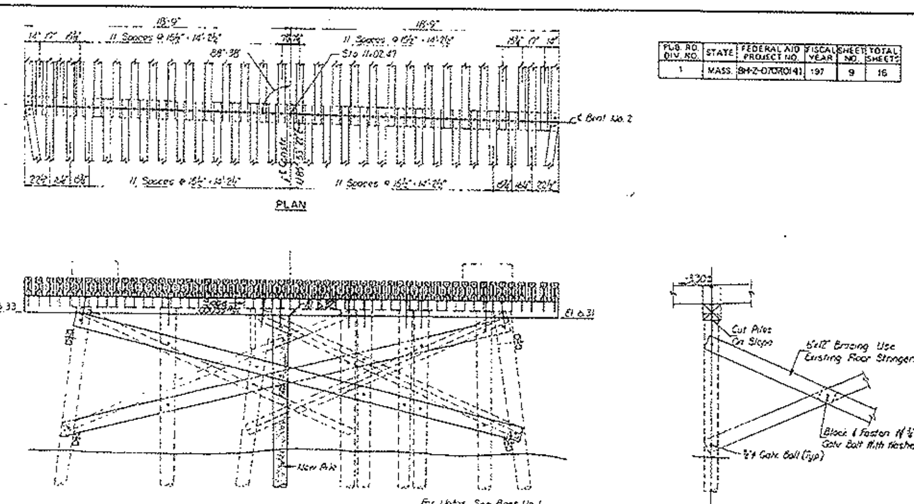
Note:
1) Remove Exist. Bridge Deck And Pile Caps All Bents Except As Otherwise Noted
2) Remove Exist. Bracing - Plug All Bolt Holes With Treated Oversize Wood Dowels In Exist. Wood Piles.
3) Install New Bracing Cut From Exist. Deck Stringers. Apply Two Coats Of Creosote To All Reused Wood Stringers.
4) Splice As Req'd, See Detail On Sheet No. 7.
5) Brace All Pile Bents Prior To Cutting Pile Tops.



ELEVATION

BENT NO. 1

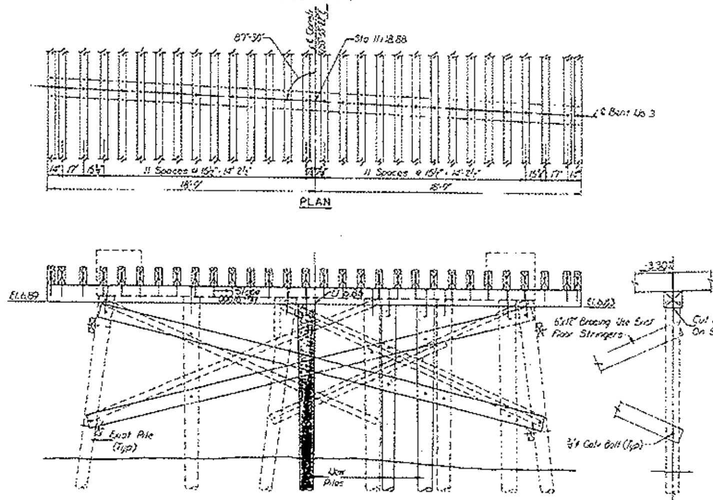
SCALE: 1/4"=1'-0"



ELEVATION

BENT NO. 2

SCALE: 1/4"=1'-0"

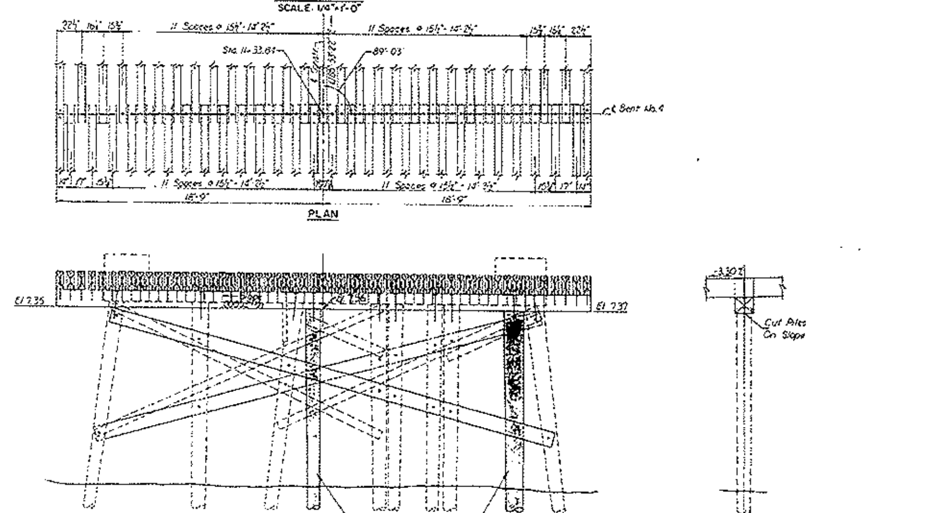


ELEVATION

SECTION

BENT NO. 3

SCALE: 1/4"=1'-0"



ELEVATION

BENT NO. 4

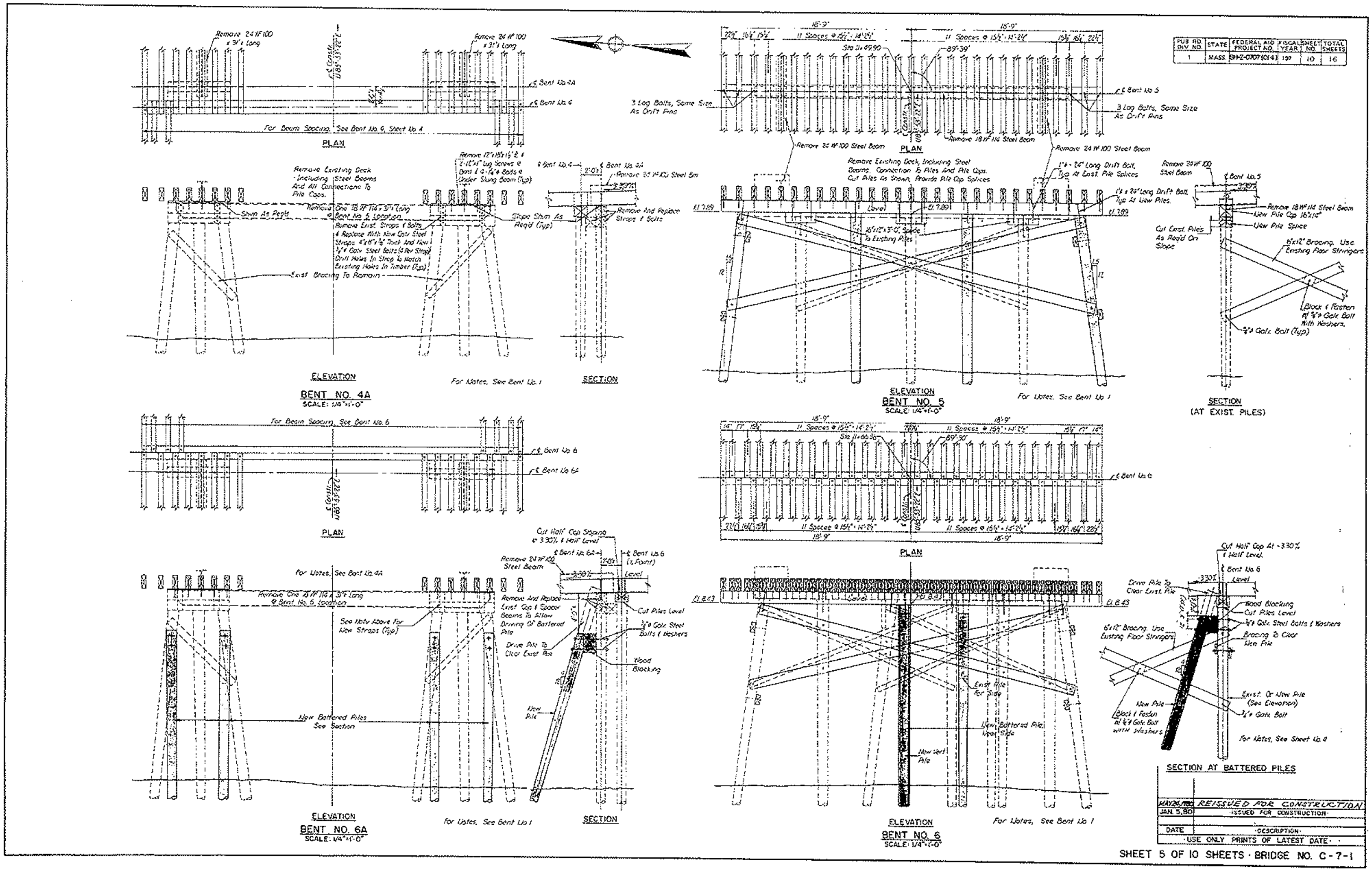
SCALE: 1/4"=1'-0"

SECTION

MAY 21, 1980	REISSUED FOR CONSTRUCTION
JAN. 5, 80	ISSUED FOR CONSTRUCTION
DATE	DESCRIPTION

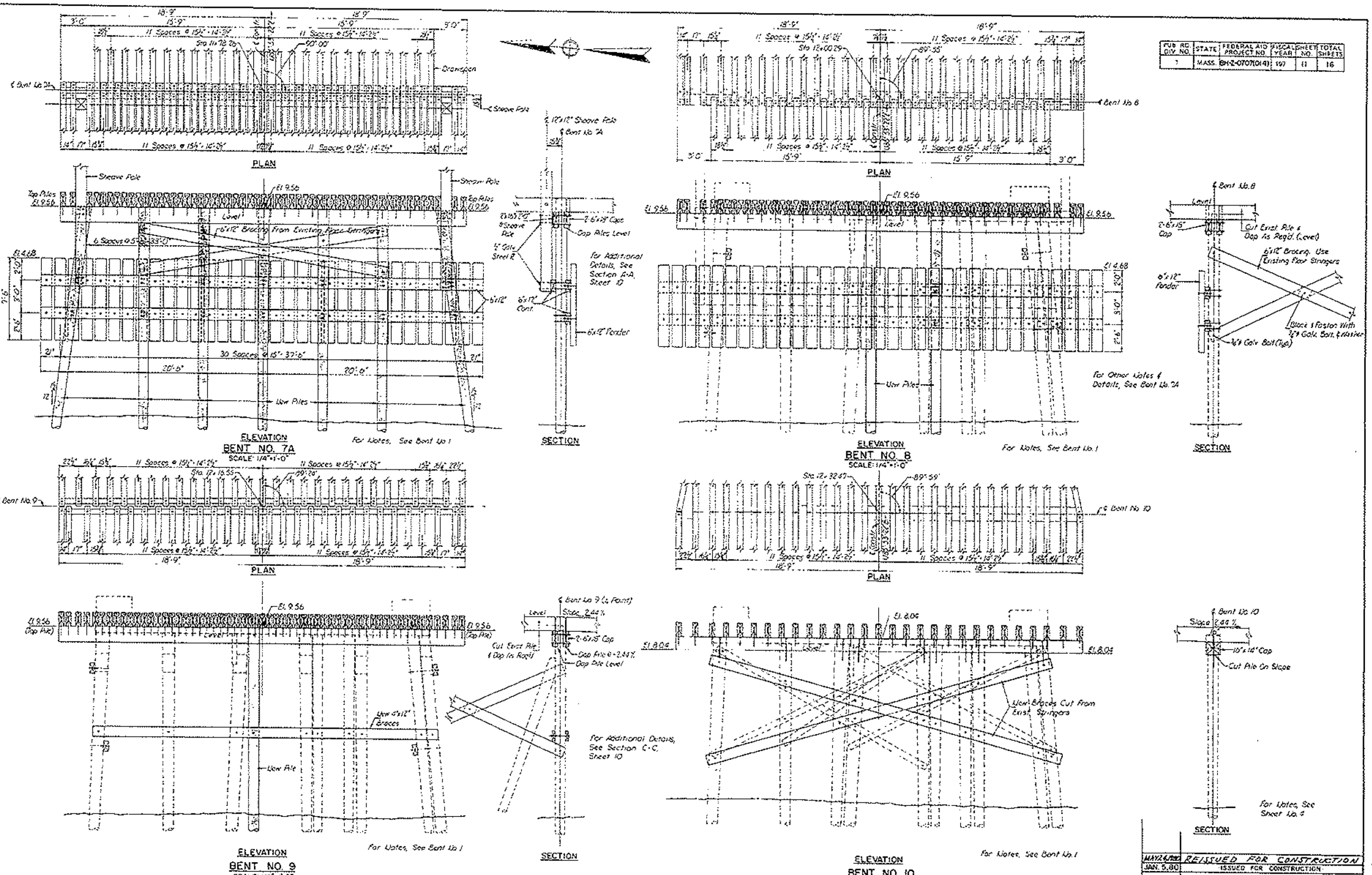
USE ONLY PRINTS OF LATEST DATE

SHEET 4 OF 10 SHEETS - BRIDGE NO. C-7-1



PUB RD DIV NO. 1 | STATE MASS. | FEDERAL AID PROJECT NO. BRZ-0707(014) | FISCAL YEAR 197 | SHEET NO. 10 | TOTAL SHEETS 16
PLAN
For Beam Spacing, See Bent No. 6, Sheet No. 4
Remove 24 WF 100 x 31' ± Long
℄ Bent No. 4A
℄ Bent No. 4
Remove Existing Deck Including Steel Beams And All Connections To Pile Caps.
Shim As Req'd
Slope Shim As Req'd (Typ)
Exist. Bracing To Remain
Remove And Replace Straps & Bolts
ELEVATION
BENT NO. 4A
SCALE: 1/4"=1'-0"
For Notes, See Bent No. 1
SECTION
3 Lag Bolts, Same Size As Drift Pins
℄ Bent No. 5
Remove 24 WF 100 Steel Beam
Remove 18 WF 114 Steel Beam
Remove Existing Deck, Including Steel Beams, Connection To Piles And Pile Caps. Cut Piles As Shown, Provide Pile Cap Splices
Typ At Exist. Pile Splices
Typ At New Piles.
Level
El. 7.89
New Pile Cap 16"x14"
New Pile Splice
Cut Exist. Piles As Req'd On Slope
6"x12" Bracing. Use Existing Floor Stringers
Block & Fasten W/ 3/4"⌀ Galv. Bolt With Washers.
3/4"⌀ Galv. Bolt (Typ)
ELEVATION
BENT NO. 5
SCALE: 1/4"=1'-0"
SECTION (AT EXIST. PILES)
For Beam Spacing, See Bent No. 6
℄ Bent No. 6
℄ Bent No. 6A
11 Spaces @ 1'5½" = 14'-2½"
18'-9"
For Notes, See Bent No. 4A
Cut Half Cap Sloping @ 3.30% & Half Level
Remove 24 WF 100 Steel Beam
Remove And Replace Exist. Cap & Spacer Beams To Allow Driving Of Battered Pile
See Note Above For New Straps (Typ)
Drive Pile To Clear Exist. Pile
Cut Piles Level
3/4"⌀ Galv. Steel Bolts & Washers
Wood Blocking
New Pile
New Battered Piles See Section
ELEVATION
BENT NO. 6A
SCALE: 1/4"=1'-0"
SECTION
El. 8.43
Exist. Pile For Slope
New Battered Pile Near Side
New Vert. Pile
ELEVATION
BENT NO. 6
SCALE: 1/4"=1'-0"
Cut Half Cap At -3.30% & Half Level.
Bracing To Clear New Pile
Exist. Or New Pile (See Elevation)
3/4"⌀ Galv. Bolt
For Notes, See Sheet No. 4
SECTION AT BATTERED PILES
MAY 26, 1980 REISSUED FOR CONSTRUCTION
JAN. 5, 80 ISSUED FOR CONSTRUCTION
DATE | DESCRIPTION
USE ONLY PRINTS OF LATEST DATE
SHEET 5 OF 10 SHEETS · BRIDGE NO. C-7-1

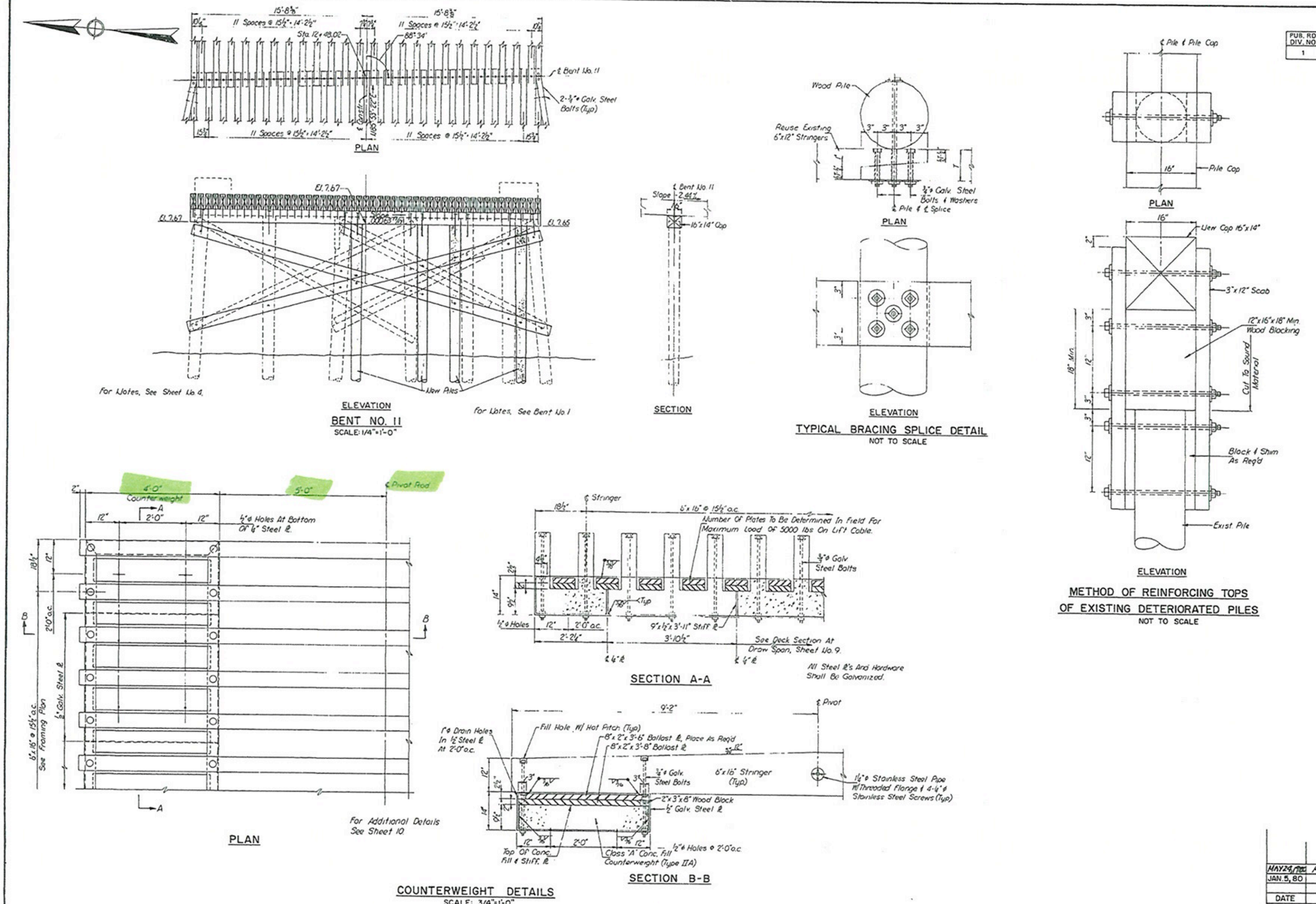
FUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
7	MASS.	BH-Z-0707(014)	197	11	16



MAY 24 1980	REISSUED FOR CONSTRUCTION
JAN. 5, 80	ISSUED FOR CONSTRUCTION
DATE	DESCRIPTION
USE ONLY PRINTS OF LATEST DATE	

SHEET 6 OF 10 SHEETS · BRIDGE NO. C-7-1

PUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
1	MASS.	BH-Z-0707(014)	197	12	16

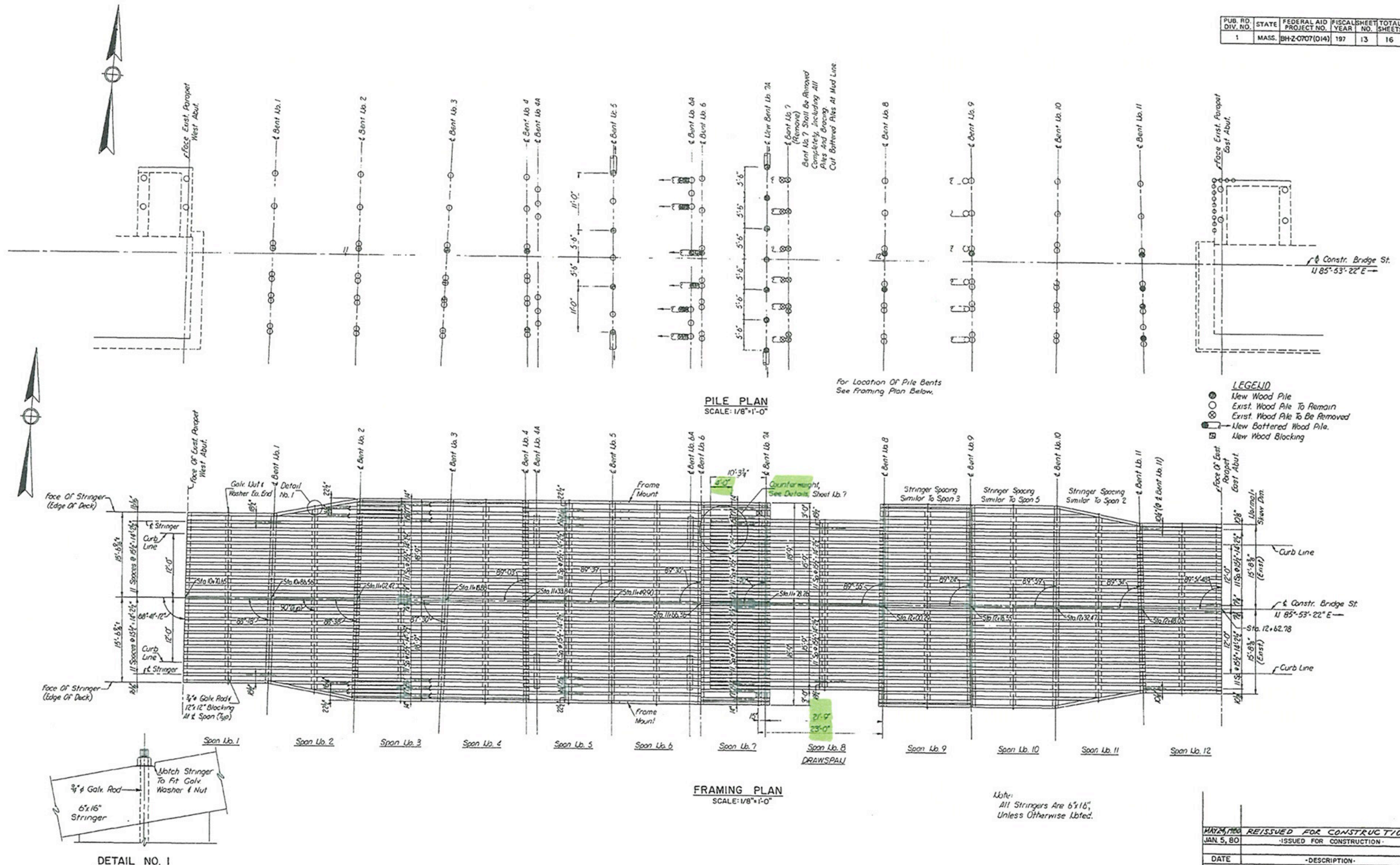


MAY 29, 1980	REISSUED FOR CONSTRUCTION
JAN. 5, 80	·ISSUED FOR CONSTRUCTION·
DATE	·DESCRIPTION·

·USE ONLY PRINTS OF LATEST DATE·

SHEET 7 OF 10 SHEETS · BRIDGE NO. C-7-1

PUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
1	MASS.	BH-Z-0707(014)	197	13	16

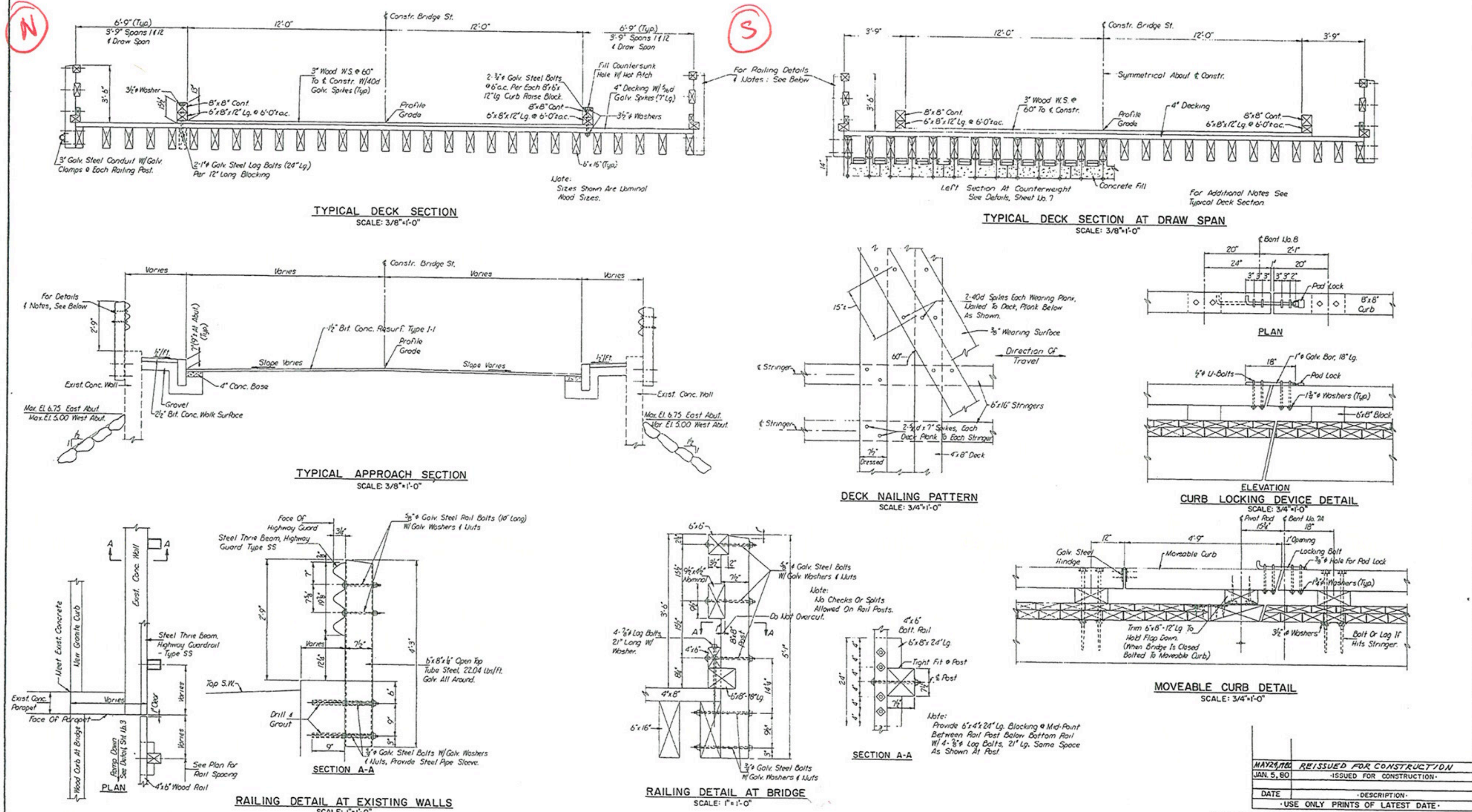


DATE	DESCRIPTION
MAY 29, 1980	REISSUED FOR CONSTRUCTION
JAN. 5, 80	·ISSUED FOR CONSTRUCTION·

·USE ONLY PRINTS OF LATEST DATE·

SHEET 8 OF 10 SHEETS · BRIDGE NO. C-7-1

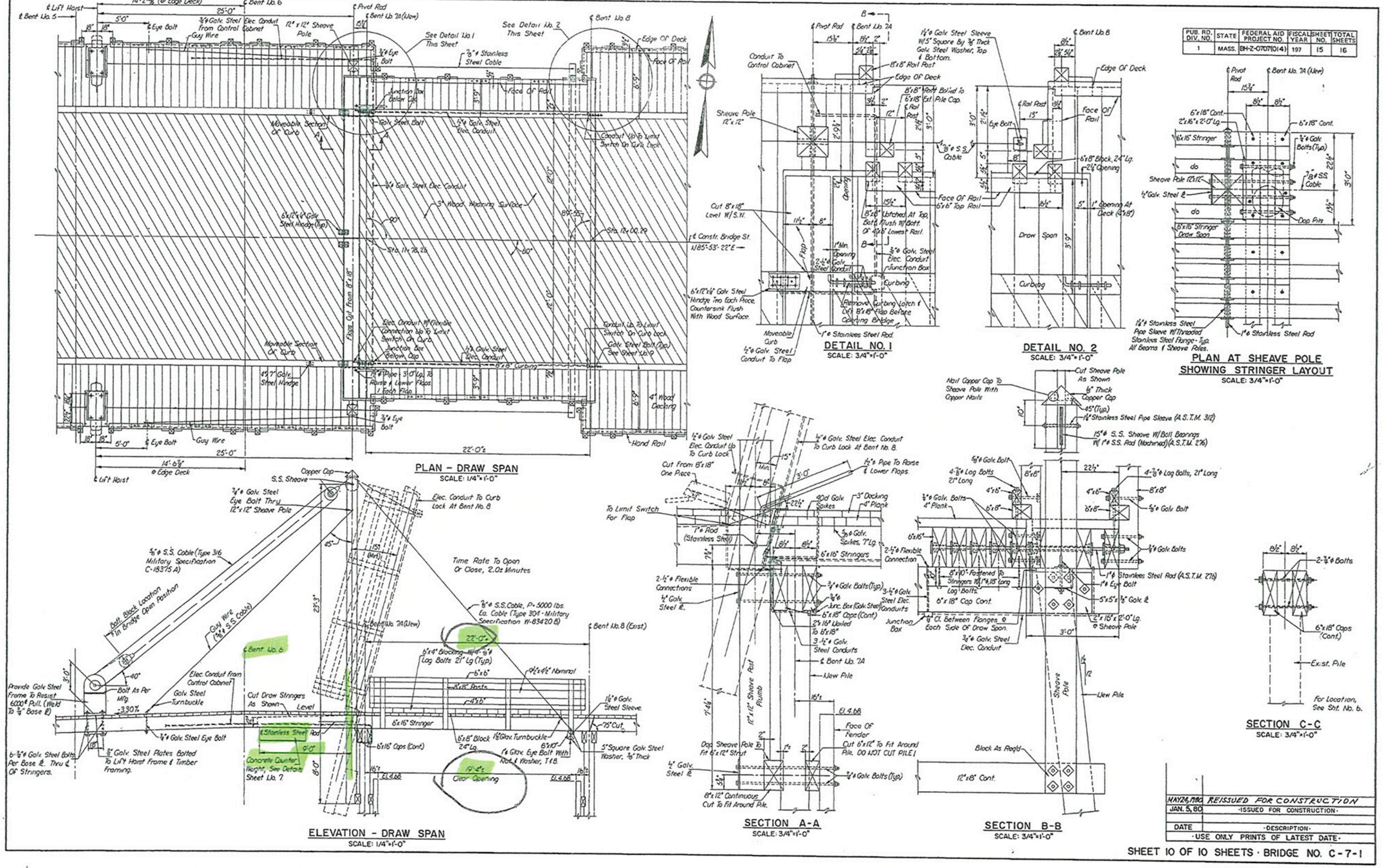
PUB. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
1	MASS.	BH-Z-0707(014)	197	14	16

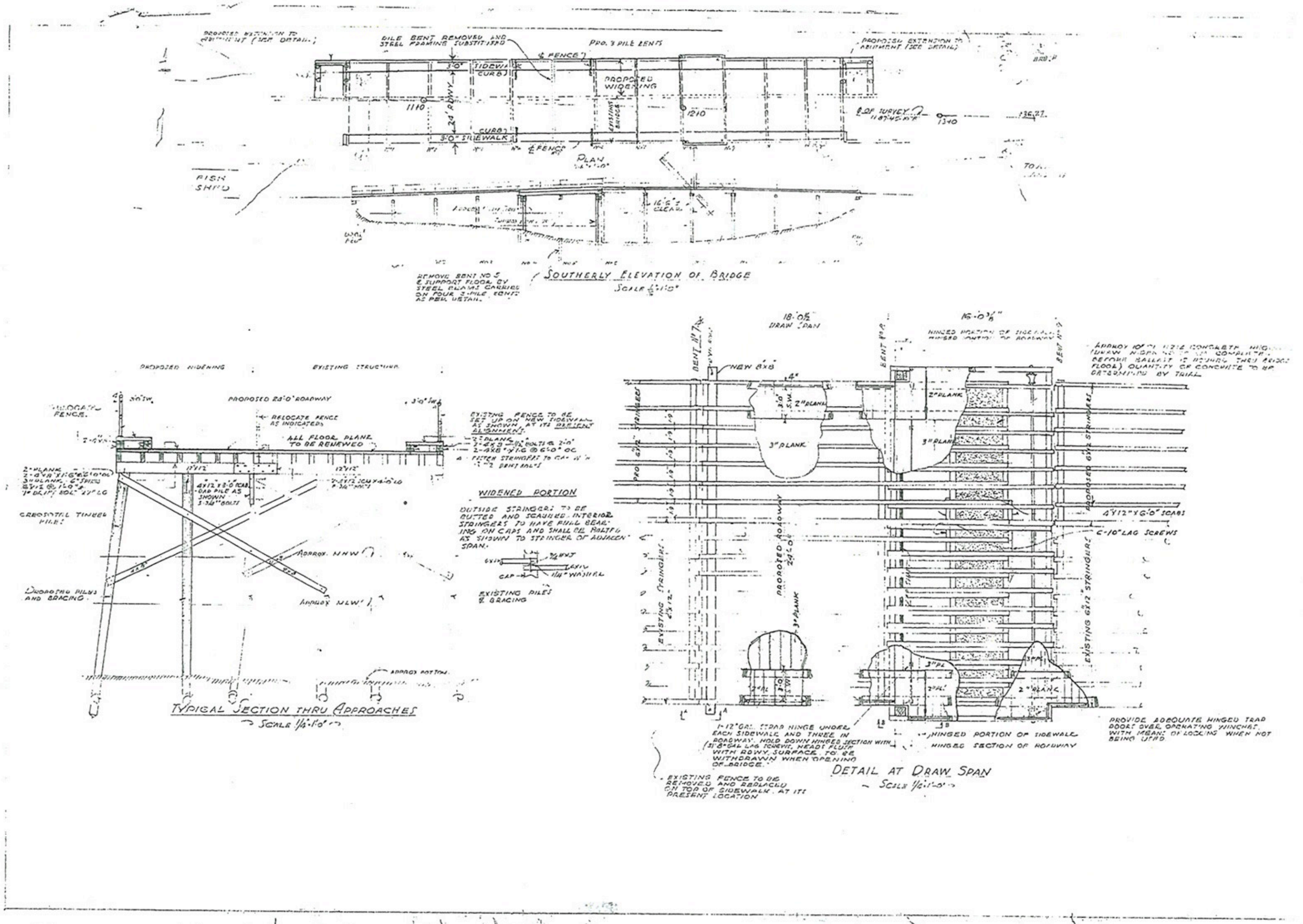


DATE	DESCRIPTION
MAY 29, 1980	REISSUED FOR CONSTRUCTION
JAN. 5, 80	ISSUED FOR CONSTRUCTION

USE ONLY PRINTS OF LATEST DATE

SHEET 9 OF 10 SHEETS · BRIDGE NO. C-7-1


PLAN - DRAW SPAN
SCALE: 1/4"=1'-0"
ELEVATION - DRAW SPAN
SCALE: 1/4"=1'-0"
DETAIL NO. 1
SCALE: 3/4"=1'-0"
DETAIL NO. 2
SCALE: 3/4"=1'-0"
PLAN AT SHEAVE POLE SHOWING STRINGER LAYOUT
SCALE: 3/4"=1'-0"
SECTION A-A
SCALE: 3/4"=1'-0"
SECTION B-B
SCALE: 3/4"=1'-0"
SECTION C-C
SCALE: 3/4"=1'-0"
PUB. RD. DIV. NO. | STATE | FEDERAL AID PROJECT NO. | FISCAL YEAR | SHEET NO. | TOTAL SHEETS
1 | MASS. | BH-Z-0707(014) | 197 | 15 | 16
Time Rate To Open Or Close, 2.0± Minutes
3" Wood Wearing Surface
4" Wood Decking
Sheave Pole 12"x12"
Bent No. 6
Bent No. 8
Pivot Rod
Guy Wire
Eye Bolt
Lift Hoist
Hand Rail
Concrete Counter Weight, See Details Sheet No. 7
Clear Opening
MAY 24, 1990 REISSUED FOR CONSTRUCTION
JAN. 5, 80 ·ISSUED FOR CONSTRUCTION·
DATE ·DESCRIPTION·
·USE ONLY PRINTS OF LATEST DATE·
SHEET 10 OF 10 SHEETS · BRIDGE NO. C-7-1



GENERAL NOTES

FOUNDATION: FOUNDATIONS MAY BE ALTERED IF NECESSARY TO SUIT CONDITIONS OF CONSTRUCTION

DESIGN: DESIGN TO [illegible] WITH THE SPECIFICATIONS OF THE AMERICAN [illegible] OF STATE [illegible] OFFICIALS (1944 EDITION), FOR H-15 LOADING

BENCH [illegible] STA 71+25, [illegible] (TOP EL + 8.01 [illegible] 1929.

[illegible] CONTRACTOR TO [illegible] IN FIELD [illegible] WITH [illegible]

QUANTITIES

CONCRETE EXCAVATION	2	C.Y
TREATED TIMBER PILES	1400	L.F.
ORDINARY BORROW	150	C.Y.
CLASS A CEM CONC MASONRY	24	C.Y.
STEEL REINF FOR STRUCTURES	2900	LBS
STRUCTURAL STEEL	10400	LBS
LUMBER (CREOSOTED)	37	MFBM
LUMBER (SALT TREATED)	2.6	MFBM
RIP RAP	70	C.Y.
RIP RAP R&R	30	C.Y.
METAL BRIDGE RAILINGS R&R		LS
REMOVAL OF BENT NO 5		LS
EXTENSION & REPAIRS OF DRAW MACHINERY		LS
REMOVAL OF PRESENT DECK		LS

ADVERTISING 5-21-49 | CONSTRUCTION 5-21-49

THE COMMONWEALTH OF MASSACHUSETTS
PROPOSED BRIDGE WIDENING

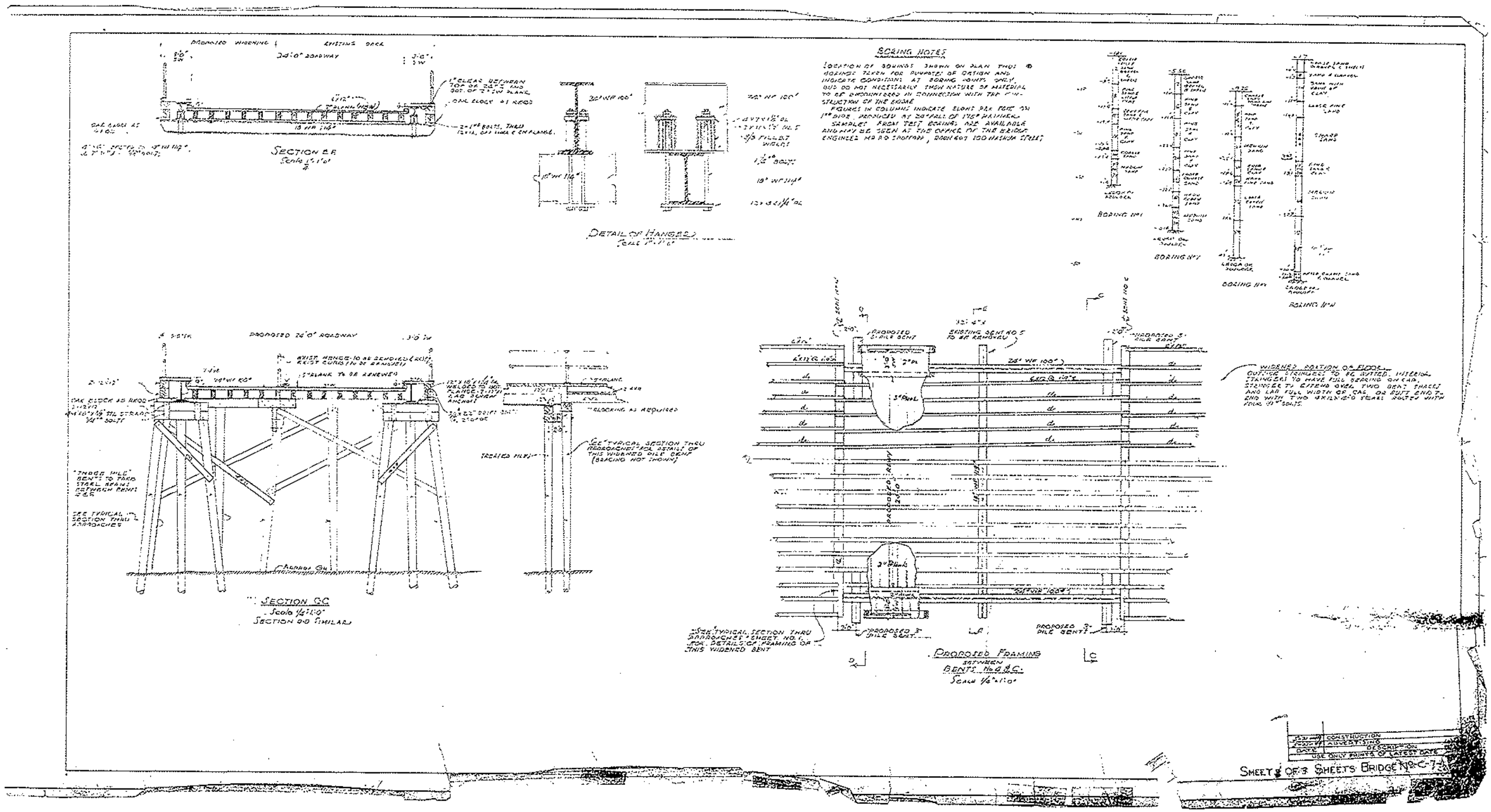
CHATHAM

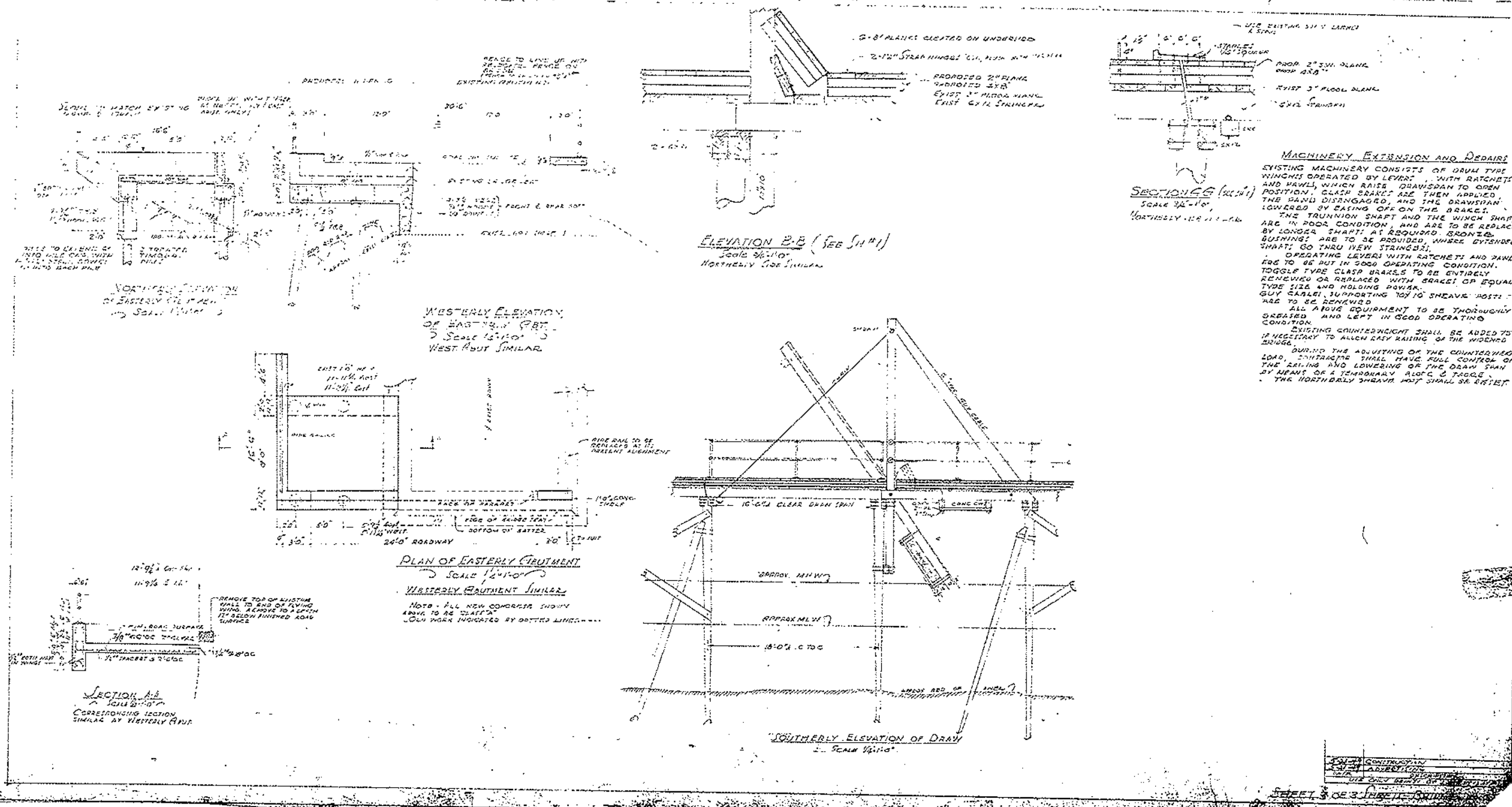
BRIDGE STREET
OVER MITCHELLS RIVER
SCALES AS NOTED
OFFICE OF
DEPARTMENT OF PUBLIC WORKS
100 NASHUA ST BOSTON MASS
APRIL 1949

BRIDGE ENGINEER — CHIEF ENGINEER

DESIGNED BY GFG TRACED BY GFG CHECKED BY C.C.

SHEET 1 OF 3 SHEETS C-7-1


SECTION B-B
DETAIL OF HANGERS
BORING NOTES
BORING No 1
BORING No 2
BORING No 3
BORING No 4
PROPOSED 24'-0" ROADWAY
SECTION C-C
SECTION D-D SIMILAR
TREATED PILES
PROPOSED FRAMING
BENTS No 4 & C
WIDENED PORTION OF FLOOR
3" PLANK
CONSTRUCTION
ADVERTISING
DATE
DESCRIPTION
USE ONLY PRINTS OF LATEST DATE
SHEET OF 3 SHEETS BRIDGE No C-7



NORTHERLY ELEVATION OF EASTERLY ABUTMENT
WESTERLY ELEVATION OF EASTERLY ABT.
WEST ABUT SIMILAR
ELEVATION B-B (SEE SH #1)
NORTHERLY SIDE SIMILAR
SECTION G-G
PLAN OF EASTERLY ABUTMENT
WESTERLY ABUTMENT SIMILAR
24'-0" ROADWAY
SECTION A-A
CORRESPONDING SECTION SIMILAR AT WESTERLY ABUT.
SOUTHERLY ELEVATION OF DRAW
APPROX. MHW
APPROX. MLW
MACHINERY EXTENSION AND REPAIRS
EXISTING MACHINERY CONSISTS OF DRUM TYPE WINCHES OPERATED BY LEVERS, WITH RATCHETS AND PAWLS, WHICH RAISE DRAWSPAN TO OPEN POSITION. CLASP BRAKES ARE THEN APPLIED, THE PAWL DISENGAGED, AND THE DRAWSPAN LOWERED BY EASING OFF ON THE BRAKES.
THE TRUNNION SHAFT AND THE WINCH SHAFT ARE IN POOR CONDITION, AND ARE TO BE REPLACED BY LONGER SHAFTS AS REQUIRED. BRONZE BUSHINGS ARE TO BE PROVIDED, WHERE EXTENDED SHAFTS GO THRU NEW STRINGERS.
OPERATING LEVERS WITH RATCHETS AND PAWLS ARE TO BE PUT IN GOOD OPERATING CONDITION. TOGGLE TYPE CLASP BRAKES TO BE ENTIRELY RENEWED OR REPLACED WITH BRAKES OF EQUAL TYPE SIZE AND HOLDING POWER.
GUY CABLES, SUPPORTING 10"x10" SHEAVE POSTS ARE TO BE RENEWED.
ALL ABOVE EQUIPMENT TO BE THOROUGHLY GREASED AND LEFT IN GOOD OPERATING CONDITION.
EXISTING COUNTERWEIGHT SHALL BE ADDED TO IF NECESSARY TO ALLOW EASY RAISING OF THE WIDENED BRIDGE.
DURING THE ADJUSTING OF THE COUNTERWEIGHT LOAD, CONTRACTOR SHALL HAVE FULL CONTROL OF THE RAISING AND LOWERING OF THE DRAW SPAN BY MEANS OF A TEMPORARY BLOCK & TACKLE.
THE NORTHERLY SHEAVE POST SHALL BE RESET.
CONSTRUCTION
ADVERTISING
SHEET 3 OF 3 SHEETS

APPENDIX B

Structures Field Inspection Reports

- 2004 Routine
- 2006 Routine
- 2008 Routine
- 2010 Routine
- 2010 Underwater
- 2010 Powder Point Bridge (Duxbury)

MASSACHUSETTS HIGHWAY DEPARTMENT
STRUCTURES INSPECTION FIELD REPORT
ROUTINE INSPECTION

2 - DIST	B.I.N.	BR. DEPT. NO.
5	437	C-07-001

CITY/TOWN	8 - STRUCTURE NO.	11-KILO. POINT	41 - STATUS	90 - ROUTINE INSP DATE
Chatham	C07001437MUNNBI	0000.322	Open	10/21-22/2004

07 - FACILITY CARRIED	MEMORIAL NAME / LOCAL NAME	27 – YR BUILT	106 - YR REBUILT	YR REHAB'D (NON 106)
Bridge Street		1936	1980	0000

06 - FEATURES INTERSECTED	26 - FUNCTIONAL CLASS.	DIST. BRIDGE INSPECTION ENGINEER
Mitchell River	08 – Minor Collector	D. Palmer (Reviewed By: [signature])

43 - STRUCTURE TYPE	22 - OWNER	21 - MAINTAINER	TEAM LEADER (Lichtenstein)	PROJECT MANAGER (Reviewed By:)
Timber Bascule	Town	Town	S. Darling MA# 41637 (signature: Scott Darling)	W. Weir MA# 40186 [signature]

107 - DECK TYPE	WEATHER	TEMP. (air)	TEAM MEMBERS
Timber	Sunny	13°C	J. Clogston

ITEM 58: 6 — DECK

DECK		DEF
1. Wearing surface	5	M/P
2. Deck Condition	6	M/P
3. Stay-in-Place Forms	N	
4. Curbs	6	M/P
5. Median	N	
6. Sidewalks	6	M/P
7. Parapets	N	
8. Railing	6	M/P
9. Anti Missile Fence	N	
10. Drainage System	N	
11. Lighting Standards	N	
12. Utilities	6	M/P
13. Deck Joints	5	S/P
14.		
15.		
16.		

Curb Reveal (in millimeters): N/E 330, S/W 330

APPROACHES

APPROACHES		DEF
a. Appr. pavement condition	5	M/P
b. Appr. Roadway Settlement	5	M/P
c. Appr. Sidewalk Settlement	5	M/P

OVERHEAD SIGNS (Y/N): N
(Attached to bridge)

		DEF
a. Condition of Welds	N	
b. Condition of Bolts	N	
c. Condition of Signs	N	

ITEM 59: 6 — SUPERSTRUCTURE

SUPERSTRUCTURE		DEF
1. Stringers	6	
2. Floorbeams	N	
3. Floor System Bracing	N	
4. Girders or Beams	N	
5. Trusses - General	N	
a. Upper Chords	N	
b. Lower Chords	N	
c. Web Members	N	
d. Lateral Bracing	N	
e. Sway Bracing	N	
f. Portals	N	
g. End Posts	N	
6. Pin & Hangers	N	
7. Conn Plt's, Gussets & Angles	N	
8. Cover Plates	N	
9. Bearing Devices	N	
10. Diaphragms/Cross Frames	6	M/P
11. Rivets & Bolts	6	M/P
12. Welds	6	
13. Member Alignment	6	M/P
14. Paint /Coating	N	
15. Kingposts	6	
Year Painted:	X	

COLLISION DAMAGE: Please Explain
None (☐) Minor (☒) Moderate (☐) Severe(☐)

LOAD DEFLECTION: Please Explain
None (☐) Minor (☒) Moderate (☐) Severe(☐)

LOAD VIBRATION: Please Explain
None (☐) Minor (☐) Moderate (☒) Severe(☐)

Any Fracture Critical Member : (Y/N) N

Any Cracks: (Y/N) N

ITEM 60: 4 — SUBSTRUCTURE (DIVE)

SUBSTRUCTURE	Dive Rpt.	This Rpt.		DEF
1. Abutments			6	
a. Pedestals	N	N		
b. Bridge Seats	N	7		
c. Backwalls	N	6		M/P
d. Breastwalls	N	6		M/P
e. Wingwalls	N	6		M/P
f. Slope Pavings/Rip-Rap	N	7		
g. Pointing	N	N		
h. Footings	N	5		M/P
i. Piles	N	H		
j. Scour	N	7		
k. Settlement	N	7		
l.				
m.				
2. Piers or Bents				
a. Pedestals	N	N		
b. Caps	N	N		
c. Columns	N	N		
d. Stems/Webs/Pierwalls	N	N		
e. Pointing	N	N		
f. Footing	N	N		
g. Piles	N	N		
h. Scour	N	N		
i. Settlement	N	N		
j.				
k				
3. Pile Bents			5	
a. Pile Caps	N	6		M/P
b. Piles	4	5		S/A
c. Diagonal Bracing	4	4		S/P
d. Horizontal Bracing	5	5		M/P
e. Fasteners	4	5		S/P
UNDERMINING (Y/N): if YES please explain				N

COLLISION DAMAGE
None (☐) Minor (☒) Moderate (☐) Severe(☐)

I-60 (Dive Report): 4 *I-60 (This Report):* 5

93b-U/W (DIVE) INSP DATE: 01/2004

X = UNKNOWN N = NOT APPLICABLE H = HIDDEN / INACCESSIBLE R = REMOVED

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	437	C-07-001	C07001437MUNNBI	10/21-22/2004

ITEM 61 — 5

CHANNEL & CHANNEL PROTECTION

	Dive Rpt.	This Rpt.	DEF
1. Channel Scour	7	7	
2. Embankment Erosion	7	7	
3. Debris	7	7	
4. Vegetation	7	7	
5. Utilities	7	H	
6. Rip-Rap/Slope Protection	7	7	
7. Aggradation	7	7	
8. Fender System	3	4	S/P
9.			

STREAM FLOW VELOCITY:

Tidal (☒) High (☐) Moderate (☐) Low (☐)

I-61 (Dive Report): 5 *I-61 (This Report):* 5

93b-U/W INSP. DATE: 01/2004

ITEM 36 *TRAFFIC SAFETY*

	36	COND	DEF
1. Bridge Railing	0	6	M/P
2. Transitions	0	0	
3. Approach Guardrail	0	6	M/P
4. Approach Guardrail Ends	0	7	

WEIGHT POSTING: *Not Applicable* ☒

	H	3	3S2	SINGLE
Actual Posting				
Recommended Posting				

Waived Date: 03/26/97 **EJDMT Date:**

	At bridge N/E	At bridge S/W	Other Advance N/E	Other Advance S/W
Signs in Place				
Legibility/ Visibility	/	/	/	/

CLEARANCE POSTING: *Not Applicable* ☒

	N/E ft	N/E in	S/W ft	S/W in	meter
Actual Field Measurement					
Posted Clearance					

	At bridge N/E	At bridge S/W	Advance N/E	Advance S/W
Signs in Place (Y=Yes N=No)				
Legibility/ Visibility	/	/	/	/

ACCESSIBILITY: (Y/N/P)

	Needed	Used
Lift Bucket	N	N
Ladder	N	N
Boat	Y	Y
Wader	N	N
Inspector 50	N	N
Rigging	N	N
Staging	Y	Y
Traffic Control	N	N
RR Flagger	N	N
Police	N	N
Other:		

TOTAL HOURS: 41

PLANS: (Y/N) Y

(V.C.R.): (Y/N) N

TAPE #:

List of Field Tests Performed:

RATING:

Rating Report (Y/N): Y

Date: 02/97

(To be filled out by DBIE)

Request for Rating or Rerating (Y/N): N

If YES please give priority: HIGH (☐) MEDIUM (☐) LOW (☐)

Reason: D.P.

CONDITION RATING GUIDE (for Items 58, 59, 60)

	CODE	CONDITION	DEFECTS
	N	Not Applicable	
G	9	Excellent	Excellent condition.
G	8	Very Good	No problem noted.
G	7	Good	Some minor problems.
F	6	Satisfactory	Structural elements show some minor deterioration.
F	5	Fair	All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
P	4	Poor	Advanced section loss, deterioration, spalling or scour.
P	3	Serious	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
C	2	Critical	Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
C	1	"Imminent" Failure	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put it back in light service.
	0	Failed	Out of service - beyond corrective action.

DEFICIENCY REPORTING GUIDE

DEFICIENCY: A defect in a structure that requires corrective action

CATEGORIES OF DEFICIENCIES:

M= Minor Deficiency - Deficiencies which are minor in nature, generally do not impact the structural integrity of the bridge and could easily be repaired. Examples include but are not limited to: Spalled concrete,, Minor pot holes, Minor corrosion to steel, Minor scouring, Clogged drainage, etc.

S= Severe/Major Deficiency - Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but are not limited to: Moderate to major deterioration in concrete, Exposed and corroding rebars, Considerable settlement, Considerable scouring or undermining, Moderate to extensive corrosion to structural steel with measurable loss of section, etc.

C-S= Critical-Structural Deficiency - A deficiency in a structural element of a bridge that poses an extreme unsafe condition due to the failure or imminent failure of the element, which will affect the structural integrity of the bridge.

C-H= Critical-Hazard Deficiency - A deficiency in a component or element of a bridge that poses an extreme hazard or unsafe condition to the public, but does not impair the structural integrity of the bridge. Examples include but are not limited to: Loose concrete hanging down over traffic or pedestrians, A hole in a sidewalk that may cause injuries to pedestrians, Missing section of bridge railing, etc.

URGENCY OF REPAIR:

I= Immediate - [Inspector(s) contact District Bridge Inspection Engineer (DBIE) to report the Deficiency and to receive further instruction from him/her].

A= As soon as possible - [Action/Repair should be initiated by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) upon receipt of the Inspection Report].

P= Prioritize - [Shall be prioritized by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) and repairs made when funds and/or manpower is available].

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	**437**	**C-07-001**	**C07001437MUNNBI**	**10/21-22/2004**

Remarks & Photos

GENERAL:
The superstructure consists of eleven multi-timber stringer approach spans (1-7 & 9-12) with a timber deck, one movable multi-timber stringer bascule span with a timber deck (span 8), and two concrete cast-in-place abutment spans. The structure carries Bridge Street over the Mitchell River in the town of Chatham. The substructure consists of timber piles with timber caps. Pile bents are numbered 1-6, 7A and 8-11 from west to east.

ITEM 36 – TRAFFIC SAFETY

36.1 Bridge Railing (Satisfactory): There is a 1'-1" high non-mountable timber curb along the north and south curb line. The timber curbs exhibit minor punky areas, checking and splitting at random locations. At several isolated locations, the curbs are misaligned due to impact damage (**see photo 1**). The approach ends of the timber curb are tapered to transition to the approach granite curbs.

36.2 Transitions: There are no transitions between the timber bridge rail and the approach thrie beam guardrail at all four corners of the bridge.

36.3 Approach Guardrail (Satisfactory): The approach guardrail is typically in satisfactory condition with an area of minor impact damage to the northeast (**see photo 2**) and northwest approach guardrail. The approach guardrail does not appear to conform to current standards. There are four posts for the southeast approach guardrail which are not tight against the wingwall (**see photo 3**). The maximum gap between the wingwall and the post is 1¼".

ITEM 58 - DECK

58.1 Wearing Surface (Fair): The timber wearing surface typically exhibits light to moderate wear typically in the wheel lines and minor checks and splits throughout. Span 6 exhibits the heaviest wear on the timber planks (**see photo 4**). Random timber planks have been replaced throughout.

The bituminous concrete wearing surface on the abutment spans is in fair condition with map cracking up to ⅜" wide.

58.2 Deck (Satisfactory): The timber deck exhibits minor punky areas with no significant losses. The end abutment spans are cast-in-place concrete and are in satisfactory condition. There is a 1'-0" diameter by 2" deep spall around a weep hole with heavy efflorescence on the underside of the northeast approach span.

58.4 Curbs (Satisfactory): See Item 36.1.

58.6 Sidewalks (Satisfactory): The timber sidewalk typically exhibits moderate wear, minor punky areas, minor splits and checks, and a build-up of sand and debris along the curb.

58.8 Railing (Satisfactory): There are minor areas of punky wood at random locations on the bridge railing. Some rails exhibit minor splits and checks. The timber rail posts exhibit minor punky areas and moderate splitting and checking at random locations.

58.12 Utilities (Satisfactory): There are isolated broken or loose brackets for the electrical conduit on the north side of the bridge. There is a 1½" diameter transverse conduit on the west elevation of bent 7A which exhibits heavy corrosion with isolated holes along its length exposing the wire inside (**see photo 5**).

58.13 Deck Joints (Fair): Both abutment deck joints exhibit minor scraping and gouging of the steel particularly at the east deck joint. The east joint of the bascule span is extremely tight when the bridge is closed. After an opening, the bascule span deck is approximately a ½" higher than the adjacent span deck and does not close until traffic drives over the joint (**see photo 6**).

APPROACHES

a. Approach Pavement Condition (Fair): The bituminous concrete pavement at both approaches exhibits minor longitudinal and transverse cracking.

b. Approach Roadway Settlement (Fair): There is a 7'-0"± long by 4'-0"± wide area of moderate settlement in the eastbound lane of the west approach roadway.

c. Approach Sidewalk Settlement (Fair): There is up to 1¼" of settlement of the northwest and southwest approach sidewalks. The northeast approach sidewalk exhibits a 4'-0"± long area of up to 2½" of settlement.

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Remarks & Photos

59.1 Stringers (Satisfactory): The timber stringers are typically in satisfactory condition with isolated areas of punky wood, minor splits and minor scrapes on the underside of the bascule span. Isolated stringers exhibit checks up to $^5/_{16}$" wide by up to 5'-0"± long with a maximum depth of $1^7/_8$" (**see photo 7**).

59.10 Diaphragms (Satisfactory): The spacer blocks between the stringers are typically loose and/or have rotated between the stringers. Random blocks exhibit minor checking.

59.11 Rivets & Bolts (Satisfactory): There is light corrosion of bolts throughout the superstructure.

59.13 Member Alignment (Satisfactory): The toe of the bascule span appears to have shifted 1½" to the north (**see photo 8**).

59.15 Kingposts (Satisfactory): The north and south kingposts exhibit moderate checks up to ¼" wide by up to 4'-0"± long with a maximum depth of 3½" along their entire length.

Collision Damage: See Items 59.1 and 61.8.

Load Deflection: There is minor vibration under live load.

Load Vibration: There is minor vibration under live load.

ITEM 60 – SUBSTRUCTURE

60.1c Backwalls (Satisfactory): There are several vertical and diagonal cracks in the east abutment backwall.

60.1d Breastwalls (Satisfactory): There is a horizontal crack along the south half of the of the east abutment breastwall. In addition there is a 3'-0"± long by 4" high by 2" deep spall on the south half of the east abutment breastwall. The east and west abutment breastwalls also exhibit hairline cracks with efflorescence. The timber sill attached to the west abutment breastwall exhibits minor checking.

60.1e Wingwalls (Satisfactory): The southeast wingwall is covered with a concrete skim coat which exhibits isolated cracks up to $^1/_{16}$" wide with efflorescence. The southwest wingwall exhibits a full length horizontal hairline crack with several vertical hairline cracks extending from the crack.

60.1h Footings (Fair): There is a 2" wide crack through the south corner of the west abutment footing (**see photo 9**). The east and west abutment footings are partially exposed through the rip-rap.

60.3a Pile Caps (Satisfactory): The timber pile caps typically exhibit horizontal checks up to $^1/_{16}$" wide on all surfaces.

60.3b Piles (Fair): The piles typically exhibit heavy marine growth and minor section loss in the tidal zone (**see photo 10**). Above the tidal zone, piles typically exhibit vertical checks up to $^1/_{16}$" wide at random locations. Protective sleeves have been placed around random piles at bents 1, 3 and 4 since the last inspection (**see photo 11**). See Routine Underwater Inspection Report for more information.

60.3c Diagonal Bracing (Poor): The diagonal bracing typically exhibits heavy marine growth and moderate section loss in the tidal zones (**see photo 10**). The fasteners typically exhibit heavy rust with minor section loss in the tidal zones. See Routine Underwater Inspection Report for more information.

60.3e Fasteners (Fair): See Item 60.3c.

ITEM 60 – CHANNEL AND CHANNEL PROTECTION

61.8 Fender System (Poor): The east and west vertical timber facing typically exhibits moderate checks and minor splits above the tidal zone. In the tidal zone, the vertical timber facing exhibits heavy marine growth with moderate to heavy deterioration. The vertical facing on the north and south ends of the east fendering is leaning approximately 4" to the south (**see photo 12**). There is minor impact damage to the south corner of the west fendering. The timber walers exhibit moderate decay in the tidal zone. See Routine Underwater Inspection Report for more information.

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Chatham	437	C-07-001	C07001437MUNNBI	10/21-22/2004

Photo Log

1. Misalignment of north timber curb at the east end of span 2.
2. Impact damage to northeast approach guardrail.
3. 1¼" gap between southeast approach guardrail and wingwall.
4. Typical condition of timber wearing surface in span 6.
5. Utility conduit with corrosion hole on west elevation of bent 7A.
6. Bascule span deck is approximately a ½" higher than the adjacent span deck after opening.
7. $^5/_{16}$" wide by 5'-0"± long check on the north face of the ninth stringer from the south in span 8.
8. Misalignment of the toe of the bascule span at the north curb.
9. Crack in the south corner of the west abutment footing.
10. Typical deterioration of the timber pile and diagonal bracing in the tidal zone.
11. Protective sleeves placed around deteriorated piles in bent 1.
12. Impact damage to east fendering at the north end.

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	437	C-07-001	C07001437MUNNBI	10/21-22/2004

Remarks & Photos

Photo 1: Misalignment of north timber curb at the east end of span 2.

Photo 2: Impact damage to northeast approach guardrail.

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	**437**	**C-07-001**	**C07001437MUNNBI**	**10/21-22/2004**

Remarks & Photos

Photo 3: 1¼" gap between southeast approach guardrail and wingwall.

Photo 4: Typical condition of timber wearing surface in span 6.

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	437	C-07-001	C07001437MUNNBI	10/21-22/2004

Remarks & Photos

Photo 5: Utility conduit with corrosion hole on west elevation of bent 7A.

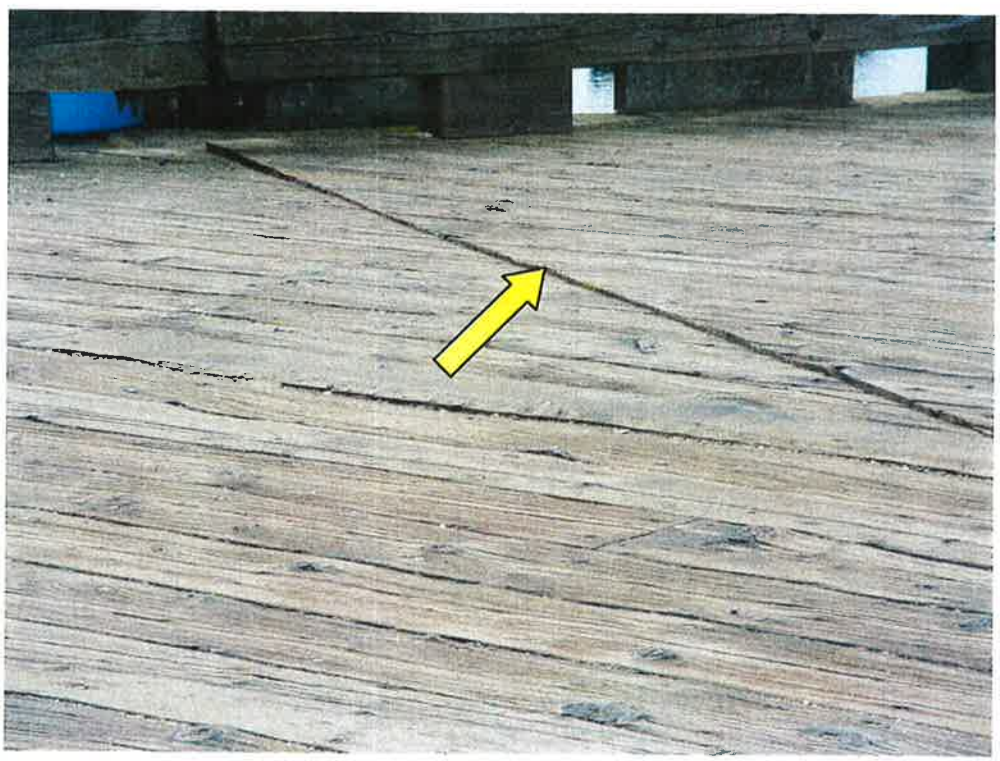

Photo 6: Bascule span deck is approximately a ½" higher than the adjacent span deck after opening.

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
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Remarks & Photos

Photo 7: $^{5}/_{16}$" wide by 5'-0"± long check on the north face of the ninth stringer from the south in span 8.

Photo 8: Misalignment of the toe of the bascule span at the north curb.

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	**437**	**C-07-001**	**C07001437MUNNBI**	**10/21-22/2004**

Remarks & Photos

Photo 9: Crack in the south corner of the west abutment footing.

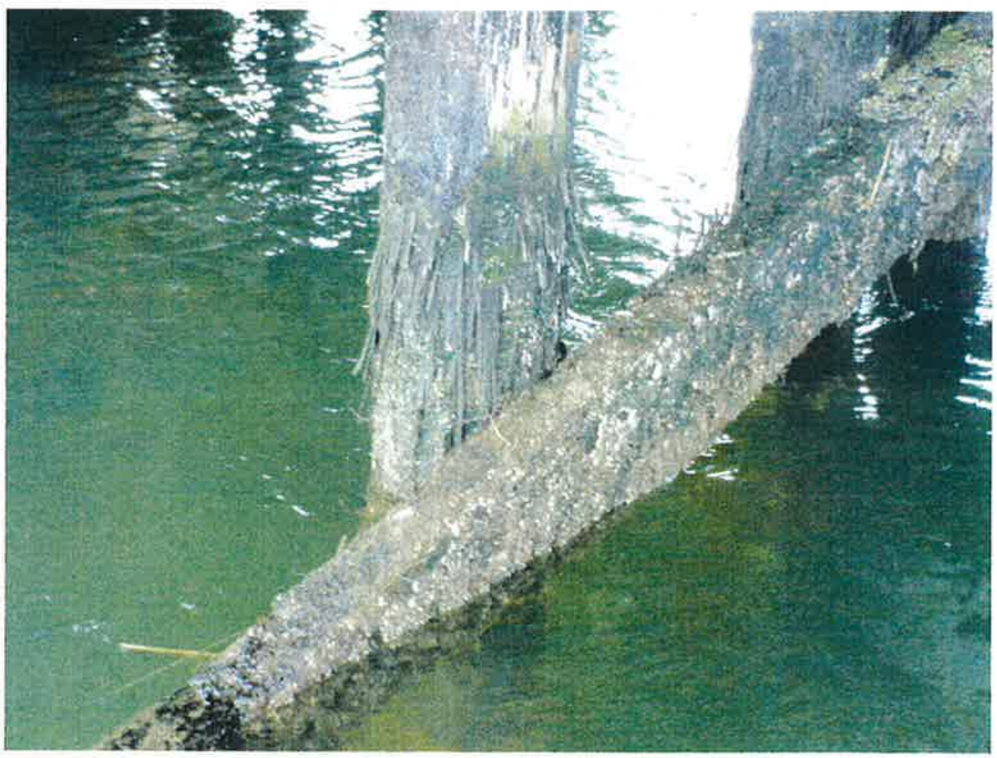

Photo 10: Typical deterioration of the timber pile and diagonal bracing in the tidal zone.

City/Town	B.I.N.	Br. Dept. No.	8 - Structure No.	90 - Inspection Date
Chatham	437	C-07-001	C07001437MUNNBI	10/21-22/2004

Remarks & Photos

Photo 11: Protective sleeves placed around deteriorated piles in bent 1.

Photo 12: Impact damage to east fendering at the north end.

Element Data Collection Form

	Month	Day	Year
	10	22	04
Town	Chatham		
District	5		

Bridge Number	C-07-001
BIN	437
Bridge Key Number	C07001437MUNNBI

Inspectors	S. Darling	J. Clogston	Lichtenstein Consulting Engineers, Inc.
	Leader	**Member**	**Agency/Consultant/Dept. Name**

Elem. #	Element Name	Units	Env-iron.	Total Quantity	Condition States (Quantity or Percent) *					Q or P*
					1	2	3	4	5	
8	Timber Sidewalk	EA/SM	3	200	75	25				P
31	Timber Deck	EA/SM	3	630		80	20			P
111	Timber Stringer	LM	3	1750	95	5				P
215	Concrete Abutment	LM	3	20		90	10			P
240	Concrete Abutment Spans	EA	3	2	100					P
228	Timber Submerged Pile	EA	3	121			100			P
235	Timber Pile Cap	LM	3	140	90	10				P
332	Timber Bridge Railing	LM	3	365	75	25				P
360	Settlement	EA	3	1	90	10				P
361	Scour	EA	3	2		100				P

* It is okay to switch between Quantity and Percent for different Elements.

Report Date: September 13, 2004

State Information

BDEPT#= C07001 Agency Br.No.

Town= Chatham

B.I.N= 437 AASHTO= 048.7

FHWA Select List= Y

Identification

(8) Structure Number	C07001437MUNNBI
(5) Inventory Route	151000000
(2) State Highway Department District	05
(3) County Code 001 (4) Place code	12995
(6) Features Intersected	WATER MITCHELL RIVER
(7) Facility Carried	HWY BRIDGE ST
(9) Location	.9 MI S OF RTE 28
(11) Kilometerpoint	0000.322
(12) Base Highway Network	N
(13) LRS Inventory Route & Subroute	000000000000
(16) Latitude	41 DEG 40 MIN 12.00 SEC
(17) Longitude	69 DEG 57 MIN 39.60 SEC
(98) Border Bridge State Code	Share %
(99) Border Bridge Structure No. #	

Structure Type and Material

(43) Structure Type Main: Timber	Code	716
Movable - Bascule	Jointless bridge type:	Not applicable
(44) Structure Type Appr: Stringer/Girder	Code	702
(45) Number of spans in main unit		001
(46) Number of approach spans		0013
(107) Deck Structure Type - Timber	Code	8
(108) Wearing Surface / Protective System:		
A) Type of wearing surface - Timber	Code	7
B) Type of membrane - None	Code	0
C) Type of deck protection - Other	Code	9

Age and Service

(27) Year Built		1936
(106) Year Reconstructed		1980
(42) Type of Service: On - Highway-Ped		
Under - Waterway	Code	55
(28) Lanes: On Structure 02	Under structure	00
(29) Average Daily Traffic		002000
(30) Year of ADT 2002 (109) Truck ADT		06 %
(19) Bypass, detour length		005 KM

2004

Geometric Data

(48) Length of maximum span	0006.7 M
(49) Structure Length	00069.1 M
(50) Curb or sidewalk: Left 01.0 M Right	01.0 M
(51) Bridge Roadway Width Curb to Curb	007.4 M
(52) Deck Width Out to Out	011.4 M
(32) Approach Roadway Width (w/shoulders)	007.3 M
(33) Bridge Median - No median Code	0
(34) Skew 00 DEG (35) Structure Flared	N
(10) Inventory Route MIN Vert Clear	99.99 M
(47) Inventory Route Total Horiz Clear	07.4 M
(53) Min Vert Clear Over Bridge Rdwy	99.99 M
(54) Min Vert Underclear ref N	00.00 M
(55) Min Lat Underclear RT ref N	00.0 M
(56) Min Lat Underclear LT	00.0 M

Navigation Data

(38) Navigation Control - Navigation control on waterway	Code	1
(111) Pier Protection	Code	1
(39) Navigation Vertical Clearance		002.4 M
(116) Vert-lift Bridge Nav Min Vert Clear		M
(40) Navigation Horizontal Clearance		0004.0 M

Classification

24 DWG

		Code
(112) NBIS Bridge Length		Y
(104) Highway System		N
(26) Functional Class -	Minor Collector	08
(100) Defense Highway		0
(101) Parallel Structure		N
(102) Direction of Traffic -	2-way traffic	2
(103) Temporary Structure		N
(105) Federal Lands Highways		0
(110) Designated National Network		N
(20) Toll -	On free road	3
(21) Maintain -	Town Agency	03
(22) Owner -	Town Agency	03
(37) Historical Significance	not eligible	N

Condition

	Code
(58) Deck	6
(59) Superstructure	6
(60) Substructure	4
(61) Channel & Channel Protection	5
(62) Culverts	N

Load Rating and Posting

		Code
(31) Design Load -	H 20=M 18	4
(63) Operating Rating Method -	Allowable Stress (AS)	2
(64) Operating Rating		36.3
(65) Inventory Rating Method -	Allowable Stress (AS)	2
(66) Inventory Rating		25.3
(70) Bridge Posting		5
(41) Structure -	Open	A

Appraisal

	Code
(67) Structural Evaluation	4
(68) Deck Geometry	4
(69) Underclearances, vert. and horiz.	N
(71) Waterway adequacy	8
(72) Approach Roadway Alignment	6
(36) Traffic Safety Features	0 0 0 0
(113) Scour Critical Bridges	3

Inspections

(90) Inspection Date ~~11/25/02~~ 10/22/04 (91) Frequency 12 MO

(92) Critical Feature Inspection:				(93) CFI DATE
(A) Fracture Critical Detail	N	00	MO A)	00/00/00
(B) Underwater Inspection	Y	12	MO B)	01/23/04
(C) Other Special Inspection	N	00	MO C)	00/00/00
(*) Other Inspection ()	N	00	MO *)	00/00/00
(*) Closed Bridge	N	00	MO *)	00/00/00
(*) UW Special Inspection	N	00	MO *)	00/00/00
(*) Damage Inspection			MO *)	00/00/00

Rating Loads

Report Date 02/01/97	H20	Type 3	Type 3S2	Type HS
Operating	27.0	37.0	56.0	40.0
Inventory	19.0	25.0	39.0	28.0

Field Posting

Status WAIVED Posting Date 03/26/97

	2 Axle	3 Axle	5 Axle
Actual			
Recommended			

Misc.

Bridge Name

N Anti-missile fence N Acrow Panel N Jointless Bridge

Accessibility (Needed/Used)

N / N	Liftbucket	N / N	Rigging
N ~~Y~~ / ~~Y~~ N	Ladder	Y N / N Y	Staging
Y / Y	Boat	N ~~Y~~ / ~~Y~~ N	Traffic Control
N / N	Wader	N / N	RR Flagperson
N ~~Y~~ / ~~Y~~ N	Inspector 50	N Y / Y N	Police

Inspection Hours: ~~040~~ 41

MASSACHUSETTS HIGHWAY DEPARTMENT
STRUCTURES INSPECTION FIELD REPORT
ROUTINE INSPECTION

2-DIST	B.I.N.	BR. DEPT. NO.
05	437	C-07-001

CITY/TOWN	8.-STRUCTURE NO.	11-Kilo. POINT	41-STATUS	90-ROUTINE INSP. DATE
CHATHAM	C07001-437-MUN-NBI	000.322	A:OPEN	OCT 10, 2006

07-FACILITY CARRIED	MEMORIAL NAME/LOCAL NAME	27-YR BUILT	106-YR REBUILT	YR REHAB'D (NON 106)
HWY BRIDGE ST		1936	1980	0000

06-FEATURES INTERSECTED	26-FUNCTIONAL CLASS	DIST. BRIDGE INSPECTION ENGINEER
WATER MITCHELL RIVER	Urban Collector	D. A. Palmer — REVIEWED BY: [signature]

43-STRUCTURE TYPE	22-OWNER	21-MAINTAINER	TEAM LEADER	PROJ MGR
Timber Movable - Bascule	Town Agency	Town Agency	S. Reichl [signature]	HNTB Corporation [signature]

107-DECK TYPE	WEATHER	TEMP. (air)	TEAM MEMBERS
Timber	Sunny	21°C	D. MYKULAK

ITEM 58 — DECK: 6

		DEF
1. Wearing surface	5	M-P
2. Deck Condition	6	M-P
3. Stay in place forms	N	-
4. Curbs	5	M-P
5. Median	N	-
6. Sidewalks	6	M-P
7. Parapets	N	-
8. Railing	6	M-P
9. Anti Missile Fence	N	-
10. Drainage System	N	-
11. Lighting Standards	N	-
12. Utilities	5	M-P
13. Deck Joints	4	S-P
14.	N	-
15.	N	-
16.	N	-

CURB REVEAL (In millimeters): N 330, S 330

APPROACHES

		DEF
a. Appr. pavement condition	5	M-P
b. Appr. Roadway Settlement	5	M-P
c. Appr. Sidewalk Settlement	5	M-P
d.	N	-

OVERHEAD SIGNS (Attached to bridge) (Y/N): N

		DEF
a. Condition of Welds	N	-
b. Condition of Bolts	N	-
c. Condition of Signs	N	-

ITEM 59 — SUPERSTRUCTURE: 5

		DEF
1. Stringers	6	M-P
2. Floorbeams	N	-
3. Floor System Bracing	N	-
4. Girders or Beams	5	M-P
5. Trusses - General	N	-
a. Upper Chords	N	-
b. Lower Chords	N	-
c. Web Members	N	-
d. Lateral Bracing	N	-
e. Sway Bracings	N	-
f. Portals	N	-
g. End Posts	N	-
6. Pin & Hangers	N	-
7. Conn Plt's, Gussets & Angles	N	-
8. Cover Plates	N	-
9. Bearing Devices	N	-
10. Diaphragms/Cross Frames	6	M-P
11. Rivets & Bolts	5	M-P
12. Welds	6	M-P
13. Member Alignment	6	M-P
14. Paint/Coating	5	M-P
15. Kingposts	6	M-P

Year Painted: N

COLLISION DAMAGE: *Please explain*
None ( ) Minor (X) Moderate ( ) Severe ( )

LOAD DEFLECTION: *Please explain*
None ( ) Minor (X) Moderate ( ) Severe ( )

LOAD VIBRATION: *Please explain*
None ( ) Minor (X) Moderate ( ) Severe ( )

Any Fracture Critical Member: (Y/N) N

Any Cracks: (Y/N) N

ITEM 60 — SUBSTRUCTURE: 4

	Dive	Cur		DEF
1. Abutments			5	
a. Pedestals	N	N		-
b. Bridge Seats	N	7		-
c. Backwalls	N	6		M-P
d. Breastwalls	N	6		M-P
e. Wingwalls	N	6		M-P
f. Slope Paving/Rip-Rap	N	7		-
g. Pointing	N	N		-
h. Footings	N	5		M-P
i. Piles	N	H		-
j. Scour	N	7		-
k. Settlement	N	7		-
l.	N	N		-
m.	N	N		-
2. Piers or Bents			N	
a. Pedestals	N	N		-
b. Caps	N	N		-
c. Columns	N	N		-
d. Stems/Webs/Pierwalls	N	N		-
e. Pointing	N	N		-
f. Footing	N	N		-
g. Piles	N	N		-
h. Scour	N	N		-
i. Settlement	N	N		-
j.	N	N		-
k.	N	N		-
3. Pile Bents			5	
a. Pile Caps	N	6		M-P
b. Piles	4	5		S-P
c. Diagonal Bracing	4	4		S-A
d. Horizontal Bracing	5	4		S-A
e. Fasteners	3	4		S-P

UNDERMINING (Y/N) If YES please explain: N

COLLISION DAMAGE:
None ( ) Minor (X) Moderate ( ) Severe ( )

SCOUR: *Please explain*
None (X) Minor ( ) Moderate ( ) Severe ( )

I-60 (Dive Report): 4 *I-60 (This Report):* 5

93B-U/W (DIVE) Insp 02/15/2006

X=UNKNOWN N=NOT APPLICABLE H=HIDDEN/INACCESSIBLE R=REMOVED

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 10, 2006

REMARKS

GENERAL REMARKS

The superstructure consists of eleven (11) multi-timber stringer approach spans (Spans 1-7 and 9-12) with a timber deck, one (1) movable multi-timber stringer bascule span (Span 8) with a timber deck and two (2) cast-in-place concrete abutment spans. The substructure consists of concrete abutments and timber pile bents. The timber pile bents are numbered 1-6, 7A and 8-11 from west to east. The structure carries Bridge Street over the Mitchell River in the town of Chatham.

ITEM 58 - DECK

Item 58.1 - Wearing surface

(Poor): The timber wearing surface generally exhibits minor to moderate wear, particularly in the wheel lines, with minor punkiness, splitting and checking throughout. The knots in the wood and the nail heads generally protrude above the surface. Span 6 exhibits the heaviest wear **(see Photo 3)**. There are local areas of moderate to heavy deterioration within several of the spans and a few areas with loose and slightly raised up planking in Spans 1 and 12. The approximate area of moderate to heavy deterioration is as follows: Span 1 - 1 s.f., Span 5 - 2 s.f., Span 8 - 4 s.f., Span 9 - 2 s.f. and Span 12 - 5 s.f. **(see Photo 4).**

The bituminous wearing surface for the abutment spans is in fair condition with random cracking up to 3/8" wide and minor wear, particularly in the wheel lines.

Item 58.2 - Deck Condition

(Satisfactory): The timber deck exhibits some random minor punkiness on the underside, but there are no significant deteriorated areas.

The cast-in-place concrete deck for the abutment spans exhibits a 1'-0" diameter by 2" deep spall around a weep hole with heavy efflorescence on the underside at the northeast corner of the bridge.

Item 58.4 - Curbs

(Fair): The timber curbs exhibit minor punkiness, splitting and checking throughout. The worst case is at the south curb of the bascule span (Span 8) at the east end where there is a 3'-0" length of curb with moderate to heavy deterioration **(see Photo 5)**. At several locations the curbs are also slightly misaligned transversely **(see Photo 6)**.

Item 58.6 - Sidewalks

(Satisfactory): The timber sidewalks generally exhibit minor wear, splitting and checking throughout with a minor build up of sand and debris along the curbs.

Item 58.8 - Railing

(Satisfactory): See comments for Item 36a.

Item 58.12 - Utilities

(Fair): There are several deteriorated, broken and loose or missing support brackets for the electrical conduit running along the north side of the bridge **(see Photo 7)**. There are deteriorated, broken and loose electrical conduits with exposed wiring running along the west side of Bents 5 and 7A **(see Photo 8)**.

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REMARKS

Item 58.13 - Deck Joints
(Poor): The steel armoring at both abutment deck joints exhibits minor scraping and gouging, particularly at the east abutment. The timber joint at the east end of the bascule span (Span 8) is extremely tight when the bridge is closed **(see Photo 5)**. Based upon previous inspections, the bascule span deck remains approximately 1/2" higher than the adjacent span deck at this joint after an opening and does not close completely until traffic drives over the joint. The bascule span was not operating during this inspection due to the fact that the winch on the south side of the bridge was malfunctioning. See the Electrical/Mechanical Inspection Report for more information regarding this issue. The four (4) northern most steel hinge plates for the timber joint at the west end of the bascule span (Span 8) are missing screws, loose and banging under live load impacts **(see Photo 9)**.

APPROACHES

Approaches a - Appr. pavement condition
(Fair): The bituminous pavement at both approaches exhibits minor longitudinal and transverse cracking. The cracks have generally been sealed **(see Photo 10)**.

Approaches b - Appr. Roadway Settlement
(Fair): There is some minor settlement in the westbound lane of the east approach **(see Photo 10)**. The settlement noted during the previous inspection in the westbound lane of the west approach appears to have been repaired **(see Photo 11)**.

Approaches c - Appr. Sidewalk Settlement
(Fair): There is up to 1.25" of settlement at the northwest and southwest approach sidewalks. The northeast approach sidewalk exhibits a 4'-0" long area with up to 2.5" of settlement.

ITEM 59 - SUPERSTRUCTURE

Item 59.1 - Stringers
(Satisfactory): The timber stringers generally exhibit minor splitting and checking. Isolated stringers exhibit checks up to 5/16" wide by 5'-0" long with a maximum depth of 1 7/8" **(see Photo 12)**. There is some minor collision damage (scrapes and gouges) to the underside of the stringers in the bascule span (Span 8). There is a 3'-0" long by 6" high spall with exposed and rusted rebar on the south side of the abutment span beam at the northeast corner of the bridge.

Item 59.4 - Girders or Beams
(Fair): The north end of the bascule span (Span 8) timber lifting beam, located at the bascule span toe beneath the stringers, has been temporarily repaired with steel through bolts and metal straps around its perimeter **(see Photo 13)**. The Harbor Master informed the inspection crew that the beam had major cracking and splitting at this location and that this is only an interim repair. A new beam has been ordered and will be installed in the near future.

Item 59.10 - Diaphragms/Cross Frames
(Satisfactory): The timber spacer blocks between the stringers are generally loose and/or have rotated. Random blocks exhibit minor checking.

Item 59.11 - Rivets & Bolts
(Fair): There is minor corrosion of the bolts throughout the superstructure. The bascule span (Span 8) counterweight steel shell connection bolts (located in Span 7) exhibit moderate to heavy corrosion with some very minor section loss **(see Photo 14)**.

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REMARKS

Item 59.12 - Welds
(Satisfactory): The bascule span (Span 8) counterweight steel shell welds (located in Span 7) are generally in satisfactory condition with some minor rusting **(see Photo 14)**.

Item 59.13 - Member Alignment
(Satisfactory): The toe of the bascule span (Span 8) appears to have shifted 1.5" to the north **(see Photo 5)**.

Item 59.14 - Paint/Coating
(Fair): The bascule span (Span 8) counterweight steel shell galvanized coating (located in Span 7) exhibits moderate to heavy corrosion with some very minor section loss on its west end **(see Photo 14)**.

Item 59.15 - Kingposts
(Satisfactory): The timber kingposts exhibit checks up to 1/4" wide by 4'-0" long with a maximum depth of 3.5" along their entire length, particularly at the south post.

SuperStructure Collision Notes
See comments for Item 59.1.

SuperStructure Load Deflection Notes
There is minor deflection under live load.

SuperStructure Load Vibration Notes
There is minor vibration under live load.

ITEM 60 - SUBSTRUCTURE

Item 60.1.c - Backwalls
(Satisfactory): There are several vertical and diagonal cracks in the east abutment backwall.

Item 60.1.d - Breastwalls
(Satisfactory): There is a horizontal crack along the south half of the east abutment breastwall. Additionally, there is a 3'-0" long by 4" high by 2" deep spall on the south half of the east abutment breastwall. Both the east and west abutment breastwalls exhibit hairline cracks with efflorescence. The timber sill attached to the west abutment breastwall exhibits minor checking.

Item 60.1.e - Wingwalls
(Satisfactory): The southeast wingwall is covered with a concrete skim coat which exhibits isolated cracks up to 1/16" wide with efflorescence. The southwest wingwall exhibits a full length horizontal hairline crack with several vertical hairline cracks extending from the horizontal crack.

Item 60.1.h - Footings
(Fair): There are 2" wide cracks through the south corner of the west abutment footing **(see Photo 15)**. Both the east and west abutment footings at the south end are partially exposed through the rip-rap. Note these footings appear to be only a concrete apron, but there are no available plans to support this.

Item 60.3.a - Pile Caps
(Satisfactory): The timber pile caps generally exhibit horizontal checks up to 1/16" wide on all surfaces.

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REMARKS

Item 60.3.b - Piles
(Fair): The timber piles generally exhibit heavy marine growth with minor to moderate brooming and section loss in the tidal zone **(see Photo 16)**. Above the tidal zone, the piles generally exhibit vertical checks up to 1/8" wide at random locations. There is little to no protective creosote coating remaining on the piles. Protective sleeves have been placed around random piles at Bents 1, 2, 3 and 4 **(see Photo 16)**. See the Routine Underwater Inspection Report for more information.

Item 60.3.c - Diagonal Bracing
(Poor): **(DEF=S/A)** The timber bracing (for each individual pile bent) generally exhibits moderate to heavy deterioration and section loss in the tidal zone. **The worst cases are at the north end of Bent 5 where there is a 5'-0" section of the bracing missing (see Photo 17) and at Bent 6 where the center bracing is missing.**

Item 60.3.d - Horizontal Bracing
(Poor): **(DEF=S/A)** The timber bracing (between pile bents) generally exhibits moderate to heavy deterioration and section loss in the tidal zone. **The worst case is at the south end of Bent 8 where there is a 4'-0" section of the bracing missing (see Photo 18).**

Item 60.3.e - Fasteners
(Poor): The fasteners that attach the bracing generally exhibit moderate to heavy corrosion with moderate to heavy section loss in the tidal zone (primarily at the bolt ends, the washers and the nuts) **(see Photos 17 and 18)**.

SubStructure Collision Notes
See Item 61.8.d

ITEM 61 - CHANNEL AND CHANNEL PROTECTION

Item 61.8 - Fender System
Horizontal timber members supporting the vertical timber fender members are attached directly to the piles at Bent #7A and Bent #8. Newer pressure treated horizontal planks on either side of the vertical fender members hold the vertical timbers in place.

Item 61.8.c - Horizontal Bracing
(Poor): **(DEF=S/A)** The horizontal timber members generally exhibit moderate splitting and checking above the tidal zone. **In the tidal zone, these members exhibit heavy marine growth with moderate to heavy deterioration and section loss (up to 100%) (see Photo 18).** See Routine Underwater Inspection Report for more information.

Item 61.8.d - Vertical Bracing
(Serious): **(DEF=S/A)** The vertical timber members generally exhibit moderate splitting and checking above the tidal zone. **In the tidal zone, these members exhibit heavy marine growth with moderate to heavy deterioration and section loss (up to 100%). The east fender also exhibits impact damage at its north and south ends with several vertical timber members leaning/rotated (see Photo 19).** This impact damage is due to the angle of approach of marine traffic to the bridge from the north and south. See the Routine Underwater Inspection Report for more information.

Item 61.8.e - Fasteners
(Fair): Fasteners have heavy surface rust and are deteriorated within the tidal zone. See Routine Underwater Inspection Report for more information.

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REMARKS

TRAFFIC SAFETY

Item 36a - Bridge Railing
(Satisfactory): Some timber rails exhibit minor splitting and checking. Some timber posts exhibit moderate splitting and checking.

Item 36b - Transitions
There are no transitions between the timber bridge rail and the approach thrie beam guardrail at all four corners of the bridge.

Item 36c - Approach Guardrail
(Fair): The approach guardrails exhibit minor to moderate impact damage at the northwest (15'-0" long by 3" deflection), northeast (25'-0" long by 1'-6" deflection) **(see Photo 1)** and southeast (20'-0" long by 4" deflection) corners of the bridge. The southeast guardrail also has five (5) posts that are not up tight against the abutment wingwall with up to a 1.25" gap **(see Photo 2)**. The guardrails consist of multiple types of construction and material and are not continuous for their entire length.

Photo Log

Photo 1 : Impact damage to the northeast approach guardrail, looking west.
Photo 2 : 1 1/4" gap between the southeast approach guardrail post and wingwall, looking east.
Photo 3 : Typical condition of the timber wearing surface in Span 6, looking northwest.
Photo 4 : Moderate to heavy deterioration of the timber wearing surface in Span 12, looking northwest.
Photo 5 : Mod/hvy deterioration of curb in bascule span at toe, looking east. Note tight deck joint & 1 1/2" shift of bascule span toe to north.
Photo 6 : Transverse misalignment of the north curb at the east end of Span 12, looking west.
Photo 7 : Temporary nylon rope support for the electrical conduit on the north side of the bridge at Bent 10, looking down.
Photo 8 : Deteriorated, broken & loose electrical conduit with exp. wiring on west side of Bent 5 at north end, looking northeast.
Photo 9 : Loose steel hinge plate for the deck joint at the west end of the bascule span (Span 8), looking north.
Photo 10 : Minor cracking and settlement at the east approach, looking south.
Photo 11 : Apparent repair to the westbound lane of the west approach, looking north.
Photo 12 : 5/16" wide by 5'-0" long check on the north side of Stringer 9 from the south in the bascule span (Span 8), looking southeast.
Photo 13 : Temporary repair to the north end of the bascule span (Span 8) timber lifting beam, looking west and down.
Photo 14 : Mod/hvy corrosion of bascule span cntrwght steel shell & connection bolts (Span 7), looking north. Note steel welds ok.
Photo 15 : 2" wide cracks through the south corner of the west abutment footing, looking northwest.
Photo 16 : Typ. condition of timber piles/bracing, south end of Bent 3, looking west. Note protective sleeve repairs on other piles in view.
Photo 17 : Missing sect. of diag. bracing, north end of Bent 5, looking NE. Note condition of fasteners on remaining portion at pile.
Photo 18 : Missing sect. of horiz. bracing, south end of Bent 8, looking NW. Note cond. of fasteners on remaining portion & fender walers.
Photo 19 : Typical condition of the vertical timber members of the fender at Bent 8, looking northeast. Note the impact damage at both ends.

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PHOTOS

Photo 1: **Impact damage to the northeast approach guardrail, looking west.**

Photo 2: **1 1/4" gap between the southeast approach guardrail post and wingwall, looking east.**

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PHOTOS

Photo 3: **Typical condition of the timber wearing surface in Span 6, looking northwest.**

Photo 4: **Moderate to heavy deterioration of the timber wearing surface in Span 12, looking northwest.**

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PHOTOS

Photo 5: Mod/hvy deterioration of curb in bascule span at toe, looking east. Note tight deck joint & 1 1/2" shift of bascule span toe to north.

Photo 6: Transverse misalignment of the north curb at the east end of Span 12, looking west.

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PHOTOS

Photo 7: **Temporary nylon rope support for the electrical conduit on the north side of the bridge at Bent 10, looking down.**

Photo 8: **Deteriorated, broken & loose electrical conduit with exp. wiring on west side of Bent 5 at north end, looking northeast.**

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PHOTOS

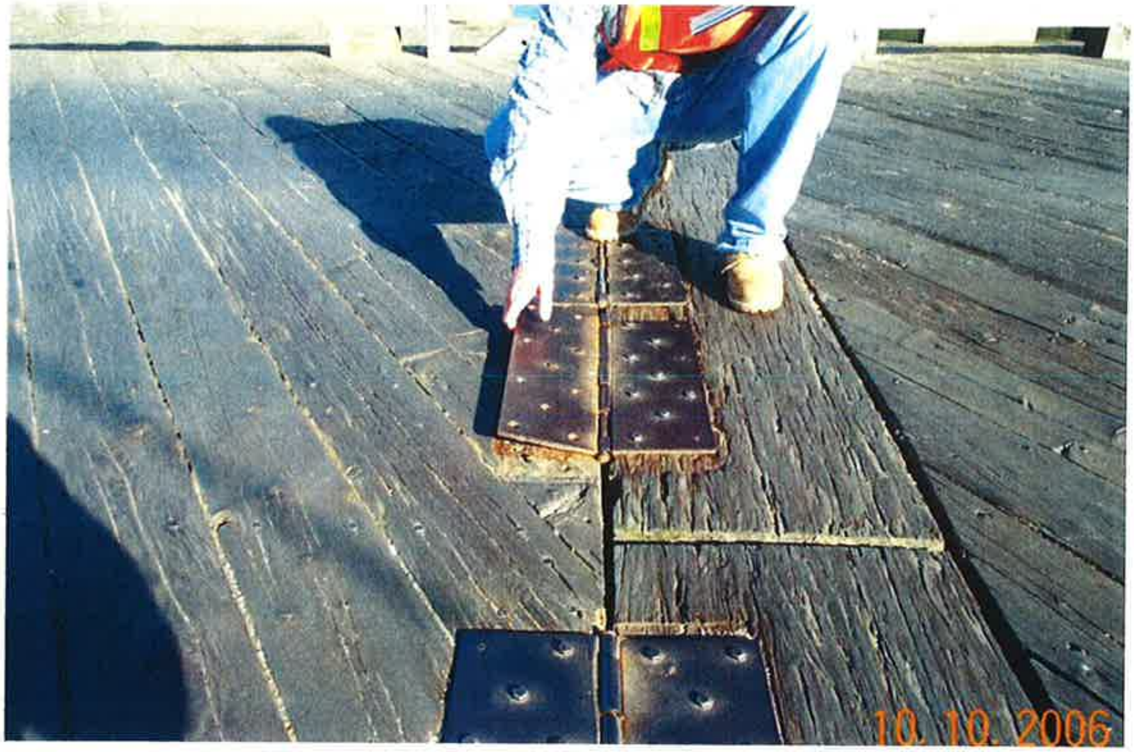

Photo 9: **Loose steel hinge plate for the deck joint at the west end of the bascule span (Span 8), looking north.**

Photo 10: **Minor cracking and settlement at the east approach, looking south.**

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PHOTOS

Photo 11: **Apparent repair to the westbound lane of the west approach, looking north.**

Photo 12: **5/16" wide by 5'-0" long check on the north side of Stringer 9 from the south in the bascule span (Span 8), looking southeast.**

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PHOTOS

Photo 13: **Temporary repair to the north end of the bascule span (Span 8) timber lifting beam, looking west and down.**

Photo 14: **Mod/hvy corrosion of bascule span cntrwght steel shell & connection bolts (Span 7), looking north. Note steel welds ok.**

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PHOTOS

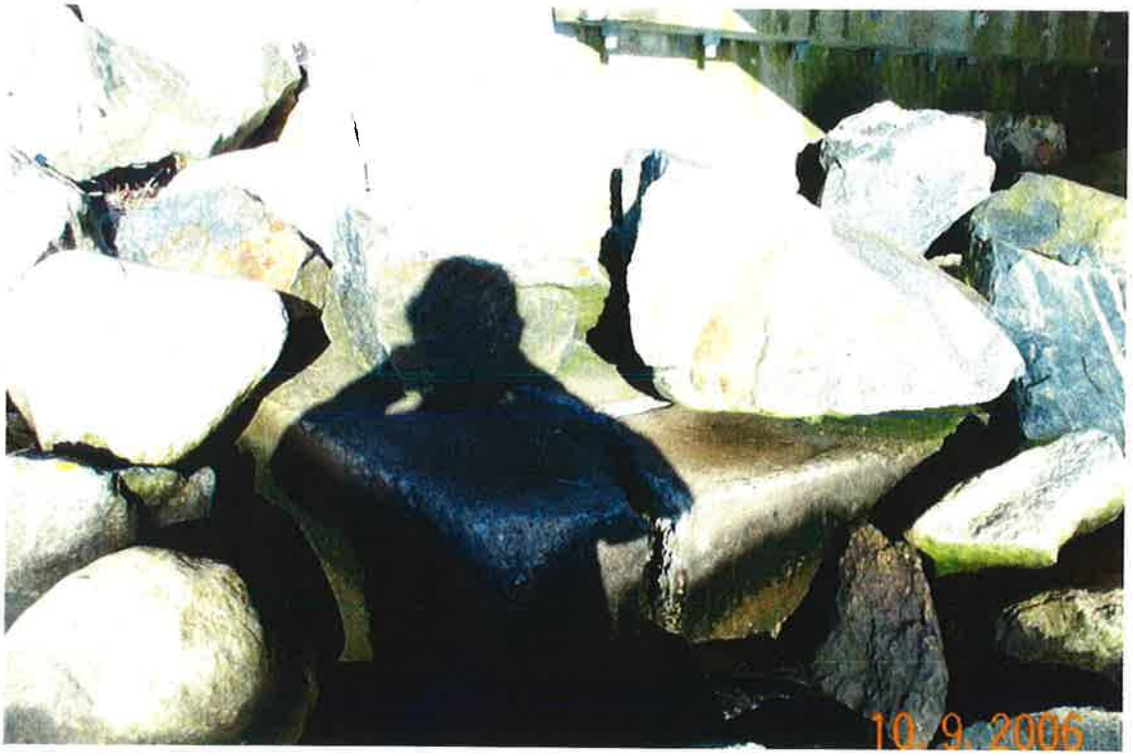

Photo 15: 2" wide cracks through the south corner of the west abutment footing, looking northwest.

Photo 16: Typ. condition of timber piles/bracing, south end of Bent 3, looking west. Note protective sleeve repairs on other piles in view.

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PHOTOS

Photo 17: **Missing sect. of diag. bracing, north end of Bent 5, looking NE. Note condition of fasteners on remaining portion at pile.**

Photo 18: **Missing sect. of horiz. bracing, south end of Bent 8, looking NW. Note cond. of fasteners on remaining portion & fender walers.**

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PHOTOS

Photo 19: **Typical condition of the vertical timber members of the fender at Bent 8, looking northeast. Note the impact damage at both ends.**

MASSACHUSETTS HIGHWAY DEPARTMENT
STRUCTURES INSPECTION FIELD REPORT
ROUTINE INSPECTION

2-DIST	B.I.N.	BR. DEPT. NO.
05	437	C-07-001

CITY/TOWN: CHATHAM	8.-STRUCTURE NO.: C07001-437-MUN-NBI	11-Kilo. POINT: 000.322	41-STATUS: A:OPEN	90-ROUTINE INSP. DATE: OCT 7, 2008
07-FACILITY CARRIED: HWY BRIDGE ST	MEMORIAL NAME/LOCAL NAME:	27-YR BUILT: 1936	106-YR REBUILT: 1980	YR REHAB'D (NON 106): 2007
06-FEATURES INTERSECTED: WATER MITCHELL RIVER	26-FUNCTIONAL CLASS: Urban Collector	DIST. BRIDGE INSPECTION ENGINEER: D. A. Palmer		
43-STRUCTURE TYPE: 716 : Timber Movable - Bascule	22-OWNER: Town Agency	21-MAINTAINER: Town Agency	TEAM LEADER S. M. Darling	PROJ MGR Transystems Lichtenstein
107-DECK TYPE: 8 : Timber	WEATHER: Sunny	TEMP. (air): 16°C	TEAM MEMBERS: J. KLOFAS	

ITEM 58 — DECK: 6

		DEF
1.Wearing surface	5	M-P
2.Deck Condition	6	M-P
3.Stay in place forms	N	-
4.Curbs	5	M-P
5.Median	N	-
6.Sidewalks	6	M-P
7.Parapets	N	-
8.Railing	6	M-P
9.Anti Missile Fence	N	-
10.Drainage System	N	-
11.Lighting Standards	N	-
12.Utilities	5	M-P
13.Deck Joints	4	S-P
14.	N	-
15.	N	-
16.	N	-

CURB REVEAL (In millimeters): N 330, S 330

APPROACHES

		DEF
a. Appr. pavement condition	5	M-P
b. Appr. Roadway Settlement	5	M-P
c. Appr. Sidewalk Settlement	5	M-P
d.	N	-

OVERHEAD SIGNS (Attached to bridge) (Y/N): N

		DEF
a. Condition of Welds	N	-
b. Condition of Bolts	N	-
c. Condition of Signs	N	-

ITEM 59 — SUPERSTRUCTURE: 6

		DEF
1.Stringers	6	M-P
2.Floorbeams	N	-
3.Floor System Bracing	N	-
4.Girders or Beams	7	-
5.Trusses - General	N	-
a. Upper Chords	N	-
b. Lower Chords	N	-
c. Web Members	N	-
d. Lateral Bracing	N	-
e. Sway Bracings	N	-
f. Portals	N	-
g. End Posts	N	-
6.Pin & Hangers	N	-
7.Conn Plt's, Gussets & Angles	N	-
8.Cover Plates	N	-
9.Bearing Devices	N	-
10.Diaphragms/Cross Frames	6	M-P
11.Rivets & Bolts	5	M-P
12.Welds	6	M-P
13.Member Alignment	6	M-P
14.Paint/Coating	5	M-P
15.King Posts	6	M-P

Year Painted: N

COLLISION DAMAGE: *Please explain*
None ( ) Minor X) Moderate ( ) Severe ( )

LOAD DEFLECTION: *Please explain*
None ( ) Minor X) Moderate ( ) Severe ( )

LOAD VIBRATION: *Please explain*
None ( ) Minor X) Moderate ( ) Severe ( )

Any Fracture Critical Member: (Y/N) N

Any Cracks: (Y/N) N

ITEM 60 — SUBSTRUCTURE: 4

	Dive	Cur		DEF
1. Abutments			5	
a. Pedestals	N	N		-
b. Bridge Seats	N	7		-
c. Backwalls	N	6		M-P
d. Breastwalls	N	6		M-P
e. Wingwalls	N	6		M-P
f. Slope Paving/Rip-Rap	N	7		-
g. Pointing	N	N		-
h. Footings	N	5		M-P
i. Piles	N	H		-
j. Scour	N	N		-
k. Settlement	N	7		-
l.	N	N		-
m.	N	N		-
2. Piers or Bents			N	
a. Pedestals	N	N		-
b. Caps	N	N		-
c. Columns	N	N		-
d. Stems/Webs/Pierwalls	N	N		-
e. Pointing	N	N		-
f. Footing	N	N		-
g. Piles	N	N		-
h. Scour	N	N		-
i. Settlement	N	N		-
j.	N	N		-
k.	N	N		-
3. Pile Bents			5	
a. Pile Caps	N	6		M-P
b. Piles	4	5		S-P
c. Diagonal Bracing	4	4		S-A
d. Horizontal Bracing	4	4		S-A
e. Fasteners	3	4		S-P

UNDERMINING (Y/N) If YES please explain: N

COLLISION DAMAGE:
None ( ) Minor X) Moderate ( ) Severe ( )

SCOUR: *Please explain*
None (X) Minor) Moderate ( ) Severe ( )

I-60 (Dive Report): 4 *I-60 (This Report):* 5

93B-U/W (DIVE) Insp 01/10/2008

X=UNKNOWN N=NOT APPLICABLE H=HIDDEN/INACCESSIBLE R=REMOVED

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ITEM 61 — CHANNEL & CHANNEL PROTECTION

4

	Dive	Cur	DEF
1.Channel Scour	7	H	-
2.Embankment Erosion	7	7	-
3.Debris	7	7	-
4.Vegetation	7	7	-
5.Utilities	7	H	-
6.Rip-Rap/Slope Protection	7	7	-
7.Aggradation	7	7	-
8.Fender System	3	3	S-A

STREAM FLOW VELOCITY:
Tidal (X) High ( ) Moderate ( ) Low ( ) None ( )

ITEM 61 (Dive Report): 4 *ITEM 61 (This Report)* 5

93b-U/W INSP. DATE: 01/10/2008

ITEM 36 — TRAFFIC SAFETY

	36	COND	DEF
A. Bridge Railing	0	5	M-P
B. Transitions	0	0	-
C. Approach Guardrail	0	5	M-P
D. Approach Guardrail Ends	0	7	-

WEIGHT POSTING

Not Applicable X

	H	3	3S2	Single
Actual Posting	N	N	N	N
Recommended Posting	N	N	N	N

Waived Date: 03/26/1997 EJDMT Date: 00/00/00

	At bridge E	At bridge W	Other Advance E	Other Advance W
Signs In Place (Y=Yes,N=No, NR=NotRequired)				
Legibility/ Visibility				

CLEARANCE POSTING

Not Applicable ☐

	N ft	N in	S ft	S in	meter
Actual Field Measurement		0		0	
Posted Clearance		0		0	

	At bridge N	At bridge S	Advance N	Advance S
Signs In Place (Y=Yes,N=No, NR=NotRequired)	N	N	N	N
Legibility/ Visibility				

ACCESSIBILITY (Y/N/P)

	Needed	Used
Lift Bucket	N	N
Ladder	N	N
Boat	Y	Y
Waders	N	N
Inspector 50	N	N
Rigging	N	N
Staging	Y	Y
Traffic Control	N	N
RR Flagger	N	N
Police	N	N
Other:		
	N	N

TOTAL HOURS 29

PLANS (Y/N): Y

(V.C.R.) (Y/N): N

TAPE#: ______

List of field tests performed:

RATING

Rating Report (Y/N): Y

Date: 02/01/1997

Inspection data at time of existing rating
I 58: 7 I 59: 7 I 60: - Date :00/00/00

(To be filled out by DBIE)
Request for Rating or Rerating (Y/N): N

If YES please give priority:
HIGH ( ) MEDIUM ( ) LOW ( )

REASON: ______

CONDITION RATING GUIDE (For Items 58, 59, 60 and 61)

	CODE	CONDITION	DEFECTS
	N	NOT APPLICABLE	
G	9	EXCELLENT	Excellent condition.
G	8	VERY GOOD	No problem noted.
G	7	GOOD	Some minor problems.
F	6	SATISFACTORY	Structural elements show some minor deterioration.
F	5	FAIR	All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
P	4	POOR	Advance section loss, deterioration, spalling or scour.
P	3	SERIOUS	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
C	2	CRITICAL	Advance deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
C	1	"IMMINENT" FAILURE	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put it back in light service.
	0	FAILED	Out of service - beyond corrective action.

DEFICIENCY REPORTING GUIDE

DEFICIENCY: A defect in a structure that requires corrective action.

CATEGORIES OF DEFICIENCIES:

M= Minor Deficiency - Deficiencies which are minor in nature, generally do not impact the structural integrity of the bridge and could easily be repaired. Examples include but are not limited to: Spalled concrete, Minor pot holes, Minor corrosion of steel, Minor scouring, Clogged drainage, etc.

S= Severe/Major Deficiency - Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but are not limited to: Moderate to major deterioration in concrete, Exposed and corroded rebars, Considerable settlement, Considerable scouring or undermining, Moderate to extensive corrosion to structural steel with measurable loss of section, etc.

C-S= Critical Structural Deficiency - A deficiency in a structural element of a bridge that poses an extreme unsafe condition due to the failure or imminent failure of the element which will affect the structural integrity of the bridge.

C-H= Critical Hazard Deficiency - A deficiency in a component or element of a bridge that poses an extreme hazard or unsafe condition to the public, but does not impair the structural integrity of the bridge. Examples include but are not limited to: Loose concrete hanging down over traffic or pedestrians, A hole in a sidewalk that may cause injuries to pedestrians, Missing section of bridge railing, etc.

URGENCY OF REPAIR:

I = Immediate- [Inspector(s) immediately contact District Bridge Inspection Engineer (DBIE) to report the Deficiency and to receive further instruction from him/her].
A = ASAP- [Action/Repair should be initiated by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) upon receipt of the Inspection Report].
P = Prioritize- [Shall be prioritized by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) and repairs made when funds and/or manpower is available].

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

REMARKS

BRIDGE ORIENTATION
The bridge is oriented west/east with the Mitchell River oriented north/south.

GENERAL REMARKS
Bridge C-07-001 (437) carries Bridge Street over the Mitchell River in the Town of Chatham. The superstructure consists of eleven (11) timber multi-stringer approach spans (spans 1-7 and 9-12) with a timber deck and one (1) movable timber multi-stringer bascule span (span 8) with a timber deck. In addition, there are two (2) cast-in-place concrete abutment spans adjacent to the abutments. The substructure consists of concrete abutments and timber pile bents. The timber pile bents are numbered 1-6, 7A and 8-11 from west to east. There are smaller supplemental bents at bents 4 and 6 which are numbered 4A and 6A, respectively.

ITEM 58 - DECK

Item 58.1 - Wearing surface
(Fair): The timber wearing surface has moderate wear, particularly in the wheel lines, with slight punkiness, splits and checks throughout. The knots in the wood and the nail heads generally protrude above the surface **(see photo 1)**. Random wearing surface planks have been replaced throughout the deck.

The bituminous wearing surface over the abutment spans has random cracks up to 3/8" wide and minor wear, particularly in the wheel lines.

Item 58.2 - Deck Condition
(Satisfactory): The timber deck has some random areas with slight punkiness on the underside, however, there are no significantly deteriorated areas.

There is a 1'-0" diameter by 2" deep spall around a weep hole with heavy efflorescence on the underside of the cast-in-place concrete deck for the east abutment span.

Item 58.4 - Curbs
(Fair): The timber curbs which also act as a traffic rail have minor splits and checks throughout. The worst case is at the east end of the bascule span (span 8) south curb where a 3'-0" length of curb is heavily deteriorated **(see photo 2)**. At several locations the curb/traffic rails are misaligned transversely up to 1 1/2" **(see photo 3)**.

Item 58.6 - Sidewalks
(Satisfactory): The timber sidewalk has minor wear, splits and checks throughout with minor build-up of sand and debris along the curbs.

Item 58.8 - Railing
(Satisfactory): There are minor to moderate checks and splits in the timber pedestrian rails and posts.

Item 58.12 - Utilities
(Fair): There are several deteriorated, broken, loose or missing support brackets for the electrical conduit along the north side of the bridge. At one location in span 11, the conduit has been temporarily fastened with rope. In addition, there are deteriorated, broken and loose electrical conduits with exposed wiring along the west side of bents 5 and 7A which appear abandoned **(see photo 4)**.

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CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

REMARKS

Item 58.13 - Deck Joints
(Poor): The steel armor at both abutment deck joints exhibits minor scraps and gouges, particularly at the east abutment. The timber joint at the east end of the bascule span (span 8) is extremely tight when the bridge is closed. The bascule span deck remains approximately 1/2" higher than the adjacent span deck at this joint after an opening and does not close completely until traffic drives over the joint. There is 1 1/2" of lateral misalignment between the span 8 and span 9 deck along the bent 8 deck joint **(see photo 5)**.

APPROACHES

Approaches a - Appr. pavement condition
(Fair): The bituminous pavement at both approaches exhibits longitudinal and transverse cracks up to 1" wide. Previously sealed cracks in the east approach have opened up.

Approaches b - Appr. Roadway Settlement
(Fair): An 8'-0" wide by 16'-0" long bituminous patch in the westbound lane of the west approach has settled up to 1". A 3'-0" long by 1'-2" wide area of the east approach pavement has settled 1 3/4" along the south end of the east abutment deck joint.

Approaches c - Appr. Sidewalk Settlement
(Fair): The northwest and southwest approach sidewalks have settled up to 2". The northeast approach sidewalk has a 2'-1" wide area with up to 4" of settlement along the curb **(see photo 6)**.

ITEM 59 - SUPERSTRUCTURE

Item 59.1 - Stringers
(Satisfactory): The timber stringers exhibit minor shakes and checks which are typically 1/8" wide **(see photo 7)** with isolated stringers checked up to 5/16" wide **(see photo 8)**. There is minor collision damage (scrapes and gouges) to the underside of the stringers in the bascule span (span 8) **(see photo 9)**. There is a 3'-0" long by 6" high spall with exposed and rusted rebar on the south side of the abutment span beam at the northeast corner of the bridge.

Item 59.4 - Girders or Beams
(Good): The bascule span (span 8) timber lifting beam has been replaced since the last inspection **(see photo 10)**.

Item 59.10 - Diaphragms/Cross Frames
(Satisfactory): Many of the timber spacer blocks between the stringers are loose and/or have rotated **(see photo 11)**. Random blocks exhibit minor shakes and checking. There is an isolated spacer block in span 12 which exhibits severe deterioration between the third and fourth stringers from the south.

Item 59.11 - Rivets & Bolts
(Fair): There is minor corrosion of the bolts throughout the superstructure. The bascule span (span 8) counterweight steel shell connection bolts (located in span 7) exhibit moderate to heavy corrosion with some minor section loss.

Item 59.12 - Welds
(Satisfactory): The bascule span (span 8) counterweight steel shell welds (located in span 7) are generally in satisfactory condition with some minor rusting.

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CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

REMARKS

Item 59.13 - Member Alignment
(Satisfactory): The toe end of the bascule span (span 8) appears to have shifted 1 1/2" to the north, see Item 58.13 for additional comments.

Item 59.14 - Paint/Coating
(Fair): The bascule span (span 8) counterweight steel shell galvanized coating (located in span 7) exhibits moderate to heavy corrosion with some minor section loss on its west end **(see photo 12)**.

Item 59.15 - King Posts
(Satisfactory): The timber king posts exhibit checks up to 1/4" wide by 4'-0" long with a maximum depth of 3" throughout their entire height with the heaviest concentration on the north face of the south post **(see photo 13)**.

SuperStructure Collision Notes
There is minor collision damage (scrapes and gouges) to the underside of the stringers in the bascule span (span 8) (see photo 9).

SuperStructure Load Deflection Notes
There is minor deflection under live load.

SuperStructure Load Vibration Notes
There is minor vibration under live load.

ITEM 60 - SUBSTRUCTURE

Item 60.1 - Abutments
Item 60.1.c - Backwalls
(Satisfactory): There are several vertical and diagonal cracks in the east abutment backwall.

Item 60.1.d - Breastwalls
(Satisfactory): There is an 1/8" wide horizontal crack along the south half of the east abutment breastwall with a 4'-6" wide by up to 5" high by 2" deep spall along the crack. Both the east and west abutment breastwalls exhibit hairline cracks with efflorescence. The timber sill attached to the west abutment breastwall exhibits minor checking.

Item 60.1.e - Wingwalls
(Satisfactory): The southeast wingwall is covered with a concrete skim coat which exhibits isolated cracks up to 1/16" wide with efflorescence. The southwest wingwall exhibits a full length horizontal hairline crack with several vertical hairline cracks extending from the horizontal crack.

Item 60.1.h - Footings
(Fair): Both the east and west abutment footings at the south end are partially exposed through the rip-rap. There are up to 3" wide cracks through the south corner of the west abutment footing **(see photo 14)**. Note these footings appear to be a concrete apron, but there are no available plans to support this.

Item 60.3 - Pile Bents
Item 60.3.a - Pile Caps
(Satisfactory): The timber pile caps typically have up to 1/16" wide checks on all surfaces. Isolated timber caps have 1/8" to 1/4" wide checks which measure up to 3'-0" long **(see photo 15)**.

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REMARKS

Item 60.3.b - Piles
(Fair): The timber piles typically have heavy marine growth with minor to moderate brooming and section loss in the tidal zone **(see photo 16)**. Above the tidal zone, the piles have vertical checks up to 1/8" wide at random locations. Random piles throughout have had a section removed from the upper portion of the pile typically 3" deep by 2'-6" high. There is little to no protective creosote coating remaining on the piles. Protective sleeves have been placed around several piles at bents 1, 2, 3 and 4. See the attached Routine Underwater Inspection Report for more information.

Item 60.3.c - Diagonal Bracing
(Poor): **(DEF=S/A)** The timber bracing (for each individual pile bent) generally exhibits moderate to heavy deterioration and section loss in the tidal zone. **The worst case is at the north end of bent 5 where there is a 5'-0" section of the bracing which has completely deteriorated.**

Item 60.3.d - Horizontal Bracing
(Poor): **(DEF=S/A)** The timber bracing (between pile bents) generally exhibits moderate to heavy deterioration and section loss in the tidal zone. **The worst case is at the south end of bent 8 where there is a 4'-0" section of the bracing which has completely deteriorated.**

Item 60.3.e - Fasteners
(Poor): The fasteners that attach the bracing generally exhibit moderate to heavy corrosion with moderate to heavy section loss in the tidal zone.

SubStructure Collision Notes
See Item 61.8.d for comments.

ITEM 61 - CHANNEL AND CHANNEL PROTECTION

Item 61.8 - Fender System
Item 61.8.c - Horizontal Bracing
(Poor): **(DEF=S/A)** The horizontal timber members generally exhibit moderate splitting and checking above the tidal zone. **In the tidal zone, these members exhibit heavy marine growth with moderate to heavy deterioration and section loss (up to 100%)**. See the attached Routine Underwater Inspection Report for more information.

Item 61.8.d - Vertical Bracing
(Serious): **(DEF=S/A)** The vertical timber members generally exhibit moderate splitting and checking above the tidal zone. **In the tidal zone, these members exhibit heavy marine growth with moderate to heavy deterioration and section loss (up to 100%)**. The east fender also exhibits impact damage at its north and south ends with several vertical timber members leaning/rotated **(see photo 17).** See the attached Routine Underwater Inspection Report for more information.

Item 61.8.e - Fasteners
(Fair): Fasteners have heavy surface rust and are deteriorated within the tidal zone. See the attached Routine Underwater Inspection Report for more information.

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REMARKS

TRAFFIC SAFETY

Item 36a - Bridge Railing
(Fair): The timber curbs which are non-mountable act as a traffic rail and do not conform to the current standards. See Item 58.4 for comments.

Item 36b - Transitions
(Missing): There are no transitions between the timber pedestrian rail and the approach thrie beam guardrails at all four corners of the bridge.

Item 36c - Approach Guardrail
(Fair): The southeast guardrail has five posts that are not up tight against the abutment wingwall with up to a 1 1/2" gap **(see photo 18)**. There is minor impact damage to the northeast approach guardrail. The guardrails consist of multiple types (thrie beam and w-beam) which are not continuous for their entire length and do not conform to the current standards.

Item 36d - Approach Guardrail Ends
(Good): The buried end sections of the approach guardrails do not conform to the current standards.

Photo Log

Photo 1 :	Worn wearing surface with protruding knots and nail heads. Note also the very tight joint (toe end of bascule span).
Photo 2 :	Deterioration of the south curb/traffic rail at the east end of span 8.
Photo 3 :	1 1/2" of misalignment of the north curb/traffic rail between spans 2 and 3.
Photo 4 :	Deteriorated utility conduit with exposed wires at bent 7A.
Photo 5 :	1 1/2" of misalignment of the bascule span toe towards the north.
Photo 6 :	4" deep settlement of the northeast approach sidewalk.
Photo 7 :	1/8" wide check in timber stringer S2 of span 10.
Photo 8 :	Up to 5/16" checks in timber stringer S9 of span 8.
Photo 9 :	Collision damage to the underside of the bascule span (span 8) stringers.
Photo 10 :	New bascule span lifting beam.
Photo 11 :	Loose and rotated spacer blocks in span 3.
Photo 12 :	Failed galvanized coating on the underside of the counterweight steel shell.
Photo 13 :	Checks in the north face of the bascule span south king post.
Photo 14 :	3" wide crack in the south end of the west abutment footing/apron.
Photo 15 :	1/4" wide check in the underside of the bent 5 cap.
Photo 16 :	Typical condition of timber piles/bracing in the tidal zone (north end of bent 4 shown).
Photo 17 :	Collision damage and heavy deterioration to south end of the bent 8 fender.
Photo 18 :	1 1/2" gaps between the southeast approach guardrail posts and the face of the wingwall.

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CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

PHOTOS

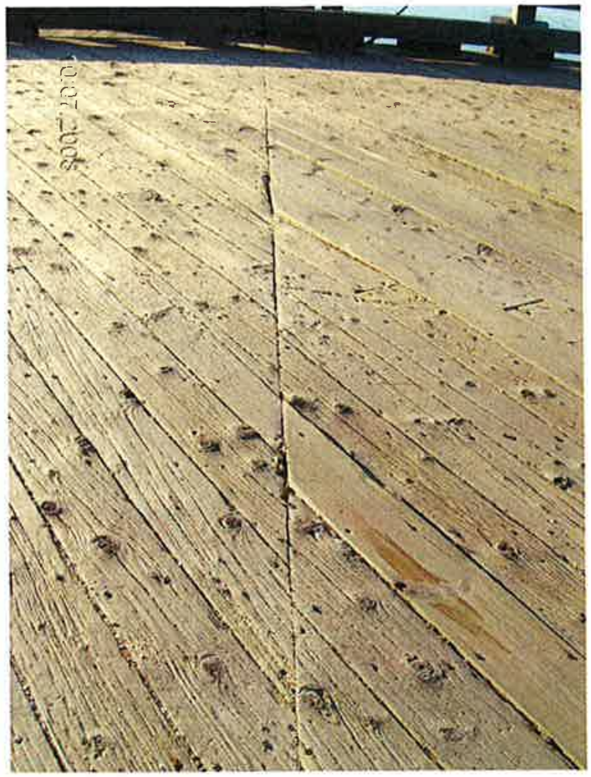

Photo 1: Worn wearing surface with protruding knots and nail heads. Note also the very tight joint (toe end of bascule span).

Photo 2: Deterioration of the south curb/traffic rail at the east end of span 8.

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PHOTOS

Photo 3: **1 1/2" of misalignment of the north curb/traffic rail between spans 2 and 3.**

Photo 4: **Deteriorated utility conduit with exposed wires at bent 7A.**

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PHOTOS

Photo 5: **1 1/2" of misalignment of the bascule span toe towards the north.**

Photo 6: **4" deep settlement of the northeast approach sidewalk.**

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PHOTOS

Photo 7: 1/8" wide check in timber stringer S2 of span 10.

Photo 8: Up to 5/16" checks in timber stringer S9 of span 8.

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CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

PHOTOS

Photo 9: **Collision damage to the underside of the bascule span (span 8) stringers.**

Photo 10: **New bascule span lifting beam.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
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PHOTOS

Photo 11: **Loose and rotated spacer blocks in span 3.**

Photo 12: **Failed galvanized coating on the underside of the counterweight steel shell.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

PHOTOS

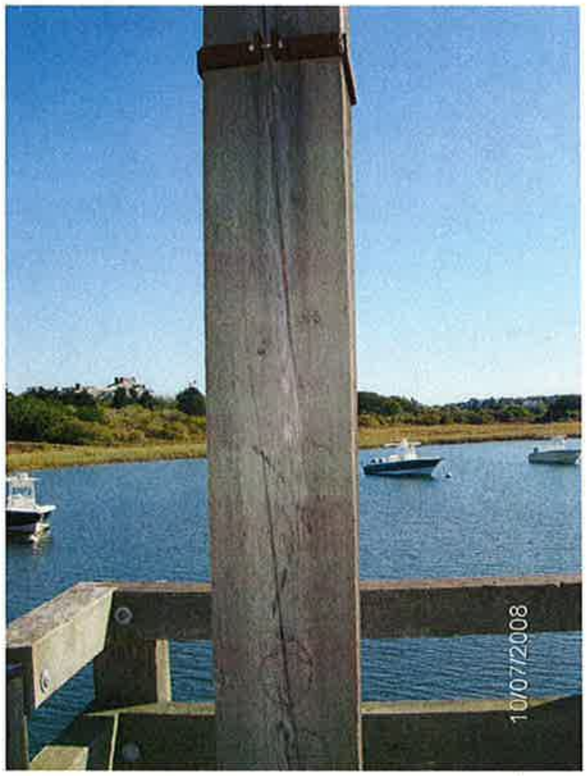

Photo 13: Checks in the north face of the bascule span south king post.

Photo 14: 3" wide crack in the south end of the west abutment footing/apron.

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PHOTOS

Photo 15: 1/4" wide check in the underside of the bent 5 cap.

Photo 16: Typical condition of timber piles/bracing in the tidal zone (north end of bent 4 shown).

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CHATHAM	437	C-07-001	C07001-437-MUN-NBI	OCT 7, 2008

PHOTOS

Photo 17: **Collision damage and heavy deterioration to south end of the bent 8 fender.**

Photo 18: **1 1/2" gaps between the southeast approach guardrail posts and the face of the wingwall.**

Report Date: January 21, 2011

State Information

BDEPT#= C07001 Agency Br.No.

Town= Chatham L.O.

B.I.N= 437 AASHTO= 045.5

FHWA Select List= Y

Identification

(8) Structure Number		C07001437MUNNBI
(5) Inventory Route		151000000
(2) State Highway Department District		05
(3) County Code	001 (4) Place code	12995
(6) Features Intersected		WATER MITCHELL RIVER
(7) Facility Carried		HWY BRIDGE ST
(9) Location		.9 MI S OF RTE 28
(11) Kilometerpoint		0000.322
(12) Base Highway Network		N
(13) LRS Inventory Route & Subroute	000000000000	
(16) Latitude	41DEG 40MIN 12.00SEC	
(17) Longitude	69DEG 57MIN 39.60SEC	
(98) Border Bridge State Code	Share %	
(99) Border Bridge Structure No. #		

Structure Type and Material

(43) Structure Type Main:	Timber	Code	716
Movable - Bascule	Jointless bridge type: Not applicable		
(44) Structure Type Appr: Stringer/Girder		Code	702
(45) Number of spans in main unit			001
(46) Number of approach spans			0013
(107) Deck Structure Type -	Timber	Code	8
(108) Wearing Surface / Protective System:			
A) Type of wearing surface -	Timber	Code	7
B) Type of membrane -	None	Code	0
C) Type of deck protection -	Other	Code	9

Age and Service

(27) Year Built			1936
(106) Year Reconstructed			1980
(42) Type of Service: On -	Highway-Ped		
Under -	Waterway	Code	55
(28) Lanes: On Structure	02	Under structure	00
(29) Average Daily Traffic			002100
(30) Year of ADT	2008	(109) Truck ADT	06 %
(19) Bypass, detour length			005KM

Geometric Data

(48) Length of maximum span			0006.7M
(49) Structure Length			00069.1M
(50) Curb or sidewalk:	Left 01.0 M	Right	01.0M
(51) Bridge Roadway Width Curb to Curb			007.4M
(52) Deck Width Out to Out			011.4M
(32) Approach Roadway Width (w/shoulders)			007.3M
(33) Bridge Median -	No median	Code	0
(34) Skew	00 DEG	(35) Structure Flared	N
(10) Inventory Route MIN Vert Clear			99.99M
(47) Inventory Route Total Horiz Clear			07.4M
(53) Min Vert Clear Over Bridge Rdwy			99.99M
(54) Min Vert Underclear ref	N		00.00M
(55) Min Lat Underclear RT ref	N		00.0M
(56) Min Lat Underclear LT			00.0M

Navigation Data

(38) Navigation Control -	Navigation control on waterway	Code	1
(111) Pier Protection		Code	1
(39) Navigation Vertical Clearance			002.4M
(116) Vert-lift Bridge Nav Min Vert Clear			M
(40) Navigation Horizontal Clearance			0004.0M

Classification

		Code
(112) NBIS Bridge Length		Y
(104) Highway System		N
(26) Functional Class -	Urban Collector	17
(100) Defense Highway		0
(101) Parallel Structure		N
(102) Direction of Traffic -	2-way traffic	2
(103) Temporary Structure		N
(105) Federal Lands Highways		0
(110) Designated National Network		N
(20) Toll -	On free road	3
(21) Maintain -	Town Agency	03
(22) Owner -	Town Agency	03
(37) Historical Significance	not eligible	N

Condition

	Code
(58) Deck	5
(59) Superstructure	6
(60) Substructure	4
(61) Channel & Channel Protection	4
(62) Culverts	N

Load Rating and Posting

		Code
(31) Design Load -	H 20=M 18	4
(63) Operating Rating Method -	Allowable Stress (AS)	2
(64) Operating Rating		36.3
(65) Inventory Rating Method -	Allowable Stress (AS)	2
(66) Inventory Rating		25.3
(70) Bridge Posting		5
(41) Structure -	Open	A

Appraisal

	Code
(67) Structural Evaluation	4
(68) Deck Geometry	2
(69) Underclearances, vert. and horiz.	N
(71) Waterway adequacy	8
(72) Approach Roadway Alignment	6
(36) Traffic Safety Features	0 0 0 0
(113) Scour Critical Bridges	5

Inspections

(90) Inspection Date 10/05/10 (91) Frequency 12 MO

(92) Critical Feature Inspection: (93) CFI DATE

(A) Fracture Critical Detail	N	00	MO A)	00/00/00
(B) Underwater Inspection	Y	12	MO B)	11/30/10
(C) Other Special Inspection	N	00	MO C)	00/00/00
(*) Other Inspection (Flood Insp.)	N	00	MO *)	10/24/05
(*) Closed Bridge	N	00	MO *)	00/00/00
(*) UW Special Inspection	N	00	MO *)	00/00/00
(*) Damage Inspection			MO *)	00/00/00

Rating Loads

Report Date 02/01/97	H20	Type 3	Type 3S2	Type HS
Operating	27.0	37.0	56.0	40.0
Inventory	19.0	25.0	39.0	28.0

Field Posting

Status WAIVED Posting Date 03/26/97

	2 Axle	3 Axle	5 Axle
Actual			
Recommended			
Missing Signs N			

Misc.

Bridge Name

N Anti-missile fence N Acrow Panel N Jointless Bridge

Freeze/Thaw N : Not Applicable

Accessibility (Needed/Used)

N / N Liftbucket	N / N Rigging	N / N Other
N / N Ladder	Y / Y Staging	
Y / Y Boat	N / N Traffic Control	
N / N Wader	N / N RR Flagperson	Inspection Hours: 028
N / N Inspector 50	N / N Police	

MASSACHUSETTS DEPARTMENT OF TRANSPORTATION

STRUCTURES INSPECTION FIELD REPORT

ROUTINE INSPECTION

2-DIST	B.I.N.	BR. DEPT. NO.
05	437	C-07-001

CITY/TOWN	8.-STRUCTURE NO.	11-Kilo. POINT	41-STATUS	90-ROUTINE INSP. DATE
CHATHAM	C07001-437-MUN-NBI	000.322	A:OPEN	OCT 5, 2010

07-FACILITY CARRIED	MEMORIAL NAME/LOCAL NAME	27-YR BUILT	106-YR REBUILT	YR REHAB'D (NON 106)
HWY BRIDGE ST		1936	1980	2007

06-FEATURES INTERSECTED: WATER MITCHELL RIVER

26-FUNCTIONAL CLASS: Urban Collector

DIST. BRIDGE INSPECTION ENGINEER D. A. Palmer — REVIEWED BY: [signature]

43-STRUCTURE TYPE: 716 : Timber Movable - Bascule

22-OWNER: Town Agency | 21-MAINTAINER: Town Agency

TEAM LEADER A. Amuzgar [signature] | PROJ MGR HNTB Corporation [signature]

107-DECK TYPE: 8 : Timber | WEATHER: Rain | TEMP. (air): 15°C

TEAM MEMBERS: J. CLOGSTON, J. CLOGSTON

ITEM 58 — DECK: 5

DECK		DEF
1.Wearing surface	5	M-P
2.Deck Condition	5	M-P
3.Stay in place forms	N	-
4.Curbs	5	M-P
5.Median	N	-
6.Sidewalks	6	M-P
7.Parapets	N	-
8.Railing	6	M-P
9.Anti Missile Fence	N	-
10.Drainage System	N	-
11.Lighting Standards	N	-
12.Utilities	5	M-P
13.Deck Joints	4	S-P
14.	N	-
15.	N	-
16.	N	-

CURB REVEAL (In millimeters): N 330 | S 330

APPROACHES

APPROACHES		DEF
a. Appr. pavement condition	5	M-P
b. Appr. Roadway Settlement	X	M-P
c. Appr. Sidewalk Settlement	5	M-P
d.	N	-

OVERHEAD SIGNS (Attached to bridge) (Y/N): N

		DEF
a. Condition of Welds	N	-
b. Condition of Bolts	N	-
c. Condition of Signs	N	-

ITEM 59 — SUPERSTRUCTURE: 6

SUPERSTRUCTURE		DEF
1.Stringers	6	M-P
2.Floorbeams	N	-
3.Floor System Bracing	N	-
4.Girders or Beams	7	-
5.Trusses - General	N	-
a. Upper Chords	N	-
b. Lower Chords	N	-
c. Web Members	N	-
d. Lateral Bracing	N	-
e. Sway Bracings	N	-
f. Portals	N	-
g. End Posts	N	-
6.Pin & Hangers	N	-
7.Conn Plt's, Gussets & Angles	N	-
8.Cover Plates	N	-
9.Bearing Devices	N	-
10.Diaphragms/Cross Frames	6	M-P
11.Rivets & Bolts	5	M-P
12.Welds	6	M-P
13.Member Alignment	6	M-P
14.Paint/Coating	5	M-P
15.King Posts	6	M-P

Year Painted: N

COLLISION DAMAGE: *Please explain*
None ( ) Minor (X) Moderate ( ) Severe ( )

LOAD DEFLECTION: *Please explain*
None ( ) Minor (X) Moderate ( ) Severe ( )

LOAD VIBRATION: *Please explain*
None ( ) Minor ( ) Moderate (X) Severe ( )

Any Fracture Critical Member: (Y/N) N

Any Cracks: (Y/N) N

ITEM 60 — SUBSTRUCTURE: 4

SUBSTRUCTURE	Dive	Cur		DEF
1. Abutments			5	
a. Pedestals	N	N		-
b. Bridge Seats	N	7		-
c. Backwalls	N	6		M-P
d. Breastwalls	N	6		M-P
e. Wingwalls	N	6		M-P
f. Slope Paving/Rip-Rap	N	7		-
g. Pointing	N	N		-
h. Footings	N	5		M-P
i. Piles	N	H		-
j. Scour	N	N		-
k. Settlement	N	7		-
l.	N	N		-
m.	N	N		-
2. Piers or Bents			N	
a. Pedestals	N	N		-
b. Caps	N	N		-
c. Columns	N	N		-
d. Stems/Webs/Pierwalls	N	N		-
e. Pointing	N	N		-
f. Footing	N	N		-
g. Piles	N	N		-
h. Scour	N	N		-
i. Settlement	N	N		-
j.	N	N		-
k.	N	N		-
3. Pile Bents			5	
a. Pile Caps	N	6		M-P
b. Piles	4	5		S-P
c. Diagonal Bracing	4	4		S-A
d. Horizontal Bracing	4	4		S-A
e. Fasteners	3	4		S-P

UNDERMINING (Y/N) If YES please explain: N

COLLISION DAMAGE:
None (X) Minor ( ) Moderate ( ) Severe ( )

SCOUR: *Please explain*
None (X) Minor ( ) Moderate ( ) Severe ( )

I-60 (Dive Report): 4 | *I-60 (This Report):* 5

93B-U/W (DIVE) Insp: 01/07/2010

X=UNKNOWN N=NOT APPLICABLE H=HIDDEN/INACCESSIBLE R=REMOVED

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ITEM 61 4

CHANNEL & CHANNEL PROTECTION

	Dive	Cur	DEF
1.Channel Scour	7	H	-
2.Embankment Erosion	7	7	-
3.Debris	7	7	-
4.Vegetation	7	7	-
5.Utilities	7	H	-
6.Rip-Rap/Slope Protection	7	7	-
7.Aggradation	7	7	-
8.Fender System	3	3	S-A

STREAM FLOW VELOCITY:

Tidal (X) High ( ) Moderate ( ) Low ( ) None ( )

ITEM 61 (Dive Report): 4 *ITEM 61 (This Report)* 4

93b-U/W INSP. DATE: 01/07/2010

ITEM 36 *TRAFFIC SAFETY*

	36	COND	DEF
A. Bridge Railing	0	5	M-P
B. Transitions	0	0	-
C. Approach Guardrail	0	5	M-P
D. Approach Guardrail Ends	0	7	-

WEIGHT POSTING *Not Applicable* X

	H	3	3S2	Single
Actual Posting	N	N	N	N
Recommended Posting	N	N	N	N

Waived Date: 03/26/1997 **EJDMT Date:** 00/00/00

	At bridge E	At bridge W	Other Advance E	Other Advance W
Signs In Place (Y=Yes,N=No, NR=NotRequired)				
Legibility/ Visibility				

CLEARANCE POSTING *Not Applicable* X

	N ft	N in	S ft	S in	meter
Actual Field Measurement		0		0	
Posted Clearance		0		0	

	At bridge N	At bridge S	Advance N	Advance S
Signs In Place (Y=Yes,N=No, NR=NotRequired)				
Legibility/ Visibility				

ACCESSIBILITY (Y/N/P)

	Needed	Used
Lift Bucket	N	N
Ladder	N	N
Boat	Y	Y
Waders	N	N
Inspector 50	N	N
Rigging	N	N
Staging	Y	Y
Traffic Control	N	N
RR Flagger	N	N
Police	N	N
Other:		
	N	N

TOTAL HOURS 28

PLANS (Y/N): Y

(V.C.R.) (Y/N): N

TAPE#: ____

List of field tests performed:

RATING

Rating Report (Y/N): Y

Date: 02/01/1997

Inspection data at time of existing rating

I 58: **7** I 59: **7** I 60: **6** Date : 03/02/1994

(To be filled out by DBIE)

Request for Rating or Rerating (Y/N): N

If YES please give priority: HIGH ( ) MEDIUM ( ) LOW ( )

REASON: ____

CONDITION RATING GUIDE

(For Items 58, 59, 60 and 61)

	CODE	CONDITION	DEFECTS
	N	NOT APPLICABLE	
G	9	EXCELLENT	Excellent condition.
G	8	VERY GOOD	No problem noted.
G	7	GOOD	Some minor problems.
F	6	SATISFACTORY	Structural elements show some minor deterioration.
F	5	FAIR	All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
P	4	POOR	Advance section loss, deterioration, spalling or scour.
P	3	SERIOUS	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
C	2	CRITICAL	Advance deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
C	1	"IMMINENT" FAILURE	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stablility. Bridge is closed to traffic but corrective action may put it back in light service.
	0	FAILED	Out of service - beyond corrective action.

DEFICIENCY REPORTING GUIDE

DEFICIENCY: A defect in a structure that requires corrective action.

CATEGORIES OF DEFICIENCIES:

M= Minor Deficiency - Deficiencies which are minor in nature, generally do not impact the structural integrity of the bridge and could easily be repaired. Examples include but are not limited to: Spalled concrete, Minor pot holes, Minor corrosion of steel, Minor scouring, Clogged drainage, etc.

S= Severe/Major Deficiency - Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but are not limited to: Moderate to major deterioration in concrete, Exposed and corroded rebars, Considerable settlement, Considerable scouring or undermining, Moderate to extensive corrosion to structural steel with measurable loss of section, etc.

C-S= Critical Structural Deficiency - A deficiency in a structural element of a bridge that poses an extreme unsafe condition due to the failure or imminent failure of the element which will affect the structural integrity of the bridge.

C-H= Critical Hazard Deficiency - A deficiency in a component or element of a bridge that poses an extreme hazard or unsafe condition to the public, but does not impair the structural integrity of the bridge. Examples include but are not limited to: Loose concrete hanging down over traffic or pedestrians, A hole in a sidewalk that may cause injuries to pedestrians, Missing section of bridge railing, etc.

URGENCY OF REPAIR:

I = Immediate- [Inspector(s) immediately contact District Bridge Inspection Engineer (DBIE) to report the Deficiency and to receive further instruction from him/her].

A = ASAP- [Action/Repair should be initiated by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) upon receipt of the Inspection Report].

P = Prioritize- [Shall be prioritized by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) and repairs made when funds and/or manpower is available].

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REMARKS

BRIDGE ORIENTATION

Bridge C-07-001 (437) carries Bridge Street over the Mitchell River in the Town of Chatham. The bridge is oriented west/east with the Mitchell River oriented north/south.

The superstructure consists of eleven timber multi-stringer approach spans (spans 1-7 and 9-12) with a timber deck and one movable timber multi-stringer bascule span (span 8) with a timber deck.
The timber stringers are numbered from south to north. In addition, there are two, partial width, cast-in-place concrete slab spans at each end of the bridge. These spans were integrated into north side of the existing abutments to accommodate the bridge widening to the north in 1949.

The substructure consists of concrete abutments and timber pile bents. The timber pile bents are numbered 1-6, 7A and 8-11 from west to east. There are smaller supplemental bents at bents 4 and 6 which are numbered 4A and 6A, respectively (see plan view within the Routine Underwater Inspection Report, dated 1/7/10).

ITEM 58 - DECK

Item 58.1 - Wearing surface

The timber wearing surface has moderate wear, particularly in the wheel lines, with slight punkiness, splits and checks throughout. The knots in the wood and the nail heads generally protrude above the surface **(see photo 1)**. Random wearing surface planks have been replaced throughout the deck. These replacement wearing surface planks do not sit flush with the remaining, worn planks. Isolated timber wearing surface planks are loose or have deteriorated to the point of failure.

The bituminous wearing surface over the abutment spans has random cracks up to 3/8" wide and minor wear, particularly in the wheel lines.

Item 58.2 - Deck Condition

The timber deck typically exhibits some random areas with slight punkiness on the underside. There is one isolated location where one deck timber has failed between stringers 10 and 11 (numbered from the south) in span 4 **(see photo 2)**.

There is a 1'-0" diameter by 2" deep spall around a weep hole with heavy efflorescence on the underside of the cast-in-place concrete deck for the east abutment span. There is also a full depth core hole through the cast-in-place concrete deck for a soil boring that was not repaired.

Item 58.4 - Curbs

The timber curbs, which also act as a traffic rail, have minor splits and checks throughout. The worst case is at the east end of the bascule span (span 8) south curb where a 3'-0" length of curb is heavily deteriorated **(see photo 3)**. At several locations the curb/traffic rails are misaligned transversely up to 1 1/2" **(see photo 4)**.

Item 58.6 - Sidewalks

The timber sidewalks have minor wear, splits and checks throughout with minor build-up of sand and debris along the curbs.

Item 58.8 - Railing

There are minor to moderate checks and splits in the timber pedestrian rails and posts.

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Item 58.12 - Utilities
There are several deteriorated, broken, loose or missing support brackets for the electrical conduit along the north side of the bridge in spans 9 through 12. At one location in span 11, the conduit has been temporarily fastened with rope. In addition, there are deteriorated, broken and loose electrical conduits with exposed wiring along the west side of bents 5 and 7A **(see photo 5)**.

Item 58.13 - Deck Joints
The steel armor at both abutment deck joints exhibits minor scrapes and gouges, particularly at the east abutment. The timber joint at the east end of the bascule span (span 8) is extremely tight when the bridge is closed. There is 1 1/2" of lateral misalignment between the bascule span (span 8) and span 9 deck along the bent 8 deck joint at the toe end of the bascule span **(see photo 6)**.

APPROACHES

Approaches a - Appr. pavement condition
The bituminous pavement at both approaches exhibits longitudinal and transverse cracks up to 1" wide. Previously sealed cracks in the east approach have opened up. Minor pavement spalling is present along the deck joint at the west abutment.

Approaches b - Appr. Roadway Settlement
An 8'-0" wide by 16'-0" long bituminous patch in the westbound lane of the west approach has settled up to 1". A 3'-0" long by 1'-2" wide area of the east approach pavement has settled 1 3/4" along the south end of the east abutment deck joint.

Approaches c - Appr. Sidewalk Settlement
The northwest and southwest approach sidewalks have settled up to 2". The northeast approach sidewalk has a 2'-1" wide area with up to 4" of settlement along the curb.

ITEM 59 - SUPERSTRUCTURE

Item 59.1 - Stringers
The timber stringers exhibit minor shakes and checks which are typically 1/8" wide with isolated stringers checked up to 5/16" wide **(see photo 7)**. There is minor collision damage (scrapes and gouges) to the underside of the stringers in the bascule span (span 8) **(see photo 8)**.

There is a 3'-0" long by 6" high spall with exposed and rusted rebar on the south side of the abutment span beam at the northeast corner of the bridge.

Item 59.10 - Diaphragms/Cross Frames
Many of the timber spacer blocks between the stringers are loose and/or have rotated **(see photo 9)**. Random blocks exhibit minor shakes and checking. There is an isolated spacer block in span 12 which exhibits severe deterioration between the third and fourth stringers from the south.

Item 59.11 - Rivets & Bolts
There is minor corrosion of the bolts throughout the superstructure. The bascule span (span 8) counterweight steel shell connection bolts (located in span 7) exhibit moderate to heavy corrosion with some minor section loss.

Item 59.12 - Welds
The bascule span (span 8) counterweight steel shell welds (located in span 7) are generally in satisfactory condition with some minor rusting.

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REMARKS

Item 59.13 - Member Alignment
The toe end of the bascule span (span 8) appears to have shifted 1 1/2" to the north, see Item 58.13 for additional comments.

Item 59.14 - Paint/Coating
The bascule span (span 8) counterweight steel shell galvanized coating (located in span 7) exhibits moderate to heavy corrosion with some minor section loss at its west end **(see photo 10)**.

Item 59.15 - King Posts
The timber king posts exhibit checks up to 1/4" wide by 4'-0" long with a maximum depth of 3" throughout their entire height with the heaviest concentration on the north face of the south post.

SuperStructure Collision Notes
There is minor collision damage (scrapes and gouges) to the underside of the stringers in the bascule span (span 8) (see photo 8).

SuperStructure Load Deflection Notes
There is minor deflection under live load.

SuperStructure Load Vibration Notes
There is moderate vibration under live load.

ITEM 60 - SUBSTRUCTURE

Item 60.1 - Abutments
Item 60.1.c - Backwalls
There are several vertical and diagonal cracks in the east abutment backwall. There is a 12" wide by 9" high by 6" deep spall at the south end of the east abutment backwall, which also serves as a header for the sidewalk joint **(see photo 11)**.

Item 60.1.d - Breastwalls
There is a 1/8" wide horizontal crack along the south half of the east abutment breastwall with a 4'-6" wide by up to 5" high by 2" deep spall along the crack **(see photo 12)**. Both the east and west abutment breastwalls exhibit hairline cracks with efflorescence. The timber sill attached to the west abutment breastwall exhibits minor checking.

Item 60.1.e - Wingwalls
The southeast and southwest wingwalls are covered with a concrete skim coat which exhibits isolated cracks up to 1/16" wide with efflorescence. The southwest wingwall exhibits a full length horizontal crack, up to 1/8" wide, with several vertical hairline cracks and 1/8" wide by full height crack extending from the horizontal crack **(see photo 13)**.

Item 60.1.h - Footings
A concrete fender wall is partially exposed through the rip-rap at the south end of both abutments. At the south end of the west abutment, the concrete fender wall exhibits wide cracks (up to 3" wide) through the full thickness of the fender **(see photo 14)**.

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REMARKS

Item 60.3 - Pile Bents
Item 60.3.a - Pile Caps
The timber pile caps typically have up to 1/16" wide checks on all surfaces. Isolated timber caps have 1/8" to 1/4" wide checks which measure up to 3'-0" long. The south end of the pile caps at bents 3 and 4 exhibit full height splits that extend to the first pile **(see photo 15)**.

Item 60.3.b - Piles
The timber piles typically have heavy marine growth with minor to moderate brooming and section loss in the tidal zone. Isolated piles exhibit heavy brooming and advanced section loss in the tidal zone, with up to 1 1/2" deep by full circumference areas of soft, punky timber **(see photo 16)**. Above the tidal zone, the piles have vertical checks up to 1/8" wide at random locations. Random piles throughout have had a section removed from the upper portion of the pile, typically 3" deep by 2'-6" high.

At the 5th pile from south, bent 2, there is a 3/4" gap between the top of pile and the underside of the pile cap **(see photo 17).** Additionally, the 6th pile from south at bent 2 has a 4" wide by 4" deep by 5" high area of 100% loss on its north side, an 8" wide by 2 1/2" deep by 24" high area of 100% loss on its south face and a full depth 1/8" wide vertical split **(see photo 18)**. Isolated piles throughout the structure exhibit full depth by up to full height splits extending down from the top of the pile **(see photo 19).**

There is little to no protective creosote coating remaining on the piles. Protective sleeves have been placed around several piles (12 total) at bents 1, 2, 3 and 4. See the attached Routine Underwater Inspection Report, dated 1/7/10, for more information.

Item 60.3.c - Diagonal Bracing
(DEF=S/A) The diagonal timber bracing for each individual pile bent generally exhibits moderate to heavy deterioration and section loss in the tidal zone. **The worst cases are at the north end of bent 5 and the south end of bent 3 where there are 5'-0" sections of the bracing which have completely deteriorated (see photo 20).**

Item 60.3.d - Horizontal Bracing
(DEF=S/A) The timber bracing between pile bents generally exhibits moderate to heavy deterioration and section loss in the tidal zone. **The worst case is at the south end of bent 8 where there is a 4'-0" section of the bracing which has completely deteriorated (see photo 21).**

Item 60.3.e - Fasteners
The fasteners that attach the bracing members generally exhibit moderate to heavy corrosion with moderate to heavy section loss in the tidal zone **(see photo 22)**. See the Underwater Inspection Report, dated 1/7/10, for more information.

ITEM 61 - CHANNEL AND CHANNEL PROTECTION

Item 61.8 - Fender System
(DEF=S/A) The vertical and horizontal timber members generally exhibit moderate splitting and checking above the tidal zone. **In the tidal zone, these members exhibit heavy marine growth with moderate to heavy deterioration and advanced section loss (up to 100%) (see photo 23)**. The east fender exhibits impact damage at its north and south ends with several vertical timber members leaning/rotated **(see photo 24).**

The fasteners have heavy surface rust and are deteriorated within the tidal zone. See the attached Routine Underwater Inspection Report, dated 1/7/10, for more information.

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REMARKS

TRAFFIC SAFETY

Item 36a - Bridge Railing

The timber curbs, which are non-mountable, act as a traffic rail and do not conform to the current standards. See Item 58.4 for comments.

Item 36b - Transitions

There are no transitions between the timber pedestrian rail and the approach thrie beam guardrails at all four corners of the bridge **(see photo 25)**.

Item 36c - Approach Guardrail

The southeast guardrail has five posts that are not up tight against the abutment wingwall due to loose anchor bolts with up to a 1 1/2" gap between the post and wingwall **(see photos 26 and 27)**. There is minor impact damage to the northeast approach guardrail. The guardrails consist of multiple types (thrie beam and w-beam) which are not continuous for their entire length and do not conform to the current standards **(see photo 28)**.

Item 36d - Approach Guardrail Ends

The buried end sections of the approach guardrails do not conform to the current standards.

Photo Log

Photo 1 : Typical worn wearing surface with protruding knots and nail heads. Also note the replacement plank not sitting flush with worn planks.
Photo 2 : Failed deck timber between stringers 10 and 11 in span 4.
Photo 3 : Deterioration of the south curb/traffic rail at the east end of the bascule span (span 8).
Photo 4 : Typical misalignment of up to 1 1/2" of curb/traffic rails (north curb shown).
Photo 5 : Deteriorated, broken and loose electrical conduits with exposed wiring along the west side of bent 7A.
Photo 6 : 1 1/2" of misalignment of bascule span toe towards the north.
Photo 7 : Up to 5/16" checks in timber south fascia stringer in span 4.
Photo 8 : Collision damage to the underside of the bascule span (span 8) stringers.
Photo 9 : Typical loose and rotated spacer block in span 8.
Photo 10 : Failed galvanized coating at the east end of the counterweight steel shell.
Photo 11 : 12" wide by 9" high by 6" deep spall at the south end of the east abutment backwall.
Photo 12 : 1/8" wide crack with 4'-6" wide by 5" high by 2" deep spall at east abutment breastwall.
Photo 13 : Up to 1/8" wide horizontal and vertical cracks at the east end of the southwest wingwall.
Photo 14 : Major 3" wide crack/split in concrete fender wall at south end of west abutment.
Photo 15 : Full height diagonal split at south end of bent 3 pile cap.
Photo 16 : Heavy brooming and advanced section loss to the northernmost pile at bent 1.
Photo 17 : 3/4" gap between top of 5th pile from south and pile cap at bent 2.
Photo 18 : Section loss and full depth vertical split at 6th pile from south end of bent 2.
Photo 19 : Full depth by full height split on third pile from south end of bent 1.
Photo 20 : 100% loss to diagonal bracing at south end of bent 3.
Photo 21 : 100% loss to horizontal bracing between bents 8 and 9 at the south end of bent 8.
Photo 22 : Heavy rust and losses to substructure connection bolt at bent 9.
Photo 23 : Heavy marine growth with up to 100% section loss to vertical bracing members at bent 7a fender.
Photo 24 : Collision damage at the south end of the bent 8 fender.
Photo 25 : Lack of transition between bridge rail and approach rail at southwest corner of bridge.
Photo 26 : 1 1/2" gap between the southeast approach guardrail posts and the face of the wingwall.
Photo 27 : Outward rotation of southeast approach guardrail posts due to loose anchor bolts.

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REMARKS

Photo Log (Cont'd)

Photo 28 : Multiple non-standard guardrail types at northeast approach.

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PHOTOS

Photo 1: **Typical worn wearing surface with protruding knots and nail heads. Also note the replacement plank not sitting flush with worn planks.**

Photo 2: **Failed deck timber between stringers 10 and 11 in span 4.**

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PHOTOS

Photo 3: **Deterioration of the south curb/traffic rail at the east end of the bascule span (span 8).**

Photo 4: **Typical misalignment of up to 1 1/2" of curb/traffic rails (north curb shown).**

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PHOTOS

Photo 5: **Deteriorated, broken and loose electrical conduits with exposed wiring along the west side of bent 7A.**

Photo 6: **1 1/2" of misalignment of bascule span toe towards the north.**

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PHOTOS

Photo 7: **Up to 5/16" checks in timber south fascia stringer in span 4.**

Photo 8: **Collision damage to the underside of the bascule span (span 8) stringers.**

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PHOTOS

Photo 9: **Typical loose and rotated spacer block in span 8.**

Photo 10: **Failed galvanized coating at the east end of the counterweight steel shell.**

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PHOTOS

Photo 11: **12" wide by 9" high by 6" deep spall at the south end of the east abutment backwall.**

Photo 12: **1/8" wide crack with 4'-6" wide by 5" high by 2" deep spall at east abutment breastwall.**

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PHOTOS

Photo 13: Up to 1/8" wide horizontal and vertical cracks at the east end of the southwest wingwall.

Photo 14: Major 3" wide crack/split in concrete fender wall at south end of west abutment.

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PHOTOS

Photo 15: **Full height diagonal split at south end of bent 3 pile cap.**

Photo 16: **Heavy brooming and advanced section loss to the northernmost pile at bent 1.**

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PHOTOS

Photo 17: **3/4" gap between top of 5th pile from south and pile cap at bent 2.**

Photo 18: **Section loss and full depth vertical split at 6th pile from south end of bent 2.**

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PHOTOS

Photo 19: **Full depth by full height split on third pile from south end of bent 1.**

Photo 20: **100% loss to diagonal bracing at south end of bent 3.**

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PHOTOS

Photo 21: **100% loss to horizontal bracing between bents 8 and 9 at the south end of bent 8.**

Photo 22: **Heavy rust and losses to substructure connection bolt at bent 9.**

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PHOTOS

Photo 23: **Heavy marine growth with up to 100% section loss to vertical bracing members at bent 7a fender.**

Photo 24: **Collision damage at the south end of the bent 8 fender.**

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PHOTOS

Photo 25: **Lack of transition between bridge rail and approach rail at southwest corner of bridge.**

Photo 26: **1 1/2" gap between the southeast approach guardrail posts and the face of the wingwall.**

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PHOTOS

Photo 27: **Outward rotation of southeast approach guardrail posts due to loose anchor bolts.**

Photo 28: **Multiple non-standard guardrail types at northeast approach.**

MASSACHUSETTS DEPARTMENT OF TRANSPORTATION

2-DIST	B.I.N.		BR. DEPT. NO.
05	437	**UNDERWATER OPERATIONS TEAM** **ROUTINE UNDERWATER INSPECTION REPORT**	C-07-001

CITY/TOWN	8-STRUCTURE NO.	LEVEL OF INSPECTION	93B-DATE INSPECTED
CHATHAM	C07001-437-MUN-NBI	II	NOV 30, 2010

07-FACILITY CARRIED	ACCESS TO BRIDGE	UNDERWATER OPERATIONS ENGINEER
HWY BRIDGE ST	EMBANKMENT	JOHN B. DESMOND (signature)

06-FEATURES INTERSECTED	DEPTH	VISIBILITY	TEAM LEADER (DIVE MASTER)	Report submitted by:
WATER MITCHELL RIVER	4 m	3 m	RANDI E. BONICA	R. Bonica (signature)

BOTTOM CONDITION	CURRENT	TEAM MEMBERS
SAND, GRAVEL, SHELLS	TIDAL	SEE GENERAL REMARKS

ITEM 60 SUBSTRUCTURE — 4

Element	Rating	DEF
1. Abutments	N	
a. Pedestals	N	-
b. Bridge Seats	N	-
c. Backwalls	N	-
d. Breastwalls	N	-
e. Wingwalls	N	-
f. Slope Paving/Rip-Rap	N	-
g. Pointing	N	-
h. Footings	N	-
i. Piles	N	-
j. Scour	N	-
k. Settlement	N	-
l.	N	-
2. Piers or Bents	N	
a. Pedestals	N	-
b. Caps	N	-
c. Columns	N	-
d. Stems/Webs/Pierwalls	N	-
e. Pointing	N	-
f. Footing	N	-
g. Piles	N	-
h. Scour	N	-
i. Settlement	N	-
j.	N	-
k.	N	-
3. Pile Bents	4	
a. Pile Caps	N	-
b. Piles	4	S-A
c. Diagonal Bracing	4	S-A
d. Horizontal Bracing	4	S-P
e. Fasteners	3	S-A
UNDERMINING (Y/N)		N

ITEM 61 CHANNEL & CHANNEL PROTECTION — 4

Element	Rating	DEF
1. Channel Scour	7	-
2. Embankment Erosion	7	-
3. Debris	7	-
4. Vegetation	7	-
5. Utilities	7	-
6. Rip-Rap/Slope Protection	7	-
7. Aggradation	7	-
8. Fender System	2	S-A
a. Piles	N	-
b. Diagonal Bracing	N	-
c. Horizontal Bracing	3	S-P
d. Vertical Members	2	S-A
e. Fasteners	5	M-P
f. Ladders	N	-
9.	N	-

ITEM 59 SUPERSTRUCTURE

Element	Rating	DEF
	N	-
	N	-
	N	-

ITEM 62 CULVERTS — N

Element	Rating	DEF
1. Roof	N	-
2. Floor	N	-
3. Walls	N	-
4. Headwall	N	-
5. Wingwall	N	-
6. Pipe	N	-
7. Protective Coating	N	-
8. Embankment	N	-
9. Wearing Surface	N	-
10. Railing	N	-
11. Sidewalks	N	-
12. Utilities	N	-
13. Member Alignment	N	-
14. Deformation	N	-
15. Scour	N	-
16. Settlement	N	-
17.	N	-
18.	N	-
UNDERMINING (Y/N)		N

DEFICIENCY REPORTING GUIDE

DEFICIENCY: A defect in a structure that requires corrective action.

CATEGORIES OF DEFICIENCIES:

M= Minor Deficiency- - Deficiencies which are minor in nature, generally do not impact the structural integrity of the bridge and could easily be repaired. Examples include but are not limited to: Spalled concrete, Minor scouring, etc.

S= Severe/Major Deficiency- Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but are not limited to: Moderate to major deterioration in concrete, Exposed and corroding rebars, Deteriorated timber piles, Considerable settlement, Considerable scouring or undermining, etc.

C-S= Critical Structural Deficiency- A deficiency in a structural element of a bridge that poses an extreme unsafe condition due to the failure or imminent failure of the element which will affect the structural integrity of the bridge.

C-H= Critical Hazard Deficiency- A deficiency in a component or element of a bridge that poses an extreme hazard or unsafe condition to the public, but does not impair the structural integrity of the bridge. Examples include but are not limited to: Any part of piles or fender system which are projecting outward and may become a safety hazard for the navigational traffic, etc.

URGENCY OF REPAIR:

I=Immediate- [Inspector(s) immediately contact District Bridge Inspection Engineer (DBIE) to report the Deficiency and to receive further instruction from him/her.]

A=ASAP- [Action/Repair should be initiated by District Maintenance Engineer or the responsible party (if not a State owned bridge) upon receipt of the Inspection Report.]

P=Prioritize- [Shall be prioritized by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) and repairs made when funds and/or manpower is available.]

X=UNKNOWN **N=NOT APPLICABLE** **H=HIDDEN/INACCESSIBLE** **R=REMOVED**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	NOV 30, 2010

REMARKS

GENERAL REMARKS

Structure consists of eleven timber pile bents. Bents have a varied number of piles (see Plan View).

Orientation:

Bents are numbered from right (West) to left (East), looking downstream. Bents are numbered to be consistent with construction plans. Stub abutments are labeled left and right, looking downstream. Piles are lettered from upstream (North) to downstream (South). The draw span is between Bents #7A and #8.

There is evidence of extensive marine borer damage to timber piles, bracing, and the fender system, mostly in the tidal zone.

The following divers participated in this inspection.
11/23/10 Bonica, Colleran, Broz, Fitzgerald, Bondeson
11/29/10 Bonica, Desmond, Colleran, Broz, Fitzgerald
11/30/10 Bonica, Desmond, Colleran, Broz, Fitzgerald

ITEM 60 - SUBSTRUCTURE

Item 60.1 - Abutments

Stub abutments are dry at low tide and were not inspected for this report.

Item 60.3 - Pile Bents

Item 60.3.b - Piles

A repair has previously been made to 12 piles (See sketch). This repair consists of wrapping piles with a plastic wrap held on by stainless steel bands. The wrap starts about 0.5' above the mudline and continues above the tidal zone. Most of the wrapped piles appeared to be of an older vintage.
Timber piles appear to be two different vintages. The older-looking piles are bleached above the tidal zone and have little or no creosote protection remaining. These piles are in poor condition with advanced brooming and signs of deterioration in the tidal zone. Newer-looking piles have much more creosote visible above the tidal zone. These piles are in fair condition with minor to moderate brooming in the tidal zone. All piles had heavy barnacle growth in the tidal zone. Below the tidal zone the piles had marine growth.
Marine borer activity was previously noticed within the tidal zone in the piles that were wrapped. Most damage was visible at and in empty bolt holes through the piles. These holes were probably from deteriorated or removed bolts previously used to attach bracing to the piles. Some visible damage at the outside face of the piles due to marine borers was substantially greater than the original hole diameter. Some piles appeared to be partially hollow in the center of the pile at the open holes.
Teredo worms were visible in numerous piles during this inspection. The teredo worms have not noticably caused significant damage to the piles they were observed in. They were prevalent mostly in the barnacles in the tidal zone and few holes in the timber piles were found.

Item 60.3.c - Diagonal Bracing

There is diagonal bracing between Bents #2 and #3, Bents #5 and #6A, and Bents #8 and #9.
Diagonal bracing has extensive deterioration in the lower ends of the timbers, in the tidal zone. Splits, marine borer damage, and holes are prevalent. Some bracing is broken or missing.

Item 60.3.d - Horizontal Bracing

There is some deterioration in the ends of the timber horizontal bracing at Bent #9.

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	NOV 30, 2010

REMARKS

Item 60.3.e - Fasteners
Fasteners used to attach bracing to the piles are in poor condition with up to 100% section loss in the tidal zone. Following the 2002 underwater inspection, MHD divers placed bolts into the holes mentioned above. Some of these bolts had no threaded nuts installed due to the bracing blocking one side of the pile. The bolts were an attempt to limit access to the center of the piles by marine borers. Several of these bolts are severely deteriorated or missing.

ITEM 61 - CHANNEL AND CHANNEL PROTECTION

Item 61.5 - Utilities
At the upstream end of Bent #7 and #8 there is a cable encased in plastic pipe which is in good condition.

Item 61.8 - Fender System
Horizontal timber members supporting the vertical timber fender members are attached directly to piles at Bent #7A and Bent #8. Newer pressure treated horizontal planks on either side of the vertical fender members hold the vertical timbers in place.

Item 61.8.c - Horizontal Bracing
There is extensive deterioration, splits, holes, and marine borer damage with up to 100% section loss in the timbers attached to the piles. This deterioration is in the tidal zone.

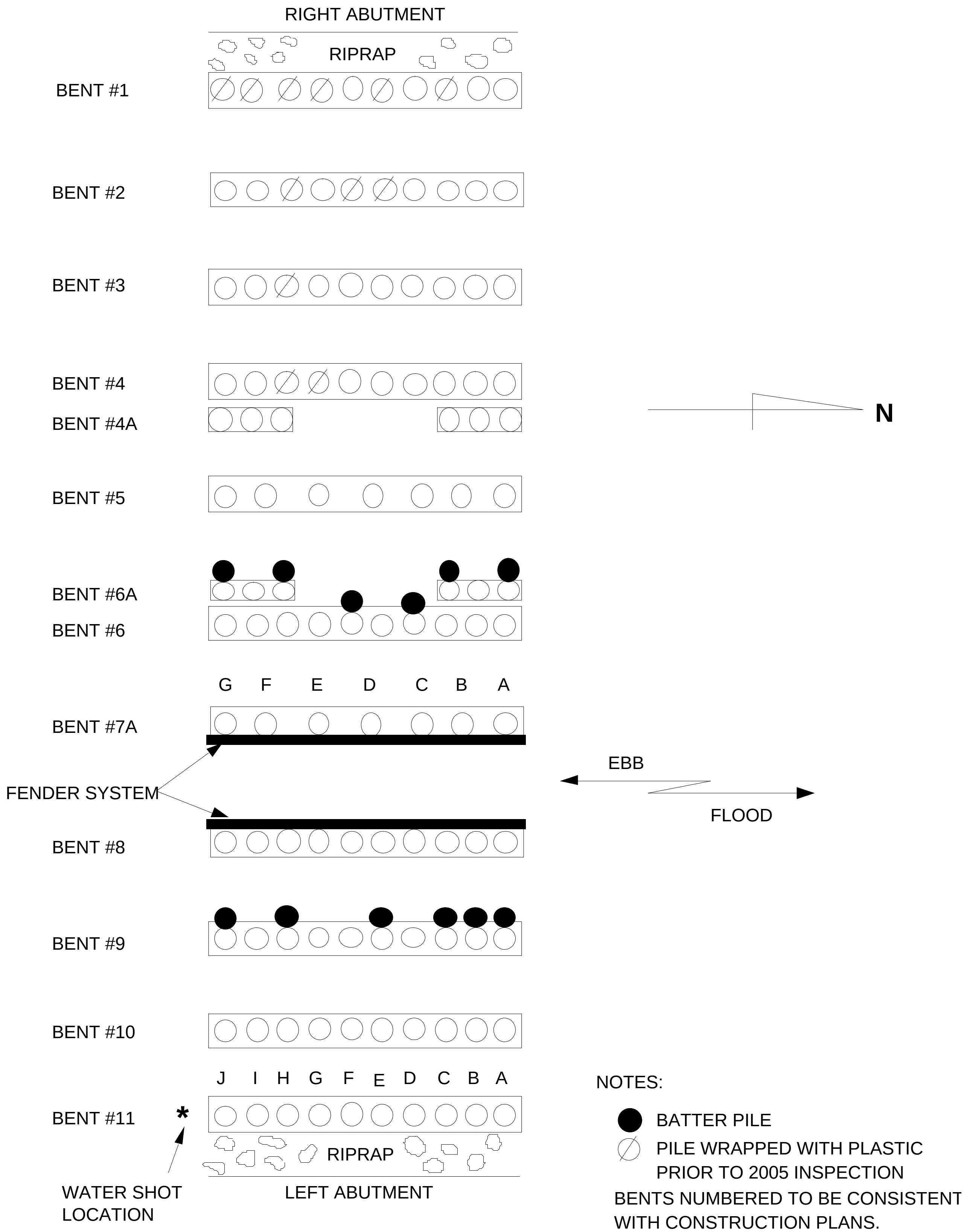
Item 61.8.d - Vertical Members
The vertical fender members have extensive deterioration and marine borer damage below the upper tidal zone. They are in critical condition with up to 100% section loss and would probably have failed if pressure treated planks were not added to both sides of the vertical timbers. The lower part of the vertical timbers are missing due to deterioration/marine borers.

Item 61.8.e - Fasteners
Fasteners have heavy surface rust and are deteriorated within the tidal zone.

Sketch / Chart Log
Sketch 1 : PLAN VIEW (NTS)
Chart 1 : SCOUR MONITORING CHART (DOWNSTREAM END)
Chart 2 : TIMBER PILE CONDITION (See Pg 7 for pile descriptions)
Chart 3 : TIMBER PILE CONDITION - DESCRIPTION

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	NOV 30, 2010

SKETCHES



Sketch 1: PLAN VIEW (NTS)

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	**437**	**C-07-001**	**C07001-437-MUN-NBI**	**NOV 30, 2010**

CHARTS

SCOUR MONITORING CHART @ DOWNSTREAM END

	12/8/95	**3/25/03**	**1/23/04**	**2/4/05**	**2/15/06**	**1/24/07**	**1/10/08**
BENT #1	3.8'	4.6'	4.2'	4.0'	4.1'	4.1'	3.8'
BENT #2	5.1'	5.6'	5.4'	5.4'	5.7'	5.6'	5.3'
BENT #3	6.2'	6.6'	6.3'	6.4'	6.5'	6.4'	6.2'
BENT #4	7.6'	7.9'	7.9'	8.0'	8.2'	8.5'	8.0'
BENT #5	9.4'	10.8'	10.1'	10.2'	10.4'	10.6'	10.1'
BENT #6	10.2'	10.8'	10.7'	10.6'	11.0'	10.8'	10.5'
BENT #7A	10.3'	11.5'	11.3'	11.1'	11.2'	10.9'	11.0'
BENT #8	10.4'	11.2'	11.2'	11.1'	11.1'	10.9'	11.0'
BENT #9	8.9'	9.8'	9.8'	9.6'	9.7'	9.7'	9.6'
BENT #10	7.9'	8.2'	7.9'	8.0'	8.0'	8.0'	8.0'
BENT #11	4.6'	4.6'	4.7'	4.6'	4.5'	4.5'	4.6'
Y	5.5'	9.6'	4.6'	8.8'	6.2'	7.4'	6.4'
CORRECTION FACTOR	-	+4.1'	-0.9'	+3.3'	+0.7'	+1.9'	+0.9'

	1/8/09	**1/6/10**					
BENT #1	3.8'	3.9'					
BENT #2	5.4'	5.7'					
BENT #3	6.1'	6.6'					
BENT #4	8.0'	7.7'					
BENT #5	10.0'	10.2'					
BENT #6	10.6'	10.9					
BENT #7A	11.0'	11.1'					
BENT #8	10.8'	11.1					
BENT #9	9.4'	9.8'					
BENT #10	8.0'	8.1'					
BENT #11	4.5'	4.8'					
Y	6.6'	7.7'					
CORRECTION FACTOR +2.2'	+1.1'						

Notes

1. Water control shot (Y) = Waterline to bottom of bent cap at downstream end of Bent #11.
2. For comparison all soundings are adjusted to 1995 water level.

Chart 1: **SCOUR MONITORING CHART (DOWNSTREAM END)**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	NOV 30, 2010

CHARTS

TIMBER PILE CONDITION

	PILE 'A'	PILE 'B'	PILE 'C'	PILE 'D'	PILE 'E'	PILE 'F'	PILE 'G'	PILE 'H'	PILE 'I'	PILE 'J'
BENT #1	2	2	W	1	W	1*	W	W	W	W
BENT #2	1	1	1*	1	W	W	1	W	1	1*
BENT #3	1	1	1*	1	2*	1	2	W	2	2*
BENT #4	2	2	1*	1	1	1	W	W	1	1*
BENT #4A	1	1	1*	---	---	---	---	1	1	3
BENT #5	1	1	1	1	1*	1	1	---	---	---
BENT #6A	1	1	1	---	---	---	---	1	1*	1
	BAT 1*		BAT 1*					BAT 1*		BAT 1*
BENT #6	1	1	3	1	1	2	2	1	1	1
				BAT 1*		BAT 1				
BENT #7A	1	1	1	1	1	1	1	---	---	---
CHANNEL										
BENT #8	1	1	1	1	3*	1	1	1	1*	1
BENT #9	2	1	1	1	1	2*	1	1	2	2
	BAT 1	BAT 2	BAT 2*		BAT 1			BAT 1*		BAT 2*
BENT #10	1	1	1	1	1	1	1	1	1	1
BENT #11	2*	1	1*	1*	1*	1*	1*	1	1	1

Chart 2: TIMBER PILE CONDITION (See Pg 7 for pile descriptions)

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
CHATHAM	437	C-07-001	C07001-437-MUN-NBI	NOV 30, 2010

CHARTS

General Notes:
1. Bents are numbered from right to left, looking downstream.
2. Piles are lettered from upstream to downstream.
3. Batter piles (BAT) are next to adjacent vertical pi
4. Evidence of marine borer activity in the pile is indicated by (*).
5. Pile previously wrapped in plastic is indicated by (W).
6. General Condition of Piles:
    1. Minor checks (<0.1' Wide), delamination (<0.1' Pen).
    2. Checks (0.1' Wide), delamination (0.1' - 0.3' Pen).
    3. Larger checks and splits, extensive delamination.

Specific Notes:
1. Marine borer activity observed throughout the timber pile, from mudline to upper tidal zone.
    Bent #2 - Pile 'C'
    Bent #3 - Pile 'E'
    Bent #4A - Pile 'C'
    Bent #6A - Batter Pile 'C'
    Bent #6 - Pile 'G'
    Bent #9 - Batter Pile 'H'
2. Marine borer activity observed in the tidal zone.
    Bent #1 - Pile 'F'
    Bent #2 - Pile 'J'
    Bent #3 - Pile 'C'
    Bent #4 - Pile 'C', 'J'
    Bent #5 - Pile 'E'
    Bent #6A - Batter Pile 'A'
    Bent #6 - Batter Pile 'D'
    Bent #8 - Pile 'E', 'I'
    Bent #9 - Pile 'F'; Batter Pile 'C', 'J'
    Bent #11 - Pile 'A', 'C', 'D', 'E', 'F', 'G'
3. Marine borer activity at the mudline.
    Bent #3 - Pile 'J'
    Bent #6A - Pile 'I'; Batter Pile 'H', 'J'
4. Condition (3) Piles:
    Bent #4A - Pile 'J', Split at top of pile, estimated 0.4' wic
    Bent #6 - Pile 'C', Saw-cut at top of pile, split above the cut to the cap
    Bent #8 - Pile 'E', 80% section loss due to marine borers, 1 1/2"-2" diameter hole in tidal zone

Chart 3: TIMBER PILE CONDITION - DESCRIPTION

MASSACHUSETTS DEPARTMENT OF TRANSPORTATION
STRUCTURES INSPECTION FIELD REPORT
ROUTINE INSPECTION

2-DIST	B.I.N.	BR. DEPT. NO.
05	438	D-14-003

CITY/TOWN	8.-STRUCTURE NO.	11-Kilo. POINT	41-STATUS	90-ROUTINE INSP. DATE
DUXBURY	D14003-438-MUN-NBI	000.000	P:POSTED	AUG 27, 2010

07-FACILITY CARRIED	MEMORIAL NAME/LOCAL NAME	27-YR BUILT	106-YR REBUILT	YR REHAB'D (NON 106)
HWY POWDER PT AV		1987	0000	2007

06-FEATURES INTERSECTED	26-FUNCTIONAL CLASS	DIST. BRIDGE INSPECTION ENGINEER
WATER DUXBURY BAY	Urban Local	D. A. Palmer

43-STRUCTURE TYPE	22-OWNER	21-MAINTAINER	TEAM LEADER	PROJ MGR
702 : Timber Stringer/Girder	Town Agency	Town Agency	W. C. Doherty	WSP SELLS

107-DECK TYPE	WEATHER	TEMP. (air)	TEAM MEMBERS
8 : Timber	Rain/Fair	28°C	S. R. LANSING, M. P. SULLIVAN

ITEM 58 DECK: 6

DECK		DEF
1.Wearing Surface	5	S-P
2.Deck Condition	6	S-P
3.Stay in place forms	N	-
4.Curbs	7	M-P
5.Median	N	-
6.Sidewalks	6	M-P
7.Parapets	N	-
8.Railing	6	M-P
9.Anti Missile Fence	N	-
10.Drainage System	N	-
11.Lighting Standards	N	-
12.Utilities	N	-
13.Deck Joints	N	-
14.	N	-
15.	N	-
16.	N	-

CURB REVEAL (In millimeters): N 255, S 250

APPROACHES

APPROACHES		DEF
a. Appr. Pavement Condition	6	M-P
b. Appr. Roadway Settlement	6	M-P
c. Appr. Sidewalk Settlement	7	-
d. Appr. SidewalkCondition	6	-

OVERHEAD SIGNS (Attached to bridge) (Y/N): N

		DEF
a. Condition of Welds	N	-
b. Condition of Bolts	N	-
c. Condition of Signs	N	-

ITEM 59 SUPERSTRUCTURE: 6

SUPERSTRUCTURE			DEF
1.Stringers		N	-
2.Floorbeams		N	-
3.Floor System Bracing		N	-
4.Girders or Beams		6	M-P
5.Trusses - General		N	-
a. Upper Chords	N		-
b. Lower Chords	N		-
c. Web Members	N		-
d. Lateral Bracing	N		-
e. Sway Bracings	N		-
f. Portals	N		-
g. End Posts	N		-
6.Pin & Hangers		N	-
7.Conn Plt's, Gussets & Angles		N	-
8.Cover Plates		N	-
9.Bearing Devices		N	-
10. Diaphragms/Cross Frames		N	-
11. Rivets & Bolts		N	-
12. Welds		N	-
13. Member Alignment		7	-
14. Paint/Coating		N	-
15.		N	-

Year Painted: N

COLLISION DAMAGE: Please explain
None (X) Minor ( ) Moderate ( ) Severe ( )

LOAD DEFLECTION: Please explain
None ( ) Minor ( ) Moderate (X) Severe ( )

LOAD VIBRATION: Please explain
None ( ) Minor ( ) Moderate (X) Severe ( )

Any Fracture Critical Member: (Y/N) N

Any Cracks: (Y/N) N

ITEM 60 SUBSTRUCTURE: 5

SUBSTRUCTURE	Dive	Cur		DEF
1. Abutments			6	
a. Pedestals	N	N		-
b. Bridge Seats	N	N		-
c. Backwalls	N	N		-
d. Breastwalls	N	N		-
e. Wingwalls	N	N		-
f. Slope Paving/Rip-Rap	N	N		-
g. Pointing	N	N		-
h. Footings	N	N		-
i. Piles	N	N		-
j. Scour	N	N		-
k. Settlement	N	N		-
l. Retaining Wall	N	6		M-P
m.Debris	N	6		S-P
2. Piers or Bents			N	
a. Pedestals	N	N		-
b. Caps	N	N		-
c. Columns	N	N		-
d. Stems/Webs/Pierwalls	N	N		-
e. Pointing	N	N		-
f. Footing	N	N		-
g. Piles	N	N		-
h. Scour	N	N		-
i. Settlement	N	N		-
j.	N	N		-
k.	N	N		-
3. Pile Bents			5	
a. Pile Caps	N	7		M-P
b. Piles	5	5		S-A
c. Diagonal Bracing	N	7		-
d. Horizontal Bracing	N	N		-
e. Fasteners	N	6		M-P

UNDERMINING (Y/N) If YES please explain: N

COLLISION DAMAGE:
None (X) Minor ( ) Moderate ( ) Severe ( )

SCOUR: Please explain
None (X) Minor ( ) Moderate ( ) Severe ( )

I-60 (Dive Report): 5 I-60 (This Report): 5

93B-U/W (DIVE) Insp: 07/02/2008

X=UNKNOWN N=NOT APPLICABLE H=HIDDEN/INACCESSIBLE R=REMOVED

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

ITEM 61 7

CHANNEL & CHANNEL PROTECTION

	Dive	Cur	DEF
1.Channel Scour	7	7	-
2.Embankment Erosion	7	7	-
3.Debris	8	8	-
4.Vegetation	8	8	-
5.Utilities	X	N	-
6.Rip-Rap/Slope Protection	N	N	-
7.Aggradation	8	8	-
8.Fender System	N	N	-

STREAM FLOW VELOCITY: Tidal (X) High ( ) Moderate ( ) Low ( ) None ( )

ITEM 61 (Dive Report): 7 ITEM 61 (This Report) 7

93b-U/W INSP. DATE: 07/02/2008

ITEM 36 TRAFFIC SAFETY

	36	COND	DEF
A. Bridge Railing	0	6	M-P
B. Transitions	0	N	-
C. Approach Guardrail	0	6	M-P
D. Approach Guardrail Ends	0	N	-

WEIGHT POSTING Not Applicable [ ]

	H	3	3S2	Single
Actual Posting	08	11	16	N
Recommended Posting	08	11	16	N

Waived Date: 00/00/00 EJDMT Date: 00/00/00

	At bridge E	At bridge W	Other Advance E	Other Advance W
Signs In Place (Y=Yes,N=No, NR=NotRequired)	Y	Y	N	Y
Legibility/ Visibility	7 / 7	7 / 5		7 / 5

CLEARANCE POSTING Not Applicable X

	N ft	N in	S ft	S in	meter
Actual Field Measurement		0		0	
Posted Clearance		0		0	

	At bridge N	At bridge S	Advance N	Advance S
Signs In Place (Y=Yes,N=No, NR=NotRequired)				
Legibility/ Visibility				

ACCESSIBILITY (Y/N/P)

	Needed	Used
Lift Bucket	N	N
Ladder	P	N
Boat	Y	Y
Waders	Y	Y
Inspector 50	N	N
Rigging	N	N
Staging	N	N
Traffic Control	N	N
RR Flagger	N	N
Police	N	N
Other:	N	N

TOTAL HOURS 33

PLANS (Y/N) Y

(V.C.R.) (Y/N) N

TAPE#:

List of field tests performed: Visual Inspection

RATING

Rating Report (Y/N): Y

Date: 12/01/2007

Inspection data at time of existing rating

I 58: 7 I 59: 7 I 60: 5 Date : 08/28/2006

(To be filled out by DBIE)

Request for Rating or Rerating (Y/N): N

If YES please give priority: HIGH ( ) MEDIUM ( ) LOW ( )

REASON:

CONDITION RATING GUIDE (For Items 58, 59, 60 and 61)

	CODE	CONDITION	DEFECTS
	N	NOT APPLICABLE	
G	9	EXCELLENT	Excellent condition.
G	8	VERY GOOD	No problem noted.
G	7	GOOD	Some minor problems.
F	6	SATISFACTORY	Structural elements show some minor deterioration.
F	5	FAIR	All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
P	4	POOR	Advance section loss, deterioration, spalling or scour.
P	3	SERIOUS	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
C	2	CRITICAL	Advance deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
C	1	"IMMINENT" FAILURE	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put it back in light service.
	0	FAILED	Out of service - beyond corrective action.

DEFICIENCY REPORTING GUIDE

DEFICIENCY: A defect in a structure that requires corrective action.

CATEGORIES OF DEFICIENCIES:

M= Minor Deficiency- Deficiencies which are minor in nature, generally do not impact the structural integrity of the bridge and could easily be repaired. Examples include but are not limited to: Spalled concrete, Minor pot holes, Minor corrosion of steel, Minor scouring, Clogged drainage, etc.

S= Severe/Major Deficiency- Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but are not limited to: Moderate to major deterioration in concrete, Exposed and corroded rebars, Considerable settlement, Considerable scouring or undermining, Moderate to extensive corrosion to structural steel with measurable loss of section, etc.

C-S= Critical Structural Deficiency - A deficiency in a structural element of a bridge that poses an extreme unsafe condition due to the failure or imminent failure of the element which will affect the structural integrity of the bridge.

C-H= Critical Hazard Deficiency - A deficiency in a component or element of a bridge that poses an extreme hazard or unsafe condition to the public, but does not impair the structural integrity of the bridge. Examples include but are not limited to: Loose concrete hanging down over traffic or pedestrians, A hole in a sidewalk that may cause injuries to pedestrians, Missing section of bridge railing, etc.

URGENCY OF REPAIR:

I = Immediate- [Inspector(s) immediately contact District Bridge Inspection Engineer (DBIE) to report the Deficiency and to receive further instruction from him/her].

A = ASAP- [Action/Repair should be initiated by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) upon receipt of the Inspection Report].

P = Prioritize- [Shall be prioritized by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) and repairs made when funds and/or manpower is available].

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BRIDGE ORIENTATION
Bridge No. D-14-003 (438) carries Powder Point Avenue traffic East and West over Duxbury Bay that is tidal. The orientation of the bridge correlates to the original bridge plans. The superstructure consists of one hundred ten (110) simply supported timber beam spans that are supported by two (2) abutment pile bents (Bent #1 and Bent #110) and one hundred nine (109) pile bents. The spans and pile bents are numbered from the West to the East and the abutments are labeled West and East. Each timber pier bent has five (5) piles that are labeled (A to E) from the North to the South. There are eleven (11) timber beams that are numbered from the North to the South.

GENERAL REMARKS
POSTING SIGNS:
The at bridge posting signs show mismatched lettering and the West approach sign has a low sight line that could easily be obscured (see Photo #1). The West advanced posting sign shows minor vegetation growth and is twisted away from the roadway.

ITEM 58 - DECK

Item 58.1 - Wearing Surface
The top face of the exposed timber deck is moderately weathered with checking and scattered areas of cupping, ring checks (some with missing sections), splits, a few loose planks and areas of rot at the South curb (see Photos #2 ,#3 & #5 to #11), **S/P**. For additional comments see Item 58.2.

Item 58.2 - Deck Condition
The top face of the exposed timber deck is moderately weathered with checking (some areas show heavier checking), scattered areas of cupping and/or slight twisting, several raised spikes, ring checks (some with missing sections), splits and a few loose planks (see Photos #2 & #3). There are scattered areas of rotted and split planks measuring up to 6.0' long and a few locations up to full depth, **S/P**. There are many areas along and under the South curb that are beginning to rot (1" width) due to wet accumulation of sand (see Photos #7 & #9). There are several replaced planks mainly at the West portion of the bridge. The underside of the deck shows scattered areas of light moss growth and lichen growth with minor areas of white and brown rot (see Photo #14). Specific deficiencies are noted as follows:

Span #1:
Northwest corner shows a few areas of rotted plank for a distance up to 18" from the North curb (see Photo #5).
Span #7:
Cracked and punky section near midspan close to the South curb, measuring 2.0' long.
Span #20:
Rotted and split plank near Bent #21, measuring 6.0' long (see Photo #6).
Span #21:
Rotted and split plank near midspan at the centerline, measuring 2.0' long.
Span #23:
Split and rotted planks at the South curb near Bent #24, measuring 2.5' long (see Photo #7).
Span #30:
Rotted and split section, nearly full length of plank x up to 3" wide near Bent #31.
Bent #37:
Cracked and rotted section at the South end, measuring 6.0' long x 3" wide x full depth.
Span #43:
Rotted and split section at the North end near Bents #43 and #44, measuring 3.0' long x 3" wide.
Span #44:
Rotted and split section at the North curb, measuring 2.0' long x 3" wide.

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Item 58.2 - Deck Condition (Cont'd)

Span #45:
Rotted and split section measuring up to 1.25' long x 3" wide near midspan (see Photo #8).
Span #46:
Rotted and split plank approximately 50%, at the North portion.
Span #57:
Rotted and split section at the North end near Bent #58, measuring 2.5' long x 3" wide.
Span #61:
Several areas of moderate brown rot throughout the bottom face (see Photo #14).
Span #63:
Heavy rotting at the curb near midspan, measuring up to 5" wide.
Span #66:
Asphalt patch near center of roadway (see Photo #10).
Span #70:
Two (2) rotted and split areas including incipient pop-out, measuring up to 2.0' long x 3" wide.
Span #76:
Rotted section near midspan, measuring 2.5' long x 3" wide.
Span #80:
Two (2) rotted and split sections, measuring 20" long x 2" wide x full depth and 1.5' long x 4" wide. Span shows cupping throughout (see Photo #11).
Span #83:
Rotting plank near midspan at the center of roadway, measuring 15" long.
Span #86:
Rotting plank near midspan at the North side, measuring 1.5' long.

Item 58.4 - Curbs
The North timber wheel guard shows scattered checking, many not snug nuts, loose bolts and loose (pushed up) vertical spikes (typical at the splice locations). The South curb (vertical face of the sidewalk) shows a few checks and moderate lichen growth throughout (see Photos #7, #9 & #11).

Item 58.6 - Sidewalks
The timber sidewalk show conditions similar to the timber deck with a few loose planks, minor to moderate lichen growth along the South edge and many planks that have curled, cupped and bowed upward. There are many loose spikes along the South side of the sidewalk. Span #24 shows planks with recent lag screw repair work. Span #50 shows minor damage and splitting at the ends along the curbs. Span #60 shows a section that dips downward at Bent #60.

Item 58.8 - Railing
The timber bridge rails show many loose bolts, occasional missing bolts (Span #34B South Rail, Bent #2 North Rail) and the top rail has several curled and twisted planks (some cupped) with a few loose spikes. There are many rails along the North side that are cracked and split at the bent splice/joint locations. There is moderate to heavy lichen growth (heaviest along the middle 1/3 portion) along the North face of the South rail and along the top of the North rail (see Photos #9 & #12). In Span #3, there is a missing nut at the North side near the center. Bent #40 shows a rotting top rail at the South side that measures 6" to 8" long. There is a missing nut at the second post at the South side of Span #66 and a loose nut at Bent #71 with additional scattered loose nuts throughout.

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APPROACHES

Approaches a - Appr. Pavement Condition
The West approach roadway shows many medium to wide longitudinal and random cracks and several depressions, especially along the South edge of the roadway (see Photo #1). The East approach roadway shows many depressions and ruts with vegetation growth at the end of the bridge (see Photo #4). There are minor slippage spalls along the transverse joint that is settled up to 3".

Approaches b - Appr. Roadway Settlement
The approach roadways slope rapidly away from the bridge and there is minor settlement that measures up to 3/4", especially at the East end of the bridge.

Approaches c - Appr. Sidewalk Settlement
The East approach sidewalk shows settlement up to 2" at the bridge and both approaches have a sharp downgrade from the bridge (see Photo #4).

Approaches d - Appr. SidewalkCondition
The East approach sidewalk has a large asphalt patch at the middle.

ITEM 59 - SUPERSTRUCTURE

Item 59.4 - Girders or Beams
The timber beams typically show a few scattered minor edge ring checks, minor splits at the end, scattered minor marine growth throughout, scattered white fungi growth, mainly along the deck and and beam interface. At Bent #44 there is brown rot at Beams #1 and #2. In Span #96, Beam #4 shows a 16" long hairline to narrow horizontal crack to the South face that extends to the bottom face, at midspan (see Photo #15). Several beams show minor bows (sweep) mainly to the center beams and along the North side with a few showing minor twisting.

Item 59.13 - Member Alignment
Several beams show minor bows (sweep) mainly to the center beams and along the North side with a few showing minor twisting.

SuperStructure Load Deflection Notes
There was minor to moderate deflection noted under all live load conditions.

SuperStructure Load Vibration Notes
There was moderate to heavy vibration under all live load conditions.

ITEM 60 - SUBSTRUCTURE

Item 60.1 - Abutments
The abutments consist of pile bents (Bent #1 and Bent #110) and timber retaining walls. See Item 60.3 for comments for the pile bents and Item 60.11 for comments for the retaining walls.

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Item 60.1.l - Retaining Wall
The vertical timber walls behind the bents show a few minor checks, short vertical edge splits, small areas of punky timber and light moss growth. The West timber wingwalls show scattered checks, many voids and asphalt piled up against the exterior face. The Northeast concrete block wall shows minor to moderate chipping and spalling along the joints (see Photo #61). The Southeast timber wingwall shows many large voids measuring up to 4.5" that extend up to one block deep, areas of minor rotting, a few checks and splits with necking down of the piles at the ground (see Photo #62)

Item 60.1.m - Debris
There is minor to moderate debris accumulation and vegetation growth under Spans #1 and #2.

Item 60.3 - Pile Bents
Item 60.3.a - Pile Caps
The timber bent cap beams show scattered areas of minor brown and/or white rot, mainly between the cap beams at the top of the piles. Bents caps #38 and #49 have been reinforced with two galvanized steel channel sections at each location. There are areas of noted brown rot at Bent #57, East face below beam #7, Bent #62 at the West cap below Beams #1 and #2 and at Bent #63 at the East face of the West Cap beam between Beams #5 and #6, including the spacer blocks at this location.

Item 60.3.b - Piles
The upper portions of the timber piles typically show scattered areas of minor to moderate insect damage (mainly in the non-tidal areas and above the tidal zone), checks, splits, minor to moderate brooming and areas of rot located mainly at/or just below the bent caps. Types of rot noted included dry, saturated, brown and white rot.

The tidal zone area shows lichen growth, minor to heavy marine barnacle growth, soft (punky) timber measuring up to 3" deep, rotting, delamination, brooming, splitting, checking, ring checking (at the corners) and areas of section loss. The heaviest deterioration occurs in the tidal zone and below the mean low tide waterline to the mud-line. Approximately 18% of the 555 timber piles are considered to have extensive deterioration, S/A.

For detailed comments and conditions regarding pile deficiencies, refer to Charts #1 to #20 and Photos #17 to #60).

In the charts the categories for the pile condition states (following same condition states as the previous inspection) are noted as follows:

1 - Minor checks and delamination (brooming).
2 - Delamination (brooming and ring checks at corners) some deterioration extend below tidal zone with some deterioration at and above tidal zone.
3 - Extensive deterioration, mainly in the tidal zone.

Item 60.3.c - Diagonal Bracing
Many of the diagonal braces show minor to moderate warping and/or bowing (most likely from pile installation) and have large gaps at the connections that measure up to 3". There are scattered areas of minor brown and/or white rot in and around the brace connections to the piles and light to moderate rust bleeding from the connections onto the piles (see Photos #44 & #50).

Item 60.3.e - Fasteners
The bracing fasteners show minor surface corrosion of the bolts and nuts in the tidal zone. There are a few scattered areas that show loose and/or backed off nuts at the connections, especially at Bent #63 above Pile "B" (see Photo #16)

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TRAFFIC SAFETY

Item 36a - Bridge Railing
The bridge railings do not meet current MassDOT standards. See Item 58.8 for comments and conditions.

Item 36b - Transitions
There are no transitions between the bridge rail and the approach guardrail, however, there are timber posts with timber parapets at the West end and Southeast corner and concrete block at the Northeast corner (see Photos #1 & #4).

Item 36c - Approach Guardrail
The West end and Southeast corner consist of non-standard railing (timber posts and a timber rail at ground level). The timber is in satisfactory condition with minor splits and checks (see Photos #1 & #4).

Item 36d - Approach Guardrail Ends
There are no standard guardrail ends, which creates a blunt-end situation at all corners of the bridge (see Photos #1 & #4).

Sketch / Chart / Photo Log

Sketch 1 : Orientation Plan
Chart 1 : Summation of Pile Deterioration for Bents #1 - #6
Chart 2 : Summation of Pile Deterioration for Bents #7 - #12
Chart 3 : Summation of Pile Deterioration for Bents #13 - #18
Chart 4 : Summation of Pile Deterioration for Bents #19 - #24
Chart 5 : Summation of Pile Deterioration for Bents #25 - #30
Chart 6 : Summation of Pile Deterioration for Bents #31 - #35
Chart 7 : Summation of Pile Deterioration for Bents #36 - #41
Chart 8 : Summation of Pile Deterioration for Bents #42 - #46
Chart 9 : Summation of Pile Deterioration for Bents #47 - #51
Chart 10 : Summation of Pile Deterioration for Bents #52 - #57
Chart 11 : Summation of Pile Deterioration for Bents #58 - #62
Chart 12 : Summation of Pile Deterioration for Bents #63 - #67
Chart 13 : Summation of Pile Deterioration for Bents #68 - #73
Chart 14 : Summation of Pile Deterioration for Bents #74 - #79
Chart 15 : Summation of Pile Deterioration for Bents #80 - #85
Chart 16 : Summation of Pile Deterioration for Bents #86 - #91
Chart 17 : Summation of Pile Deterioration for Bents #92 - #97
Chart 18 : Summation of Pile Deterioration for Bents #98 - #102
Chart 19 : Summation of Pile Deterioration for Bents #103 - #107
Chart 20 : Summation of Pile Defects for Bents #108 - #110.
Photo 1 : West approach roadway showing cracking and depressions to the pavement and low visibility load posting sign.
Photo 2 : Typical condition of the top of the bridge, looking West from the center of the bridge.
Photo 3 : Typical condition of the top of the bridge looking East from the center of the bridge.
Photo 4 : East approach roadway showing cracking and depressions to the pavement.
Photo 5 : Northwest corner of Span #1 showing areas of splitting and rotting deck planks with debris in the voids and at the curb.
Photo 6 : Deck in Span #20, showing 6.0' long section of rotted and split plank.
Photo 7 : Deck in Span #23, near Bent #24 at the South curb, showing 2.5' long split and rotted plank.
Photo 8 : Deck in Span #45 at Bent #46, showing rotted and split plank at the North portion.

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Photo 9 : Deck in Span #50, showing rotting planks below the curb and lichen growth on sidewalk, curb and bridge rail.
Photo 10 : Deck planking at the center of Span #66, showing asphalt patch.
Photo 11 : Deck in Span #80, showing deterioration of the timber planks.
Photo 12 : Typical condition of the timber bridge rails (North rail shown near center) showing checks and lichen.
Photo 13 : Typical condition of the underside of the bridge, Span #13 shown.
Photo 14 : Underside of the timber deck in Span #61, showing scattered brown rot and fingi throughout.
Photo 15 : Beam #4 in Span #96 showing a diagonal split on the South face extending to the bottom face.
Photo 16 : Pier bent cap above Pile "B", showing backed off connection nuts.
Photo 17 : Typical condition of the timber piles above the mud line, looking West from Bent #85.
Photo 18 : Bent #1, Pile "A", showing extensive deterioration, especially at the ground line.
Photo 19 : Bent #2, Pile "A", showing deterioration below bent cap.
Photo 20 : Bent #3, Pile "A", showing section loss at the ground line.
Photo 21 : Bent #3, Pile "C", showing deterioration and gaps (not seated properly) at the top of the timber shoring.
Photo 22 : Bent #7, Pile "A", showing deterioration at the Northeast corner up to 7" deep.
Photo 23 : Bent #7, Pile "C", showing a wide split at the top of the East face.
Photo 24 : Bent #12, Pile "A", showing deterioration (checking and rot) at the Northeast corner.
Photo 25 : Bent #13, Pile "C", showing full height split to East face.
Photo 26 : Bent #14, Pile "C", showing marine growth, brooming and ring checks.
Photo 27 : Bent #15, Piles "A" to "E", showing deterioration, especially at Piles "A" and "B".
Photo 28 : Bent #15, Pile "E", showing checks and ring checks at the corners.
Photo 29 : Bent #16, Pile "D", showing checking and rot in the tidal zone.
Photo 30 : Bent #17, Pile "E", showing a full height check to the West face.
Photo 31 : Bent #25, Pile "B", showing dry rot at the top of the South face up to 3" deep and brown rot at the brace.
Photo 32 : Bent #26, Pile "A", showing brown rot and checking at the top of the West face.
Photo 33 : Bent #27, Pile "A", showing delamination up to 7" in tidal zone (approximately 50% loss).
Photo 34 : Bent #29, Pile "A", showing a wide split to the North face.
Photo 35 : Bent #38, Pile "A", showing 7" deep split in South face in the tidal zone.
Photo 36 : Bent #39, Pile "A", showing brooming and checking in the tidal zone.
Photo 37 : Bent #40, Piles "D" and "E", showing brooming and checking up to 5" deep.
Photo 38 : Bent #42, Pile "C", showing heavy brooming and ring checks.
Photo 39 : Bent #43, Pile "A", showing ring check and wide checks up to 5" deep to the West face.
Photo 40 : Bent #44, Pile "A", showing dry rot to the North face, 3.0' high x 6" deep and brown rot at the top.
Photo 41 : Bent #45, Pile "C", showing ring checks up to 5" deep
Photo 42 : Bent #46, Pile "A", showing heavy deterioration and bowing outward at the West face.
Photo 43 : Bent #46, Pile "E", showing ring checks at the corners up to 3" wide and splitting up to 5" deep.
Photo 44 : Bent #49, Pile "A", showing extensive deterioration (rotted wood extending to the core).
Photo 45 : Bent #51, Pile "A", showing heavy deterioration below brace, including ring checking up to 4.5" deep.
Photo 46 : Bent #54, Pile "A", showing splitting up to 11" deep, severe brooming and rot up to 2" deep.
Photo 47 : Bent #59, Pile "D", showing extensive deterioration including brooming and delamination up to 2".
Photo 48 : Bent #63, Pile "A", showing extensive deterioration including 4" ring checks and punky timber.
Photo 49 : Bent #65, Pile "B", showing extensive deterioration, including checks up to 6" deep.
Photo 50 : Bent #67, Pile "A", showing dry rot at the top of the Northeast corner.

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Sketch / Chart / Photo Log (Cont'd)

Photo 51 : Bent #68, Pile "A", showing dry rot at the top of the Northwest corner up to 2" deep.
Photo 52 : Bent #69, Pile "A", showing dry rot at the top of the Northeast corner up to 1.5" deep.
Photo 53 : Bent #69, Pile "C", showing minor brown rot at the top.
Photo 54 : Bent #81, Pile "A", showing extensive deterioration including brooming and rot up to 4" deep.
Photo 55 : Bent #86, Pile "A", showing extensive deterioration, including brooming, 3" deep ring checks and bowing.
Photo 56 : Bent #87, Pile "B", showing wide split to the West face.
Photo 57 : Bent #93, Pile "E", showing extensive deterioration (mainly East face) with approximately 60% remaining.
Photo 58 : Bent #98, Pile "A", showing dry rot at the top of the East face up to 2" deep.
Photo 59 : Bent #99, Pile "B", showing extensive deterioration, including wide checks and crushing at the Northwest corner.
Photo 60 : Bent #110, Pile "B", showing rot with loss at the top of the West face up to 3" deep.
Photo 61 : Northeast wingwall, showing minor to moderate chipping and spalling along the blocks joints.
Photo 62 : Southeast wingwall, showing splits and large voids in timber and necking down of piles at the ground.

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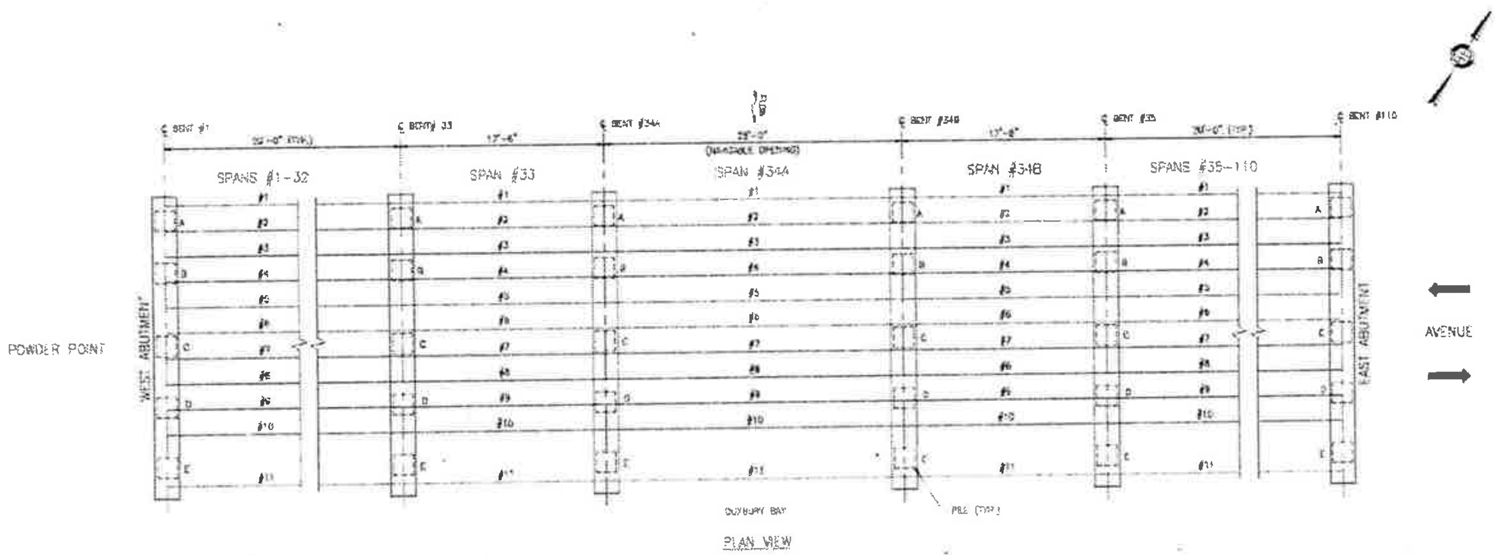
SKETCHES



Sketch 1: Orientation Plan

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CHARTS

LOCATION	CONDITION	REMARKS **Punky: Soft rot with minor penetration** **Delam.: Delamination (mainly brooming)** **Deterior.: Deterioration (Brooming, checks, rot)** **(+) Very Extensive**
BENT 1		
Pile A	3	Heavy rot and soft material at the ground line with 5" x 6" remaining section (see Photo #18)
Pile B	1	Rot up to 2" deep at perimeter of ground line; minor punkiness
Pile C	1	Rot up to 2" deep at perimeter of ground line; minor punkiness and discoloration
Pile D	1	
Pile E	3	Section loss at the ground line up to 4" deep with up to 1.5" deep punkiness.
BENT 2		
Pile A	3	Rot to South face and Northwest corner, full height x 5" wide x up to 3.5" deep; Punky throughout
		(see Photo #19)
Pile B	1	Rot initiating at top of South face
Pile C	2	Split to Southeast corner, full height x 4" wide x up to 2" deep with 1/2" deep punkiness
Pile D	1	Checking to the East and West faces with punkiness inside the checks
Pile E	1	Brown rot to South face up to 1" deep along cap
BENT 3		
Pile A	3	Section loss around ground line up to 6" deep, especially at the East face (see Photo #20)
Pile B	1	Very minor rot at the ground line
Pile C	3	Non-functioning shoring around pile; shows gaps between top shims (see Photo #21)
Pile D	1	Checks up to full height x up to 1" wide
Pile E	1	
BENT 4		
Pile A	1	
Pile B	2	Northeast corner split off with insect damage throughout all corners
Pile C	1	
Pile D	1	Discoloration to the South, East and West faces
Pile E	1	Minor brown rot initiating to South face between cap beams
BENT 5		
Pile A	1	
Pile B	1	
Pile C	1	Check to the East face, full height x 3/8" wide
Pile D	3	Rot at the Southeast corner and South face up to 1.5" deep with initial loss measuring 3" deep
		North face soft up to 1" deep at the top
Pile E	2	Loss along perimeter at ground line and behind cap beams approximately 3" high with brown rot
BENT 6		
Pile A	2	Minor rot along the perimeter at the ground line with losses up to 1" deep to the North side
Pile B	2	Minor rot at the ground line with a 1/4" full height check on the West face
Pile C	1	Minor rot at the ground line with punkiness
Pile D	2 - 3	Heavier rot at the ground line; Northwest corner loose and nailed on
Pile E		

CONDITIONS

1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 1: Summation of Pile Deterioration for Bents #1 - #6

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CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 7		
Pile A	3	Rot at the Northeast corner and East face, 7" diagonal x full height x up to 7" deep (see Photo #22)
Pile B	1	Split to the West face up to 3/4 height x 1/2" wide
Pile C	2	Split to the East face, full height with soft wood (see Photo #23)
Pile D	1	
Pile E	2	Very minor rot at the Southeast corner with full height split to the East face x 1/4" wide
BENT 8		
Pile A	1	Minor ring check at Southeast corner
Pile B	1	Minor insect damage
Pile C	2	Minor insect damage to Northeast corner; full height split to East face 3/8" wide
Pile D	2	Full height check up to 2" deep to the South face
Pile E	2	Minor insect damage throughout; rot at the mud line with brooming up to 2.5" deep
BENT 9		
Pile A	2	Minor rot and punky at the bottom; wide checks with brooming and rot up to 4" deep; insect damage
		and a full height check 1/2" wide
Pile B	2	Punky at the bottom; check to the North face; incipient ring check to Northeast corner
Pile C	2	Punky at the bottom
Pile D	2	Punky at the bottom
Pile E	2	Punky at the bottom; full height split to the East face up to 3/8" wide
BENT 10		
Pile A	2	Punky at the bottom; ring checks at edges; many checks 2'-3' from mud line; minor rot to North face
Pile B	2	Punky at the bottom; many checks and minor brooming at the bottom
Pile C	2	Punky at the bottom; many checks and minor brooming at the bottom
Pile D	3	Punky at the bottom; wide checks, minor brooming at the bottom 2'-3' from mud line; rot to the North
		face measuring up to 3.0' high x full width x up to 3" deep
Pile E	2	Punky at the bottom; same as Pile "D" but not as severe
BENT 11		
Pile A	3	Punky with insect damage up to 2" deep; Ring check to Northwest corner up to 1" deep
Pile B	2	Punky throughout tidal zone up to 1" deep
Pile C	1	Punky throughout tidal zone up to 1" deep
Pile D	1	
Pile E	2	Splitting and brooming up to 1" deep in the tidal zone; ring check to Southwest corner, 1.5" deep
BENT 12		
Pile A	3	Moderate brooming to the East face; deterioration at the top of the Northeast corner up to 3" deep
		(see Photo #24)
Pile B	2	Splitting and brooming w/ delam. up to 2" deep; ring check to Northwest corner at mud line up to 1.5" de
Pile C	1	Minor brooming
Pile D	1	Minor brooming
Pile E	1	Minor brooming; minor dry rot at Southeast corner; soft wood in tidal zone, up to 1/4" deep

CONDITIONS

1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 2: Summation of Pile Deterioration for Bents #7 - #12

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS **Punky: Soft rot with minor penetration** **Delam.: Delamination (mainly brooming)** **Deterior.: Deterioration (Brooming, checks, rot)** **(+) Very Extensive**
BENT 13		
Pile A	1	Ring check to Northeast corner up to 1" deep; full height check 3/8" wide; ring checks to SW corner
Pile B	1	3/8" wide check to North face in tidal zone
Pile C	2	Splitting and brooming, 1/2" wide split to East and West faces up to 4" deep (see Photo #25)
Pile D	1	Full height checks to the South face up to 1/2" wide
Pile E	1	Full height checks to the South face up to 3/4" wide
BENT 14		
Pile A	2	Minor checking up to 1/2" wide x 4" deep; delamination of the North Face
Pile B	2	1" wide check to the North face up to 3" deep; delamination up to 1/2 width in tidal zone
Pile C	2	Mod. brooming w/ ring checks to corners up to 2" deep; insect damage throughout (see Photo #26)
Pile D	1	
Pile E	1	
BENT 15		(see Photo #27)
Pile A	2	Minor checks/brooming with delamination up to 2" to Southeast corner; full height check to the South
		face up to 2" deep in tidal zone; ring check to Southwest corner 1.5" deep with minor rot
Pile B	2	Minor brooming, especially Northeast corner; ring check to Northwest corner 1" deep
Pile C	2	Rotting to East face below cap up to 1" deep x full width; minor white rot between caps to South face
Pile D	1	Full height checks to North and East faces up to 1" wide x 2" deep with soft wood; dry rot at top of
		Southwest corner
Pile E	3	Ring checks to the Northeast and Northwest corners up to 3" deep; check to South face 2" deep
		(see Photo #28)
BENT 16		
Pile A	2	2" delamination at Northeast and Southwest corners; 1/2" checks to top of East face with minor broomin
Pile B	1	3/8" wide full height checks up to 3" deep to the East face
Pile C	2	Minor checking and brooming and insect damage; 3/8" checks on South face up to 3" deep in tidal zone
Pile D	2	1" ring check to Northeast, Southeast and Northwest corners in tidal zone (see Photo #29)
Pile E	1	Minor brooming in tidal zone
BENT 17		
Pile A	1	Minor brown rot initiating on North face in tidal zone
Pile B	2	Moderate brooming with full height 1/2" checks to the North face
Pile C	2	Full height 3/8" checks on East face; ring checks on corners up to 4.5" deep with soft wood
Pile D	1	Punky on South face up to 1/2"; minor rot on Southwest corner above and below brace
Pile E	2	Minor to moderate brooming; 1/2" checks on the South face in tidal zone; full height split to the west fac
		repair bolt in place (see Photo #30)
BENT 18		
Pile A	2	Minor brooming; wide checks to West face and to North face 2" deep in tidal zone
		East face soft in tidal zone
Pile B	2	Minor brooming
Pile C	2	Moderate brooming to North face, especially in tidal zone
Pile D	1	Minor white rot to North face between cap beams; 3/8" check to East face
Pile E	2	Minor to moderate brooming; ring check to Southeast corner up to 3" deep; moderate insect damage

CONDITIONS

1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 3: Summation of Pile Deterioration for Bents #13 - #18

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 19		
Pile A	1	Full height 1/2" checking throughout, especially North and South faces
Pile B	1	
Pile C	2	Minor white rot at top of South face and at top of brace to East face
Pile D	2	Ring check to Northwest corner; 1/2" wide check on North face up to 4" deep
Pile E	1	Punky on West face up to 1/2" in tidal zone
BENT 20		
Pile A	2	Minor delamination (3/4") to North face with checking throughout lower tidal zone
Pile B	1	
Pile C	2	Minor delamination throughout lower tidal zone
Pile D	1	3/8" wide check full height to West face
Pile E	1	Minor white/brown rot at top of the East face with fungi growth at top of South face
BENT 21		
Pile A	3	3" ring check to Northwest corner
Pile B	2	1.5" ring check to the Northeast corner lower tidal zone; 1/2" check at the West face
Pile C	2	1.5" ring check to the Northeast corner; 1/4" check full height on East face
Pile D	2	1.5" ring check to the Northeast corner; 1/4" check up to 5" deep on the North face
Pile E	2	White rot at top of East and North faces with 1/2" checks
BENT 22		
Pile A	3	4" wide ring check at Northwest corner in upper tidal zone, heavy brooming
Pile B	2	Delamination to North face in tidal zone
Pile C	2	2.5" wide ring checks to the Northeast and Southwest corners in lower tidal zone
Pile D	2	1.5" wide ring check to Northwest corner of lower tidal zone; white rot at the top below beams; brown
		rot at the top below the brace to the East face; dry rot throughout upper half of East face (punky 1" deep)
Pile E	2	1.5" wide ring check to Southeast corner in lower tidal zone
BENT 23		
Pile A	3	3" wide ring checks to NW and NE corners in upper tidal zone; 3/4" wide check 6" deep to North face
Pile B	2	1.5" wide ring check to Northwest corner; 3/8" wide x full height check in upper tidal zone, West face
Pile C	3	4" delamination to North face
Pile D	1	3/8" wide checks in upper tidal zone; minor rot to top of East face
Pile E	1	
BENT 24		
Pile A	2	2" wide ring checks to Southwest and Northwest corners
Pile B	2	Brooming; 3/8" checks to the South face
Pile C	2	2" wide ring check at Northwest corner in upper tidal zone
Pile D	2	Brooming
Pile E	1	

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 4: Summation of Pile Deterioration for Bents #19 - #24

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 25		
Pile A	3	2" ring checks to the Northeast and Southeast corners
Pile B	2	Severe dry rot top of South face into corners up to 3" deep with insect damage (see Photo #31)
Pile C	1	
Pile D	1	Minor brown/white rot at top of the North face with 1/2" check to top of the South face
Pile E	3	2" wide ring checks to the Northeast and Southeast corners; minor brown rot at East face
BENT 26		
Pile A	3	Minor brown rot at top of the West face below cap; brown rot, ring checks and punkiness 3" deep
		at the corners; white rot between cap beams; Rot to South face, up to 4.5" deep (see Photo #32)
Pile B	1	Minor white rot at the East cap
Pile C	3	Brooming; 3" wide ring checks to the corners
Pile D	2	1/2" ring check at the Northeast corner
Pile E	3	1" wide ring check to the Southeast corner; checking to the East face in tidal zone
BENT 27		
Pile A	3	Delamination up to 7" deep throughout tidal zone showing 50% remaining (see Photo #33)
Pile B	3	Up to 3" wide ring checks to the corners; 3/4" wide check to the top of the West face
Pile C	1	3/8" wide checks to the top of the East face; minor brown rot at the top of the East face
Pile D	3	4" wide ring checks to the NE and SE corners; 2" wide ring check at the SW corner at brace
Pile E	2	3" wide ring check at the Northwest corner
BENT 28		
Pile A	1	3/8" wide check and minor ring checks at the Northeast corners
Pile B	1	3/8" wide check, full height to the West face
Pile C	2	3" wide ring check to Northwest corner
Pile D	3	4" wide ring check to Northwest corner; minor fungi growth on the East face
Pile E	2	3" wide ring check to Southeast corner
BENT 29		
Pile A	2	Minor delamination throughout; Split to North face; 2" wide ring check to NE corner (see Photo #34)
Pile B	1	1/4" wide check to top of East face
Pile C	1	Minor insect damage
Pile D	2	3" delamination to East face
Pile E	2	4" wide ring check to the Southeast corner at the lower tidal zone
BENT 30		
Pile A	2	Minor white rot between cap to South face; 2" wide ring check to the Southwest corner
Pile B	1	Minor delamination at the Northwest and Northeast corners
Pile C	2	3" wide ring check to the Northeast corner; wide check below cap on the South face
Pile D	2	Ring checks up to 2.25" wide to the Northwest and Southwest corners;
Pile E	3	3" wide ring check to the Southwest corner

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 5: Summation of Pile Deterioration for Bents #25 - #30

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 31		
Pile A	2	Minor to moderate delamination at the corners
Pile B	3	1.5" ring checks to the Northwest and Southwest corners
Pile C	3	3" wide ring check to the Northwest corner with heavy brooming
Pile D	2	2" wide ring check to the Northwest corner; minor brown rot at the East and West faces at bracing
Pile E	1	
BENT 32		
Pile A	2	2" wide ring check to Northeast corner; Full height 1" wide check to East face
Pile B	2	2" wide ring check to Southwest corner; minor white rot between brace and pile on the West face
Pile C	2	1.5" wide ring check to Northeast corner in upper tidal zone
Pile D	1	Full height checks up to 1/2" wide to East face
Pile E	3	5" wide ring checks to the Northeast and Northwest corners; Delamination of the North face up to 1.5"
		1.5" wide ring check to Southwest corner
BENT 33		
Pile A	2	Up to 3" wide ring checks to the Northeast and Southwest corners
Pile B	1	
Pile C	1	
Pile D	2	4" wide ring check to the Northeast corner; heavy brooming with rot below the cap to the West face
Pile E	2	Up to 3" wide ring checks to the Northeast, Southeast and Southwest corners
BENT 34A		
Pile A	2	3" wide ring check to Southeast corner
Pile B	1	
Pile C	2	3" wide ring check to NW corner; white rot at top of East face below brace; 1/4" wide check North face
Pile D	2	Brooming especially at mud line
Pile E	2	3" wide ring check to Southeast corner; brooming
BENT 34B		
Pile A	1	Moderate brooming and ring checks to Southwest corner
Pile B	2	Moderate delamination and ring checks to Northwest corner; brooming up to 1" deep throughout
Pile C	2	Moderate brooming ; ring check to Northwest corner
Pile D	2	Punky to South face; 1/2" check to the top of South face
Pile E	2	2" wide ring check to the Southeast and Southwest corners
BENT 35		
Pile A	2	3" wide ring check to Southeast corner
Pile B	2	3" wide ring check to Northwest corner
Pile C	2	Full height checks to East and West faces up to 1/2" wide; minor brooming in tidal zone
Pile D	2	Up to 2" wide ring check to Northwest corner
Pile E	2	Up to 2" wide ring check to Northwest corner

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 6: Summation of Pile Deterioration for Bents #31 - #35

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 36		
Pile A	2	2" wide ring check to Southwest corner in lower tidal zone
Pile B	2	1.5" wide ring check to Southeast and Northeast corners; minor to moderate brooming on West face
Pile C	2	
Pile D	2	3" ring check to Northwest corner; moderate brooming; full height 3/8" wide check to North face
Pile E	2	Moderate brooming in lower tidal zone; Full height 1/4" wide check to East face
BENT 37		
Pile A	1	
Pile B	2	2" wide ring checks to Northeast and Northwest corners; 1" wide check at the top below West cap
Pile C	3	2" wide ring check to Southeast corner in upper tidal zone; heavy brooming and ring checks
Pile D	2	2" wide ring check to Northeast corner; full height 1/2" wide check to North face
Pile E	1	Minor ring check to Northeast corner in lower tidal zone
BENT 38		**(Steel channels present on East and West faces of cap)**
Pile A	3+	7" deep split on South face in lower tidal; 9" deep to North face (pile separating in tidal zone); 3" wide rin
		checks to SE and NE corners; punky up to 1" deep; 6" deep check to West face (see Photo #35)
Pile B	1	
Pile C	2	4" wide ring check to Northwest corner; 2" wide ring check to Northeast corner
Pile D	1	1" wide ring check to NE corner; 2" wide ring check to SE corner; minor insect damage and punky
		at Northwest corner
Pile E	2	Punky at Northeast corner up to 1/2" deep in tidal zone with minor ring check
BENT 39		
Pile A	3	2" ring check to Southeast corner; 7" deep check to West face in tidal zone; 3/4" wide x 2" deep check
		to South face in tidal zone; 3/8" wide x 2" deep check to West face in tidal zone; moderate to heavy
		brooming (see Photo #36)
Pile B	2	1/2" wide check up to 3" deep in tidal zone; minor brooming
Pile C	2	1.5" wide ring check to the Northwest corner
Pile D	1	Minor brooming in tidal zone; punky up to 1/4" deep
Pile E	1	
BENT 40		
Pile A	1	Punky throughout top
Pile B	1	Minor brooming to North face; Punky up to 1/4" deep to South face
Pile C	1	3/8" wide check to top of West face
Pile D	3	3" wide ring check to Northwest corner; checks up to 5" deep in tidal zone (see Photo #37)
Pile E	3	Up to 3" wide ring checks at Northeast corner in lower tidal zone (see Photo #37)
BENT 41		
Pile A	2 - 3	White rot at top of South face at West cap beam extending to base of cap to Beam #2
		Up to 3" wide ring checks to NW and SW corners; delamination up to 1.5" deep throughout
Pile B	1	3/4" wide full height check to North face, up to 4" deep
Pile C	1	Minor brooming in tidal zone; presence of insects; minor ring check to Southeast corner
Pile D	2	2" wide ring checks to Northeast and Southeast corners
Pile E	2	2" wide ring checks to NE and SE corners; punky up to 1/4" deep

CONDITIONS

1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 7: Summation of Pile Deterioration for Bents #36 - #41

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS **Punky: Soft rot with minor penetration** **Delam.: Delamination (mainly brooming)** **Deterior.: Deterioration (Brooming, checks, rot)** **(+) Very Extensive**
BENT 42		
Pile A	2	3" wide ring check to Southwest corner; 1" wide ring check to Southeast corner
Pile B	1 - 2	3/4" wide x 4" deep check to North face in tidal zone; 5" wide ring check to Southeast corner
Pile C	3	3" ring checks to the Northeast and Southeast corners; heavy brooming (see Photo #38)
Pile D	1	Punky up to 1/4" deep throughout
Pile E	3	Delamination throughout North and East faces in tidal zone; 2.5" wide ring check to Northeast corner
BENT 43		
Pile A	3	3/4" wide checks to North and West faces above tidal zone; 1.5" ring check in tidal zone up to 5" deep
		(see Photo #39)
Pile B	1	
Pile C	2	Moderate brooming
Pile D	1	
Pile E	2	2" wide ring check to Northeast corner
BENT 44		
Pile A	3	3" wide ring check to Northeast corner; insect damage with heavy brooming to the East face
		Dry rot to the North face, 3.0' high x 6" deep (see Photo #40)
Pile B	2 - 3	2" wide ring check to SE corner; checks up to 5" deep to East face; checks up to 3/4" wide x 2.5" deep
		to North face up to full height; 1" wide ring check to Southwest corner
Pile C	2	2" wide ring check to Southeast corner; moderate brooming; 3/8" wide check at top of South face
Pile D	1	
Pile E	1	1" wide ring check to Northwest corner; 2" ring check to Northeast corner
BENT 45		
Pile A	1 - 2	Moderate brooming and checks
Pile B	2	Moderate brooming in tidal zone to West face; full height 1/2" wide check to West face
Pile C	3	3" wide ring checks to SE and SW corners; ring checks up to 2.5" deep to NE and NW corners;
		minor insect damage (see Photo #41)
Pile D	2	2" wide ring check to Northwest corner
Pile E	2	2" wide ring check to Northeast corner; moderate brooming on North face; punky up to 1/4"
BENT 46		
Pile A	3+	3" wide ring check to NW corner; 3/4" wide check 9" deep to West face; 5" deep checks to North face
		Pile appears to be bowing out along West face in upper tidal zone (see Photo #42)
Pile B	1	Insect damage at Southwest corner above tidal zone; 3/8" wide check to East face above bracing
Pile C	3	2" wide ring check to Northwest corner; moderate brooming, mainly North face
Pile D	3	3" wide ring check to Northeast corner; 2" ring check to Southeast corner
Pile E	3+	Up to 4" wide ring checks to corners; Southwest corner split up to 5" deep at lower brace;
		Checks 6" deep to South face (see Photo #43)

CONDITIONS
1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 8: Summation of Pile Deterioration for Bents #42 - #46

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 47		
Pile A	1	Full height check 2" deep to West face
Pile B	3	3" ring check, Northwest corner; 1" ring check Southwest corner; 3/8" check, South face in tidal zone
Pile C	3	Up to 3" ring checks to corners; moderate brooming throughout
Pile D	2	2" ring check to Northwest corner; 3/8" check full height to North face; brown rot at top of North face
Pile E	2	2" ring check to Northeast corner; minor to moderate delamination to West face and checks up to 1"
		deep; Dry rot at Southeast corner below brace, 3.0' high x up to 2" deep
BENT 48		
Pile A	1	
Pile B	3	Up to 4" wide ring checks to SE and NE corners; Brown rot at top of South face; 3/4" wide check
		to the top of the West face
Pile C	3	3" wide ring check to Southeast corner; 2" wide ring check to Northeast corner
Pile D	2	
Pile E	3	1/2" wide check to South face up to 2" deep; 2.5" wide ring checks to Northeast and Southeast corners
		Moderate to heavy brooming to North and East faces
BENT 49		**(Steel channels present on East and West faces of cap)**
Pile A	3	9" deep delamination to Northeast corner, wood rotted to core; extensive deterioration below brace
		(see Photo #44)
Pile B	2	Moderate to heavy brooming on the North face; wide check 2" deep; ring check to Northeast corner
Pile C	2	2" wide ring check to Northwest corner; South face punky
Pile D	2	2" wide ring check to Northwest corner; 1" delamination on North face
Pile E	3	4" wide ring checks to Southwest and Southeast corners; punky up to 1/2"
BENT 50		
Pile A	1 - 2	1/2" wide checks 3" deep to South and East faces
Pile B	2 - 3	Full height check to South face, 1" wide x 5" deep; moderate brooming in tidal zone
Pile C	2	Up to 3" wide ring checks to the Northwest and Southwest corners
Pile D	1	3/8" wide check, full height x 4" deep
Pile E	1	Minor brooming in tidal zone
BENT 51		
Pile A	3+	Rotted wood to East face and Southeast corner up to 4.5" deep with delamination throughout; moderate
		brooming to East and West faces (see Photo #45)
Pile B	1	Minor brooming; check up to 2.5" deep
Pile C	2	3" wide ring checks to Northwest and Southwest corners; 3/8" wide x 1.5" deep check to South face
Pile D	2	2" wide ring checks to Northwest and Northeast corners; minor to moderate brooming throughout
Pile E	1	

CONDITIONS

1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 9: Summation of Pile Deterioration for Bents #47 - #51

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	**438**	**D-14-003**	**D14003-438-MUN-NBI**	**AUG 27, 2010**

CHARTS

LOCATION	CONDITION	**REMARKS** **Punky: Soft rot with minor penetration** **Delam.: Delamination (mainly brooming)** **Deterior.: Deterioration (Brooming, checks, rot)** **(+) Very Extensive**
BENT 52		
Pile A	3	Minor white rot at top of the South face; 1/2" wide by 1.5" deep check to North face; 2" wide ring checks
		to Northeast corner; moderate delamination to North, West and South faces and punky throughout
Pile B	1	
Pile C	1	Minor rot at top of lower brace
Pile D	1 - 2	2" wide ring check to Northeast corner; punky on North face up to 1/4"
Pile E	1 - 2	
BENT 53		
Pile A	1 - 2	Brown rot at top of West face
Pile B	2	2" wide ring check to Northeast corner with delamination throughout
Pile C	3	2" wide ring check to SE corner; heavy brooming; punky in tidal zone; check to NE corner
		1/2" wide x 2" deep
Pile D	2 - 3	3" wide ring check to the Northeast corner
Pile E	2	2" wide ring checks to Northwest and Southeast corners; 2" delamination to South face in tidal zone
BENT 54		
Pile A	3+	Split at East and West faces 11" deep; full height checks up to 3/4" wide to West face; 1/2" wide check
		of East face; up to 4" wide ring checks to Northeast and Southwest corners; rotted North face up to 2" d
		severe broom (see Photo #46)
Pile B	2	Up to 3" ring checks to Northeast, Southwest and Southeast corners; moderate to heavy brooming
Pile C	3	4" wide ring check to Southwest corner with moderate delamination throughout; checks up to 8" deep
Pile D	2	2" wide ring check to the Northwest corner; moderate brooming and punky throughout tidal zone
Pile E	2	2" wide ring checks to corners; punky up to 1" check; 3/8" wide check to South face up to 2" deep
BENT 55		
Pile A	3	3" wide ring checks to NW and SW corners; check to East and West faces up to 2.5" deep
Pile B	1 - 2	4" wide ring check to NE corner in upper tidal zone; 1" wide ring check to SE corner
Pile C	1	3/4" wide check to top of West face; 3/8" x 3" deep check to South face
Pile D	2	3" wide ring check to Southeast corner; 3" wide ring check to Northeast corner
Pile E	1	1" wide ring check to NE corner; 3/8" wide x up to 3" deep check to North and East faces
BENT 56		
Pile A	2	1" ring check above tidal zone; 3" ring checks at Northwest, Southeast and Southwest corners
		minor to moderate brooming
Pile B	1 - 2	Moderate brooming; 1/4" x 3" deep check to West face; 2" wide ring check to Northeast corner in tidal z
Pile C	1 - 2	2" ring check to Northwest corner; moderate brooming
Pile D	1 - 2	1/4" x 3.75" deep check to North face; moderate brooming
Pile E	2	2" ring check to Southeast corner, upper tidal zone
BENT 57		
Pile A	1	
Pile B	2	1" wide ring check to Southwest corner; minor insect damage at Southwest corner
Pile C	2	2" wide ring check to NW and SE corners; 3/4" wide check to East and West face below
		lower brace; check to North face, 3/4" wide x 2" deep up to 3/4 height
Pile D	2	2" wide ring check to the Southwest and Northwest corners; punky in tidal zone up to 1/2" deep
Pile E	3	4" wide ring checks to the Northeast and Southeast corners; moderate to heavy brooming

CONDITIONS

1. Minor checks and delam. (brooming)

2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.

3. Extensive deterior. mainly in the tidal zone.

Chart 10: Summation of Pile Deterioration for Bents #52 - #57

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 58		
Pile A	1	
Pile B	3	Up to 3" wide ring checks to the Northeast, Northwest and Southeast corners
Pile C	3	4" wide ring check to Northwest corner; 2" ring check on Northeast corner; check to North face 1.5" deep
		punky up to 3/8" to East face below brace; moderate to heavy brooming
Pile D	2 - 3	2" wide ring check to Northwest and Southwest corners
Pile E	2 - 3	2" wide ring check to NW corner; moderate to heavy brooming to North and West faces in upper tidal
BENT 59		
Pile A	2	Minor to moderate brooming to the North and East faces; 5/8" wide x 2" deep check to East face
Pile B	3	Up to 3" wide ring check to Southwest, Northeast and Northwest corners; Minor delamination East and '
		faces
Pile C	1	Minor insect damage at Southeast corner
Pile D	3+	Delamination up to 2" throughout, especially at corners; heavy brooming (see Photo #47)
Pile E	3	Up to 3" wide ring checks to Northeast and Northwest corners; moderate delamination to North face;
		Checks to North and East faces up to 3/8" wide x 5" deep
BENT 60		
Pile A	2	Check below lower brace on West face, 2.5" wide x 3.5" deep; 1/2" wide ring check to the top of SW cor
Pile B	1	1" wide ring check to Southeast corner
Pile C	2	2" wide ring check to Southwest corner; checks up to 1" deep throughout
Pile D	1 - 2	2" wide ring check to Northeast corner; minor insect damage at Southwest corner in upper tidal zone
Pile E	2	2" wide ring check to Southwest corner
BENT 61		
Pile A	1	3/8" wide checks up to full height to West face x up to 1.5" deep; punky up to 1/2" in upper tidal zone
Pile B	1 - 2	1" wide ring check to NW corner; minor to moderate brooming on East face and punky up to 3/4"
Pile C	2	2" wide ring check to SW corner; 3/8" check to West face up to 4.5" deep
Pile D	2	Minor brooming; 3/8" check to South face; minor insect damage to Northeast corner
Pile E	1	
BENT 62		
Pile A	2	1.5" wide ring check to NE corner; 1" wide checks up to 4.5" deep to the East and West faces
Pile B	2 - 3	2" wide ring check to Southwest corner; 1" wide ring check to Southeast corner; moderate brooming;
		insect damage to East face in upper tidal zone
Pile C	2	2" wide ring check to Southeast corner; 1" ring check to Northwest corner
Pile D	3	2" wide ring check to Northwest corner; 3/4" check to top of West face
Pile E	2	Up to 3" wide ring checks to NE and SE corners; moderate brooming on North and West faces

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 11: Summation of Pile Deterioration for Bents #58 - #62

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 63		
Pile A	3+	4" wide ring check to South west corner; 3" ring check to Northwest corner; 1.5" x 6" deep check full hei
		to South face; punky up to 1" (see Photo #48)
Pile B	1 - 2	Several 1/4" wide checks to the North face up to 1" deep; 1/4" wide x 1" deep check to East face
Pile C	3	3" wide ring check to SE corner in tidal zone; moderate to heavy brooming; 1/2" wide x 1" deep
		check to West face
Pile D	3	4" wide ring check to Northeast corner in upper tidal zone; 1/4" wide check to the East face
Pile E	2	2" wide ring check to NE corner; minor brooming on East face; minor brown rot at top of North face
BENT 64		
Pile A	2	Moderate brooming and checking in tidal zone; 1/4" x 2" deep check
Pile B	3	4" wide ring check to SE corner; moderate to heavy brooming on South and East faces; insect
		damage to upper tidal zone
Pile C	3	Up to 4" wide ring checks to the NW and SW corners; heavy brooming and punky up to 4" deep
		beyond brooming; 3/4" x 2" deep check to the East face
Pile D	3	Heavy delamination throughout tidal zone; 1/4" wide x 2" deep check to North face; check to South face
		4.5" deep; check to East face up to 1" deep
Pile E	3	4" wide ring checks at Southeast corner in upper tidal zone; 3/4" wide x 5" deep check to South face
BENT 65		
Pile A	3	2" wide ring check to Northeast corner; moderate to heavy brooming at the North and East faces
Pile B	3+	Checks up to 6" deep to the North and South faces; 3" wide ring check to the Northwest corner
		(see Photo #49)
Pile C	2	2" wide ring check to the SW corner in lower tidal zone; 1" wide ring check to the SE corner
Pile D	1	
Pile E	2	Minor to moderate brooming and delamination
BENT 66		
Pile A	2	1" wide ring check to Southeast corner; minor brown rot at upper brace
Pile B	2	Minor to moderate brooming and checking
Pile C	2	Checks up to 3" deep to South face
Pile D	2 - 3	1" wide ring check to Northwest corner
Pile E	3	3" wide ring check to SE corner; 2" ring check to SW corner; insect damage at NW corner
BENT 67		
Pile A	2	Dry rot at Northeast corner, 15" high x 3" deep (see Photo #50)
Pile B	3	2" wide ring check to the Southwest corner; full height 3/4" wide check to South face
Pile C	3	2" ring check to Southwest corner; 4" deep check to West face; Several checks 2" deep to East face
Pile D	2	Heavy checking in tidal zone; 3/4" check full height to East face
Pile E	1	

CONDITIONS

1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 12: Summation of Pile Deterioration for Bents #63 - #67

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 68		
Pile A	3	Brown dry rot at North and South faces between caps and Northwest corner, 3" x 3" x 2" deep
		(see Photo #51); 3" wide ring check to NE corner; 5/8" wide check 2" deep to east face
Pile B	2 - 3	3/4" wide x 6" deep check, full height to North face; moderate brooming
Pile C	1	
Pile D	2	Several checks throughout
Pile E	3	2" delamination to North face; punky up to 1" deep to East face
BENT 69		
Pile A	3	4" wide ring checks to corners; dry rot at Northeast corner, 4.0' high x 1.5" deep (see Photo #52)
Pile B	1 - 2	1" wide checks to the North face up to 3" deep
Pile C	2	Minor brown rot at top (see Photo #53)
Pile D	1	Rotted at top, 2.0' high x 2" deep at South face and 12" other faces
Pile E	1 - 2	Ring check to Northeast corner; moderate brooming to North face
BENT 70		
Pile A	2	Minor brown rot at top of North face
Pile B	3	Up to 3" wide ring checks to corners; insect damage throughout and punky up to 3/4"
Pile C	2	Full height check, 1/2" wide to East face
Pile D	1	
Pile E	3	Moderate to heavy brooming with checks up to 4.5" deep; punky on East face up to 1/2"
BENT 71		
Pile A	3	Rot throughout the top up to 2" deep, especially NE corner; up to 2" wide ring checks to corners
Pile B	2	Brown rot at top of North face; 1" loss to East face in tidal zone
Pile C	2	2" wide ring check to Southeast corner; moderate to heavy checking, especially to West face
Pile D	2	Up to 3" ring checks to the Northwest, Northeast and Southeast corners; rot at top of North face
		6" high x 2" deep
Pile E	3	Rounded in tidal zone with checks up to 3" deep, minor rot at underside of brace with insect damage
BENT 72		
Pile A	2	Ring check to Southwest corner
Pile B	1	1.5" wide ring check to Northwest corner
Pile C	2	Moderate brooming
Pile D	3	Rot at top of South and North faces; 2" wide ring checks to the Northwest and Northeast corners
Pile E	3	Minor rot at the top below the West cap; large checks at all corners in the tidal zone
BENT 73		
Pile A	3	Full height check, 2" deep to South face; full height 3/8" wide check to West face
Pile B	3	Full height 1/2" wide check to South face
Pile C	3	3" wide ring checks to Northwest and Southwest corners
Pile D	1	Full height 3/8" wide check
Pile E	3	Extensive loss in tidal zone; moderate brooming on the North and East sides

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 13: Summation of Pile Deterioration for Bents #68 - #73

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS **Punky: Soft rot with minor penetration** **Delam.: Delamination (mainly brooming)** **Deterior.: Deterioration (Brooming, checks, rot)** **(+) Very Extensive**
BENT 74		
Pile A	2	Moderate brooming and ring checks at corners
Pile B	1 - 2	
Pile C	1	
Pile D	1	
Pile E	2	Minor loss and brooming in tidal zone; check to the top; ring check to Northeast corner
BENT 75		
Pile A	2	Full height 1/2" wide checks to North and South faces
Pile B	3+	Large checks; 1" x 3" deep check to West face; extensive loss
Pile C	1 - 2	Ring check to Northeast corner
Pile D	3	Heavy brooming, large checks
Pile E	2	Moderate brooming, Northeast corner ring check
BENT 76		
Pile A	2	Moderate brooming to North and East faces in tidal zone
Pile B	3	Moderate to heavy loss
Pile C	2	Large check
Pile D	2	2" wide ring check to Southeast corner mud line
Pile E	2	Several wide checks; 2" wide ring checks to Southwest and Southeast corners at mud line
BENT 77		
Pile A	2 - 3	Heavy ring checking to Southeast corner; moderate to heavy brooming
Pile B	2	1" wide ring check to Northeast corner in tidal zone
Pile C	2	
Pile D	2	2" ring check to Northwest corner
Pile E	3	1" ring check to Northwest corner; moderate to heavy brooming in tidal zone
BENT 78		
Pile A	1 - 2	
Pile B	2	Moderate brooming
Pile C	2	2" wide ring check to Southwest corner
Pile D	2 - 3	Up to 2" wide ring checks to corners; moderate to heavy brooming throughout
Pile E	2	Moderate to heavy brooming in tidal zone
BENT 79		
Pile A	2 - 3	Moderate brooming; ring check to Northeast corner, 8.0' high from mud line
Pile B	2	Heavy brooming; 3/4" wide full height check to West face
Pile C	2	Large check and brooming in tidal zone
Pile D	2	2" wide ring check to Northeast corner; full height 1/2" check to East face
Pile E	1	1" ring check to Southeast corner

CONDITIONS
1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 14: Summation of Pile Deterioration for Bents #74 - #79

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 80		
Pile A	1	
Pile B	1	
Pile C	2	Minor loss; large checks; moderate brooming and minor insect damage below brace to East face
Pile D	2	Moderate to heavy brooming at Northeast and Northwest corners
Pile E	3	Large checks; 2.5" wide ring check to Northwest corner
BENT 81		
Pile A	3+	Moderate to heavy brooming to South and East side; rotted up to 4" deep (see Photo #54)
Pile B	2	2" wide ring check to Northeast corner; 3/8" x 4.5" deep check
Pile C	2	Moderate to heavy brooming; minor punkiness
Pile D	2	Minor to moderate brooming
Pile E	1	
BENT 82		
Pile A	2	Wide check up to 3/4 height
Pile B	3	Large split, minor rot and ring checking to Northeast corner
Pile C	2 - 3	Up to 3" wide ring checks to Southeast corner
Pile D	1 - 2	Minor loss and large checks
Pile E	2	Minor loss and large checks; 1" wide ring check to the Northeast corner
BENT 83		
Pile A	3	Moderate brooming and checking and rotted up to 3" deep; 3" wide ring check to Southeast corner
Pile B	2	Moderate brooming; 2" wide ring check to Northeast corner
Pile C	3	Moderate brooming and checking; rotted up to 3" deep
Pile D	2	Moderate brooming; 3/8" wide x 2" deep check to the South face
Pile E	2	
BENT 84		
Pile A	2	3" deep check to the North and South faces
Pile B	3	Heavy brooming; large checks
Pile C	3	Heavy brooming and checking; rotted up to 3" deep; 2" wide ring check to Southwest corner
Pile D	3	Heavy brooming w/ large checks; 3" wide ring checks in tidal zone; 1" wide check to East face
Pile E	2	Moderate brooming
BENT 85		
Pile A	3	Wide checks and moderate to heavy brooming; full height 4" deep check to North face;
		3/4" wide check to East face
Pile B	1	
Pile C	1	1" wide ring check to Northeast corner
Pile D	2	2" wide ring check to Southwest corner
Pile E	2	

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 15: Summation of Pile Deterioration for Bents #80 - #85

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 86		
Pile A	3	Heavy brooming; 3" wide ring check to Southwest corner (see Photo #55); bending of pile
Pile B	2	Moderate brooming
Pile C	2	Moderate brooming
Pile D	2	Moderate to heavy brooming; 2" wide ring check to Northeast corner
Pile E	1	
BENT 87		
Pile A	2 - 3	Moderate brooming; 1/2" wide check to South face in tidal zone
Pile B	3	Wide split from top past bracing to the East and West faces (see Photo #56)
Pile C	2	
Pile D	1	1/2" check to the top of the East face
Pile E	2	
BENT 88		
Pile A	2	Checks with moderate brooming; 1/4" full height check to the East face
Pile B	1	
Pile C	1	Minor to moderate brooming
Pile D	2	1/2" check to the top of the West face; 2" wide ring checks to Northeast and Northwest corners
Pile E	1	
BENT 89		
Pile A	1	Minor brooming
Pile B	1	Minor to moderate brooming
Pile C	3	Moderate to heavy brooming; 3" wide ring check to Southeast corner
Pile D	2	Moderate brooming and checking
Pile E	2	Moderate brooming
BENT 90		
Pile A	3	1.5" wide twisted check extending 8.0' from mud line
Pile B	2	Brooming 7.0' from mud line
Pile C	1	
Pile D	1	
Pile E	2	Moderate brooming and ring checks
BENT 91		
Pile A	2	Punky to South face up to 2" deep with moderate brooming
Pile B	2	Brooming to lower 7.0'
Pile C	3	Brooming to lower 7.0'; large checks
Pile D	2	2" ring check to Southwest corner
Pile E	1	

CONDITIONS

1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 16: Summation of Pile Deterioration for Bents #86 - #91

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 92		
Pile A	2	3" wide ring check to East face
Pile B	2	Moderate brooming
Pile C	3	25% loss in tidal zone with rot up to 3" deep
Pile D	2	Ring checks; brooming to East face
Pile E	2	Ring check to Northeast corner
BENT 93		
Pile A	2	Splitting corners
Pile B	1	Wide full height check in West face
Pile C	2	Minor loss, checks and brooming, mainly at Northeast corner
Pile D	1	
Pile E	3	60% remaining with heavy loss to the East face (see Photo #57)
BENT 94		
Pile A	1 - 2	Minor checks with brooming to North face
Pile B	1	
Pile C	2	
Pile D	2	Brown rot and rust at shim below cap to East face; minor loss and large checks
Pile E	2	Minor to moderate brooming and ring checks
BENT 95		
Pile A	1	
Pile B	1	
Pile C	2 - 3	Punky with brooming to the West and North faces
Pile D	1	Ring check to Southeast corner
Pile E	2	Minor loss with large checks
BENT 96		
Pile A	2	Nearly through check
Pile B	2	Moderate brooming; minor punkiness
Pile C	2	Moderate brooming; debris (ropes) attached to bracing
Pile D	2	Moderate brooming; wide split at top with bolt
Pile E	2	Moderate brooming
BENT 97		
Pile A	3	Split through with rot up to 5" deep; Very punky to East and West faces
Pile B	1 - 2	Wide check in tidal zone
Pile C	2	Minor brooming
Pile D	1	
Pile E	2	

CONDITIONS

1. **Minor checks and delam. (brooming)**
2. **Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.**
3. **Extensive deterior. mainly in the tidal zone.**

Chart 17: Summation of Pile Deterioration for Bents #92 - #97

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 98		
Pile A	1	Dry rot at top of East face, full width x 18" high x 2" deep (see Photo #58)
Pile B	1 - 2	Minor brooming with minor white rot to South face between cap beams
Pile C	2	Wide checks and minor brooming
Pile D	2	Minor to moderate brooming, especially East face
Pile E	2	Moderate brooming; ring checks to Northeast corner up to full height
BENT 99		
Pile A	2	Wide checks and brooming
Pile B	3	Wide checks; crushing to Northwest corner with split starting at tidal zone (see Photo #59)
Pile C	2 - 3	Moderate to heavy brooming, wide checks 2" wide x 2.5" deep
Pile D	1 - 2	
Pile E	2	
BENT 100		
Pile A	2 - 3	Rot at top of Northeast corner at cap, 4" wide x 3" deep; North face soft 2.0' high at the top
Pile B	1	
Pile C	1	
Pile D	2	Minor loss, large checks; beginning to broom
Pile E	2	Wide checks
BENT 101		
Pile A	2 - 3	Brooming, minor punkiness
Pile B	2 - 3	Minor loss; large checks; split at top of South face at cap
Pile C	3	Punky and minor rot in splash zone to North side
Pile D	2 - 3	
Pile E	2	Wide checks
BENT 102		
Pile A	2 - 3	Minor loss and large checks
Pile B	3	Extensive brooming
Pile C	1	Brooming at the East and North face
Pile D	1	
Pile E	2	Moderate brooming at the North and West face

CONDITIONS

1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 18: Summation of Pile Deterioration for Bents #98 - #102

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS **Punky: Soft rot with minor penetration** **Delam.: Delamination (mainly brooming)** **Deterior.: Deterioration (Brooming, checks, rot)** **(+) Very Extensive**
BENT 103		
Pile A	2 - 3	Brooming in tidal zone with many checks at North and East faces
Pile B	2 - 3	Brooming in tidal zone with many checks at North and East faces
Pile C	2 - 3	Brooming in tidal zone with many checks at North and East faces
Pile D	1	Wide checks at top of West face
Pile E	1	
BENT 104		
Pile A	2 - 3	Splitting, brooming and necking down at the mud line; punky to North side
Pile B	1	Minor brooming
Pile C	2	Moderate checking and brooming
Pile D	2	Moderate checking and brooming in tidal zone
Pile E	1	
BENT 105		
Pile A	1	
Pile B	1	
Pile C	2	Heavy checking
Pile D	1	
Pile E	1	
BENT 106		
Pile A	2	Splitting, brooming and necking down at the bottom; punky up to 1.5" deep; brown rot with losses
		up to 2" deep at Northeast corner
Pile B	1	
Pile C	1	
Pile D	1	
Pile E	1	
BENT 107		
Pile A	1	Checks in splash zone; rot near center of East and West faces
Pile B	1	Minor dry rot in splash zone
Pile C	1	Ring check to Southwest corner with minor insect damage
Pile D	1	Dry rot just below cap beams
Pile E	1	Minor dry rot on North and East face up to 3/4" deep near center of each face

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 19: Summation of Pile Deterioration for Bents #103 - #107

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

CHARTS

LOCATION	CONDITION	REMARKS Punky: Soft rot with minor penetration Delam.: Delamination (mainly brooming) Deterior.: Deterioration (Brooming, checks, rot) (+) Very Extensive
BENT 108		
Pile A	2	Splitting at bottom
Pile B	2	Splitting and minor insect damage at bottom; ring checks
Pile C	2	Splitting and minor insect damage at bottom; punky at cap with white rot
Pile D	2	Splitting at bottom corners and full height on North face; 3/8" wide x 4" deep check to West face
Pile E	2	Splitting at bottom with insect damage and punkiness at base
BENT 109		
Pile A	1	
Pile B	1	
Pile C	1	1/2" wide check, full height to West face
Pile D	2	Northwest corner splitting off, 6" wide to West face and 3" wide to North face
Pile E	1	Punky up to 1/2" deep at perimeter at ground line
BENT 110		
Pile A	2	Rotted at bottom; full height check to West face
Pile B	2	Loss to West face below cap beam, 8" high x 8" wide x 3" deep (see Photo #60)
Pile C	1	
Pile D	1	1/4" full height check to West face
Pile E	2	Rotted at bottom; edge deterioration up to 2" deep from mid height to mud line; minor insect
		damage

CONDITIONS
1. Minor checks and delam. (brooming)
2. Delam. (brooming ring checks at corners), some deterior. extend below tidal zone with some deterior. at and above tidal zone.
3. Extensive deterior. mainly in the tidal zone.

Chart 20: Summation of Pile Defects for Bents #108 - #110.

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 1: **West approach roadway showing cracking and depressions to the pavement and low visibility load posting sign.**

Photo 2: **Typical condition of the top of the bridge, looking West from the center of the bridge.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 3: **Typical condition of the top of the bridge looking East from the center of the bridge.**

Photo 4: **East approach roadway showing cracking and depressions to the pavement.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 5: **Northwest corner of Span #1 showing areas of splitting and rotting deck planks with debris in the voids and at the curb.**

Photo 6: **Deck in Span #20, showing 6.0' long section of rotted and split plank.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 7: **Deck in Span #23, near Bent #24 at the South curb, showing 2.5' long split and rotted plank.**

Photo 8: **Deck in Span #45 at Bent #46, showing rotted and split plank at the North portion.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 9: **Deck in Span #50, showing rotting planks below the curb and lichen growth on sidewalk, curb and bridge rail.**

Photo 10: **Deck planking at the center of Span #66, showing asphalt patch.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 11: **Deck in Span #80, showing deterioration of the timber planks.**

Photo 12: **Typical condition of the timber bridge rails (North rail shown near center) showing checks and lichen.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 13: Typical condition of the underside of the bridge, Span #13 shown.

Photo 14: Underside of the timber deck in Span #61, showing scattered brown rot and fingi throughout.

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 15: **Beam #4 in Span #96 showing a diagonal split on the South face extending to the bottom face.**

Photo 16: **Pier bent cap above Pile "B", showing backed off connection nuts.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 17: **Typical condition of the timber piles above the mud line, looking West from Bent #85.**

Photo 18: **Bent #1, Pile "A", showing extensive deterioration, especially at the ground line.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 19: **Bent #2, Pile "A", showing deterioration below bent cap.**

Photo 20: **Bent #3, Pile "A", showing section loss at the ground line.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 21: **Bent #3, Pile "C", showing deterioration and gaps (not seated properly) at the top of the timber shoring.**

Photo 22: **Bent #7, Pile "A", showing deterioration at the Northeast corner up to 7" deep.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 23: Bent #7, Pile "C", showing a wide split at the top of the East face.

Photo 24: Bent #12, Pile "A", showing deterioration (checking and rot) at the Northeast corner.

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 25: **Bent #13, Pile "C", showing full height split to East face.**

Photo 26: **Bent #14, Pile "C", showing marine growth, brooming and ring checks.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 27: **Bent #15, Piles "A" to "E", showing deterioration, especially at Piles "A" and "B".**

Photo 28: **Bent #15, Pile "E", showing checks and ring checks at the corners.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 29: **Bent #16, Pile "D", showing checking and rot in the tidal zone.**

Photo 30: **Bent #17, Pile "E", showing a full height check to the West face.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 31: **Bent #25, Pile "B", showing dry rot at the top of the South face up to 3" deep and brown rot at the brace.**

Photo 32: **Bent #26, Pile "A", showing brown rot and checking at the top of the West face.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	**438**	**D-14-003**	**D14003-438-MUN-NBI**	**AUG 27, 2010**

PHOTOS

Photo 33: **Bent #27, Pile "A", showing delamination up to 7" in tidal zone (approximately 50% loss).**

Photo 34: **Bent #29, Pile "A", showing a wide split to the North face.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 35: **Bent #38, Pile "A", showing 7" deep split in South face in the tidal zone.**

Photo 36: **Bent #39, Pile "A", showing brooming and checking in the tidal zone.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 37: **Bent #40, Piles "D" and "E", showing brooming and checking up to 5" deep.**

Photo 38: **Bent #42, Pile "C", showing heavy brooming and ring checks.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	**438**	**D-14-003**	**D14003-438-MUN-NBI**	**AUG 27, 2010**

PHOTOS

Photo 39: **Bent #43, Pile "A", showing ring check and wide checks up to 5" deep to the West face.**

Photo 40: **Bent #44, Pile "A", showing dry rot to the North face, 3.0' high x 6" deep and brown rot at the top.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 41: **Bent #45, Pile "C", showing ring checks up to 5" deep**

Photo 42: **Bent #46, Pile "A", showing heavy deterioration and bowing outward at the West face.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 43: **Bent #46, Pile "E", showing ring checks at the corners up to 3" wide and splitting up to 5" deep.**

Photo 44: **Bent #49, Pile "A", showing extensive deterioration (rotted wood extending to the core).**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 45: **Bent #51, Pile "A", showing heavy deterioration below brace, including ring checking up to 4.5" deep.**

Photo 46: **Bent #54, Pile "A", showing splitting up to 11" deep, severe brooming and rot up to 2" deep.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 47: **Bent #59, Pile "D", showing extensive deterioration including brooming and delamination up to 2".**

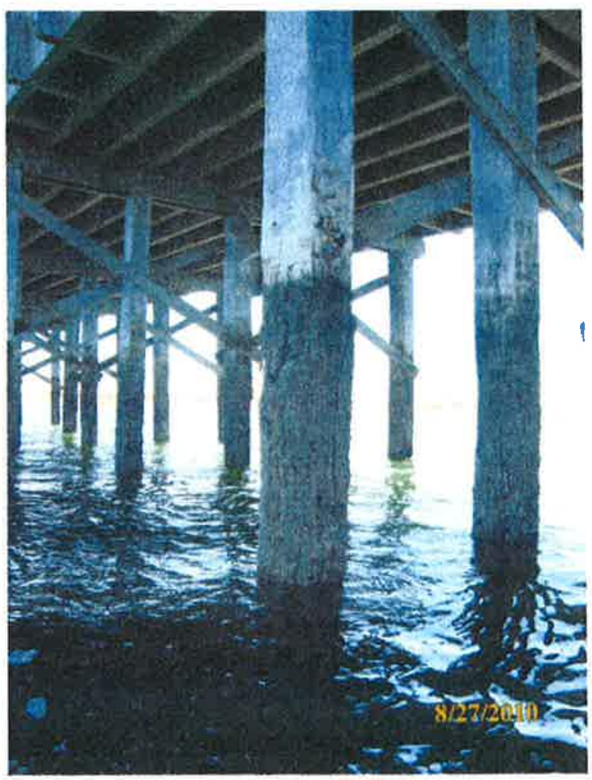


Photo 48: **Bent #63, Pile "A", showing extensive deterioration including 4" ring checks and punky timber.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 49: **Bent #65, Pile "B", showing extensive deterioration, including checks up to 6" deep.**

Photo 50: **Bent #67, Pile "A", showing dry rot at the top of the Northeast corner.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 51: **Bent #68, Pile "A", showing dry rot at the top of the Northwest corner up to 2" deep.**

Photo 52: **Bent #69, Pile "A", showing dry rot at the top of the Northeast corner up to 1.5" deep.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 53: **Bent #69, Pile "C", showing minor brown rot at the top.**

Photo 54: **Bent #81, Pile "A", showing extensive deterioration including brooming and rot up to 4" deep.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 55: **Bent #86, Pile "A", showing extensive deterioration, including brooming, 3" deep ring checks and bowing.**

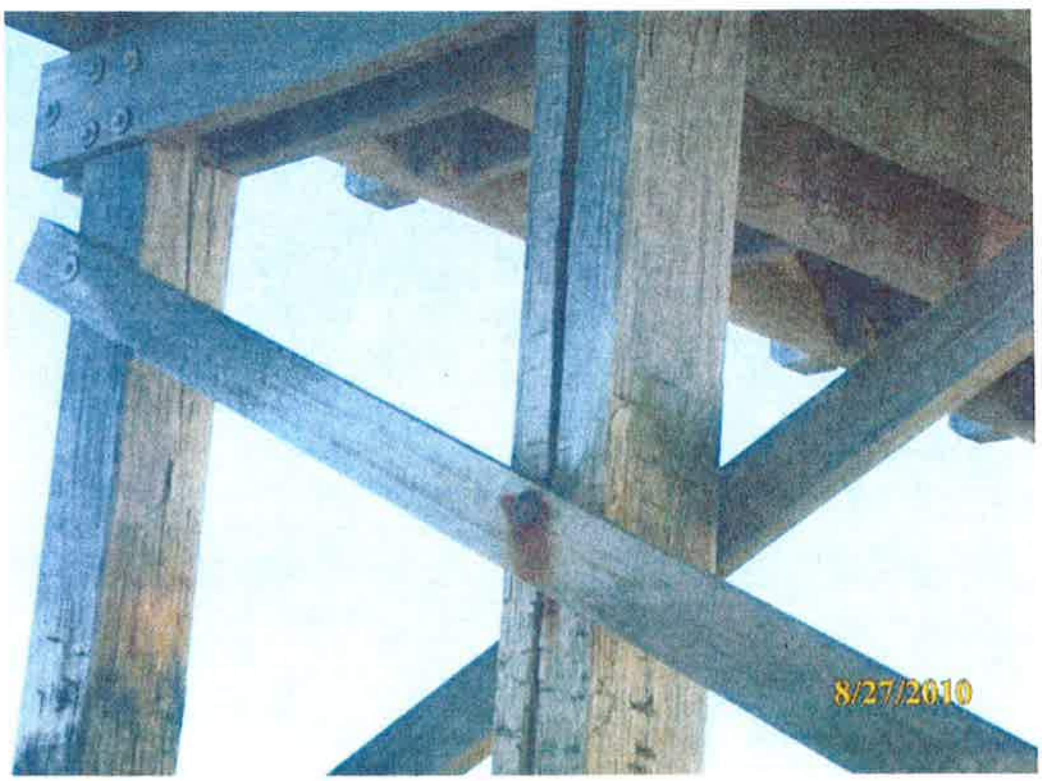


Photo 56: **Bent #87, Pile "B", showing wide split to the West face.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	**438**	**D-14-003**	**D14003-438-MUN-NBI**	**AUG 27, 2010**

PHOTOS

Photo 57: **Bent #93, Pile "E", showing extensive deterioration (mainly East face) with approximately 60% remaining.**

Photo 58: **Bent #98, Pile "A", showing dry rot at the top of the East face up to 2" deep.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 59: **Bent #99, Pile "B", showing extensive deterioration, including wide checks and crushing at the Northwest corner.**

Photo 60: **Bent #110, Pile "B", showing rot with loss at the top of the West face up to 3" deep.**

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8.-STRUCTURE NO.	INSPECTION DATE
DUXBURY	438	D-14-003	D14003-438-MUN-NBI	AUG 27, 2010

PHOTOS

Photo 61: **Northeast wingwall, showing minor to moderate chipping and spalling along the blocks joints.**

Photo 62: **Southeast wingwall, showing splits and large voids in timber and necking down of piles at the ground.**

APPENDIX C

Load Rating Summary (1997)

BRIDGE

BRIDGE RATING

PREPARED FOR

MASSACHUSETTS HIGHWAY DEPARTMENT
COMMONWEALTH OF MASSACHUSETTS

CHATHAM

BRIDGE ROAD OVER MITCHELLS BROOK

BRIDGE NO. C-07-001

BIN NO. 437

STRUCTURE NO. TWN 707-022-100

COMMONWEALTH OF MASSACHUSETTS
ABDULKADER
C.
HAMADEH
No. 29703
REGISTERED
PROFESSIONAL ENGINEER

March 1994
Date of Inspection

February 1997
Date of Rating

Submitted by:

ASEC CORPORATION
300 Congress Street Suite 303
Quincy, Massachusetts 02169

THE COMMONWEALTH OF MASSACHUSETTS
MASSACHUSETTS HIGHWAY DEPARTMENT
INTEROFFICE MEMORANDUM

TO: NBIS File

FROM: Alexander K. Bardow, P.E., Bridge Engineer

DATE: March 26, 1997

RE: BRIDGE RATING
CHATHAM
BRIDGE ROAD / MITCHELLS BROOK
BRIDGE NO. C-7-1
TWN-707-022-100
BIN = 437

Based upon the Bridge Rating Report prepared by ASEC Corporation, dated February 1997, it is recommended for Bridge No. C-7-1 that **THE POSTING BE WAIVED.**

Overall, the structure is in good condition. The controlling elements of the structure for the inventory stress levels are the draw span stringer in shear for the H20 vehicle and the pier cap in bent 7a in shear for the Type 3 and Type 3S2 vehicles. The controlling element at the operating stress levels is the pier cap in bent 7a in shear for all statutory vehicles. The rating values are 19.4 tons, 25.8 tons, and 39.3 tons for the inventory stress levels and 27.8 tons, 37.0 tons, and 56.2 tons for the operating stress levels for the H20, Type 3, and Type 3S2 vehicles, respectively. Due to the reserve operating capacity of the members which rate slightly below statutory levels for the H20 vehicle, it is suggested that the posting be waived. The bridge was previously rated in 1973 before the major rehabilitation in 1980.

The structure is a twelve span timber trestle structure with a bascule span. The majority of the bridge elements show minor punkiness. The bridge railing exhibit some minor checks, splits and vegetation growth. The approach guard rails end flush with but are not attached to the bridge rails. The wearing surface exhibits several areas of moderate deterioration. There are sand and debris deposits between the timber planking and along the gutter lines. There is plow damage to the deck joints. There is moderate settlement at both approaches and along both east sidewalk approaches.

(Continued)

There is minor impact damage to the bottom flanges of the bascule stringers. Several spacer blocks have minor cracking and have rotated between stringers. There is moderate split checking of the south kingpost. There is significant settlement of the pile bents and superstructure at and around the bascule span which has resulted in a vertical curve misalignment, however, it does not appear to be causing any structural strain or instability. A few of the hangers for the utility pipe on the north side of the bridge have deteriorated completely.

There is a vertical crack at the southeast wingwall and backwall. The east breastwall exhibits horizontal cracks and spalls. The piles at the north end of the west abutment exhibit minor punkiness and delamination. Some concrete cribbing at the north end of the east breastwall have been dislodged. There is minor erosion noted under the concrete approaches at the north end of both abutments. There is minor to moderate horizontal cracking and checking of the timber pier caps. the bracing exhibits minor to moderate cracking and splitting, heavy deterioration of the timber and corrosion of the fasteners at some of the ends. There is also extensive marine growth on the bracing and the pier piles. The pier piles show surface delamination and splitting.

The fender system, in the bascule span, exhibits scrapes and gouges. There is a hole in the horizontal support at the west side. The fasteners are corroded and the system is heavily covered in marine growth.

The following is recommended to improve and maintain the condition of the structure:

1. Consideration should be given to replacing the timber plank wearing surface.

2. The settlement of the bents should be monitored.

3. The settlement at the roadway and sidewalk approaches should be filled.

4. The cracks in the abutments should be filled.

5. The deteriorated utility pipe hangers should be replaced.

6. General maintenance and inspections should continue on regular intervals to ensure the structural adequacy and performance of the structure.

GK/MTP/mtp

cc: Rating Reports (Bridge and District copies)
Cliff Chausse, District 5 Structures Maintenance Engineer

SUMMARY OF BRIDGE RATING

TOWN/CITY: Chatham	**BRIDGE NO.:** C-07-001
CARRIES: Bridge Road over Mitchells Brook	**BIN NO:** 437
	STRUCTURE NO.: TWN 707-022-100

Vehicle Type	Code	Inventory Rating	Operating Rating	*Recommended Posting
H	1	19.6	27.8	
3	4	25.8	37.0	
3S2	5	39.3	56.2	
HS (actual weight)	--	28.2	40.4	
**HS (AASHTO equiv.)	2	15.7	22.5	

NOTES:

* To be filled in by Bridge Engineer.

** The HS Truck that is equivalent to the actual weight of the truck.

Example: 36 tons (actual weight) = HS20
27 tons (actual weight) = HS15

COMMONWEALTH OF MASSACHUSETTS
ABDULKADER C. HAMADEH
No. 29703
REGISTERED PROFESSIONAL ENGINEER

BRIDGE ENGINEER

3/4/97

DATE

BREAKDOWN OF BRIDGE RATING

TOWN/CITY: Chatham	**BRIDGE NO.:** C-07-001
CARRIES: Bridge Road over Mitchells Brook	**BIN NO:** 437
	STRUCTURE NO.: TWN 707-022-100

	INVENTORY RATING (TONS)				OPERATING RATING (TONS)			
BRIDGE COMPONENT	**TYPE H**	**TYPE 3**	**TYPE 3S2**	**HS (act) / HS (eqv)**	**TYPE H**	**TYPE 3**	**TYPE 3S2**	**HS (act) / HS (eqv)**
DECK RATING FOR MOMENT NO LOSS	28.0	47.8	72.2	50.4 / 28.0	37.4	64.0	96.5	67.4 / 37.4
DECK RATING FOR SHEAR NO LOSS	23.3	40.0	60.1	41.9 / 23.3	31.2	53.4	80.5	56.2 / 31.2
SIMPLE SPAN STRINGER RATING FOR MOMENT NO LOSS	28.3	43.7	69.0	50.9 / 28.3	38.3	59.2	93.4	68.9 / 38.3
SIMPLE SPAN STRINGER RATING FOR SHEAR NO LOSS	25.3	35.8	56.6	45.5 / 25.3	33.9	48.1	76.0	61.0 / 33.9
DRAW SPAN STRINGER RATING FOR MOMENT NO LOSS	23.0	32.9	52.1	41.5 / 23.0	30.3	43.4	68.5	54.6 / 30.3
DRAW SPAN STRINGER RATING FOR SHEAR NO LOSS	19.4	27.0	42.7	30.6 / 17.0	27.0	37.6	59.4	42.5 / 23.6

	INVENTORY RATING (TONS)				OPERATING RATING (TONS)			
BRIDGE COMPONENT	TYPE H	TYPE 3	TYPE 3S2	HS (act) / HS (eqv)	TYPE H	TYPE 3	TYPE 3S2	HS (act) / HS (eqv)
TWO SPAN CONTIN STRINGER RATING FOR MOMENT NO LOSS	34.6	53.3	84.2	62.2 / 36.6	46.6	71.7	113.0	83.9 / 46.6
TWO SPAN CONTIN STRINGER RATING FOR SHEAR NO LOSS	21.7	29.0	46.1	36.4 / 20.2	29.3	39.0	62.2	49.1 / 27.3
PILE CAP IN BENT 7A RATING FOR MOMENT NO LOSS	72.6	96.0	143.6	105.2 / 58.4	99.0	130.7	198.7	144.8 / 80.4
PILE CAP IN BENT 7A RATING FOR SHEAR NO LOSS	19.6	25.8	39.3	28.2 / 15.7	27.8	37.0	56.2	40.4 / 22.5
PILE CAP IN BENT 5 RATING FOR MOMENT NO LOSS	80.3	102.9	160.3	125.3 / 69.6	107.8	138.2	215.2	166.2 / 93.4
PILE CAP IN BENT 5 RATING FOR SHEAR NO LOSS	27.4	35.1	54.6	42.7 / 23.7	37.2	47.7	74.2	58.0 / 32.3
PILE RATING 25% LOSS	70.1	92.7	140.6	101.2 / 56.2	98.8	130.9	198.4	142.8 / 79.4

DESCRIPTION OF BRIDGE

Chatham | Bridge Road over Mitchells Brook | C-07-001

Bridge No. C-07-001, which is the subject of this report, is located on Bridge Road in Chatham, Massachusetts and conveys two lanes of traffic over Mitchells Brook. The bridge is a timber trestle structure with an overall length of 192 feet, which consists of twelve spans varying in length from 11.5 feet to 16.5 feet.

The eighth span from the west abutment is a 21 foot 9 inch long bascule span. The lift hoists are located in the sidewalks on the east end of the span and an electrical control cabinet is located on the north west side.

To provide for the public's safety and to ensure a secure operation of the bascule span, the bridge is equipped with electrically operated wood frame gates and traffic signals on both approaches. The safety gates when in the open position barricade both the sidewalks and the travelway. The traffic signals consist of two signal heads on each approach.

The curb to curb width of the roadway on the bridge is 24 feet. There are sidewalks on both the north and south sides of the bridge varying in width from 3 feet 9 inches at the abutments and the bascule span to 6 feet 9 inches on the remaining spans. The travelway is separated from the sidewalk by a 6 inch by 6 inch timber curb elevated on posts to form a 13-1/2 inch reveal along the entire structure. At the back of each sidewalk there is a timber railing which consists of two rails and a continuous protective board at the top of the sidewalk. The railing system is attached to the bridge through timber posts which are connected to the fascia stringers.

The superstructure is formed by 4 inch by 10 inch (nominal) square edge deck planks laid perpendicular to the traffic on 6 inch by 16 inch (nominal) timber stringers. These stringers are spaced at 15-1/2 inches on center. The roadway deck is topped with 3 inch (nominal) deep diagonal treated timber planks.

Total Depth ≐ 21.5'

There are eleven trestle timber bents supporting the superstructure consisting of timber piles approximately 12 inches in diameter, with timber caps. The exterior piles at several bents have a batter. All of the timber bents are braced in the plane of the bent elevation. In addition, bent no.'s 2, 3, 5, 6, 8 and 9 are braced twice in the plane of the bridge elevation.

The original bridge was constructed in 1925 with a roadway width of 15 feet 4 inches. In 1949 the bridge was widened to provide a 24 foot wide roadway for two traffic lanes and sidewalks were added.

In 1980 the bridge underwent major renovations. Over 50% of the piles were replaced and the original bent bracing was replaced with new bracing constructed from the existing stringers. The existing pile caps and the entire superstructure were completely replaced. Also at this time the mechanical, electrical and traffic control systems were reconstructed.

The original design load for the renovated bridge was an AASHTO H20-44 truck loading, which is indicated on the construction drawings. The bridge has not been rated after the 1980 renovations.

Bridge Conditions Observed During the Field Visit

ASEC Engineers conducted a field review of Bridge C-07-001 in January of 1997 and observed the following conditions:

1. The overall condition of the bridge is good.

2. The pile bent shows signs of settlement at the bascule span which has resulted in a vertical curve misalignment. Although clearly noticeable, this settlement does not result in any structural instability or strain at the present time.

3. The approach roadway surface at the west and east abutment joints has settled. The settlement has resulted in a vertical misalignment of up to 1/2 inch on the south side at each abutment and poses a hazard for pedestrians.

4. The diagonal deck wearing surface planks are in satisfactory condition with minor checks and splits, and medium punkiness at some locations. Approximately 15% of the planks have a soft rot of up to 1/2 inch from the top surface. This results in roughly a 20% loss of plank depth.

5. The curb is generally in good condition. Minor misalignment due to collisions was observed at two locations. The railing at the back of the sidewalks is in good condition with very minor splits and checks.

6. The structural deck planks are laid perpendicular to the direction of traffic and appear to be sound and solid from the underside view. The top surface of the structural deck within the roadway was not accessible for visual evaluation. The exposed top of the structural deck at both sidewalks exhibit minor checking and splitting.

7. Stringers and pile bents accessible for observation displayed no noticeable loss of section.

8. Minor cracks were observed on both abutments and the wingwalls. For detailed information of crack location and dimensions, please refer to the field notes, sketches and photographs.

9. Few of the hangers for the utility pipe on the north side of the bridge have deteriorated completely.

10. The bridge is presently not posted.

RATING ANALYSIS ASSUMPTIONS AND CRITERIA

<u>Chatham</u> <u>Bridge Road over Mitchells Brook</u> <u>C-07-001</u>

This Rating Report is based on the 1992 AASHTO Specifications for Highway Bridges with interims through 1995, including the Manual for Condition Evaluation of Bridges. The Massachusetts Highway Department Bridge Manual Part I, Section N for Bridge Rating was also utilized.

The available Rating Report for this Bridge was performed by Edwards and Kelcey in June of 1973 before the bridge was completely renovated in 1980. Therefore, that report is not utilized or referred to in the present Rating.

The bridge geometry, layout of structural members and dimensions used in this report for rating calculations are based on the construction drawings for the 1980 reconstruction project (see Available Plans). In addition, this data is supplemented with the Inspection Report of March 1994 and by field measurements obtained during a site visit by ASEC Engineers in January of 1997. The actual dimensions used in the calculations are outlined in Appendix C of this report.

The allowable tabulated stresses for timber used for the rating are those indicated on the design drawings for the 1980 bridge renovations. The inventory and operating stresses were adjusted in accordance with AASHTO modification factors for moment and shear. Details on the rating and analysis assumptions are outlined in Appendix C of this report.

EVALUATION OF RATING AND RECOMMENDATIONS

Chatham | Bridge Road over Mitchells Brook | C-07-001

Rating factors were calculated for H20, Type 3, Type 3-S2 and HS20 Trucks. Member section losses were neither observed nor assumed in the rating calculations for the bridge superstructure elements. The allowable stresses in timber were reduced, to take into account the age of the bridge, which is in service for over 15 years. In addition, allowable timber stresses for the 3-1/2 inch thick deck planks were reduced to account for the wet conditions of these members.

In computing the load rating of the bridge substructure, no section losses were observed or assumed for the pile caps. For the timber piles, a conservative 25% section loss was assumed. Even with this loss, it was determined that the piles have more than adequate capacity.

The controlling elements for this bridge are the pile caps in pier No. 7A which is located at the bascule span. The governing limitation is due to shear capacity. The inventory rating load capacities for the bridge (minimal for all members) are as follows:

Truck Type	Tons
H20	19.6
Type 3	25.8
Type 3-S2	39.3
HS20 (Actual)	28.2
HS20 (Equiv.)	15.7

The 1 to 2 inch settlement observed in the pile bents at the draw (bascule) span does not affect the capacities or the rating of the main bridge elements. The settlement has occurred entirely within the simply supported spans, therefore, the bent displacements have not produced deflection in any of the members or any additional stresses.

At this moment the above described settlement does not create a danger for the bridge structure, vehicular or pedestrian traffic. The close monitoring of the bents settlement is strongly recommended, since further settlements will increase the degree of vertical misalignment and result in undesirable member displacements.

The settlements at the approaches to the bridge should be filled to reduce the impact on motor vehicles and to improve pedestrian safety.

Cracks in the abutments should be injected and patched to prevent further crack opening and the subsequent deterioration of the concrete and reinforcement steel.

New utility pipe hangers should be installed in place of the deteriorated and failed ones on the north side.

Preventative maintenance and inspection procedures should be continued at normal and regular frequencies.

Approach Looking West (Photograph 1)

Approach Looking East (Photograph 2)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook** **Chatham, Massachusetts** **Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 1

Bridge Structure South Elevation, Looking Upstream (Photograph 3)

Bridge Structure North Elevation, Looking East (Photograph 4)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook Chatham, Massachusetts Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 2

Vertical Misalignment due to Supports Settlement
Roadway and South Sidewalk at Bascule Span, Looking South East (Photograph 5)

Deterioration of Wearing Surface at Roadway,
Looking North West from South Sidewalk (Photograph 6)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook** **Chatham, Massachusetts** **Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 3

Vertical Misalignment at Deck Joint over East Abutment, Looking North (Photograph 7)

Typical Bridge Superstructure from Underneath View in the East Most Span (Photograph 8)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook** **Chatham, Massachusetts** **Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 4

Curb Misalignment at Bascule Span, Looking South West (Photograph 9)

South Side Sidewalk Looking West (Photograph 10)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook Chatham, Massachusetts Bridge No. C-07-001 BIN No. 437**	January 1997
		Sheet No. 5

Vertical Misalignment at South East Sidewalk (Photograph 11)

Vertical Misalignment at South East Sidewalk Approach (Photograph 12)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook** **Chatham, Massachusetts** **Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 6

East Abutment and Rip-Rap, Looking South from Mid-width (Photograph 13)

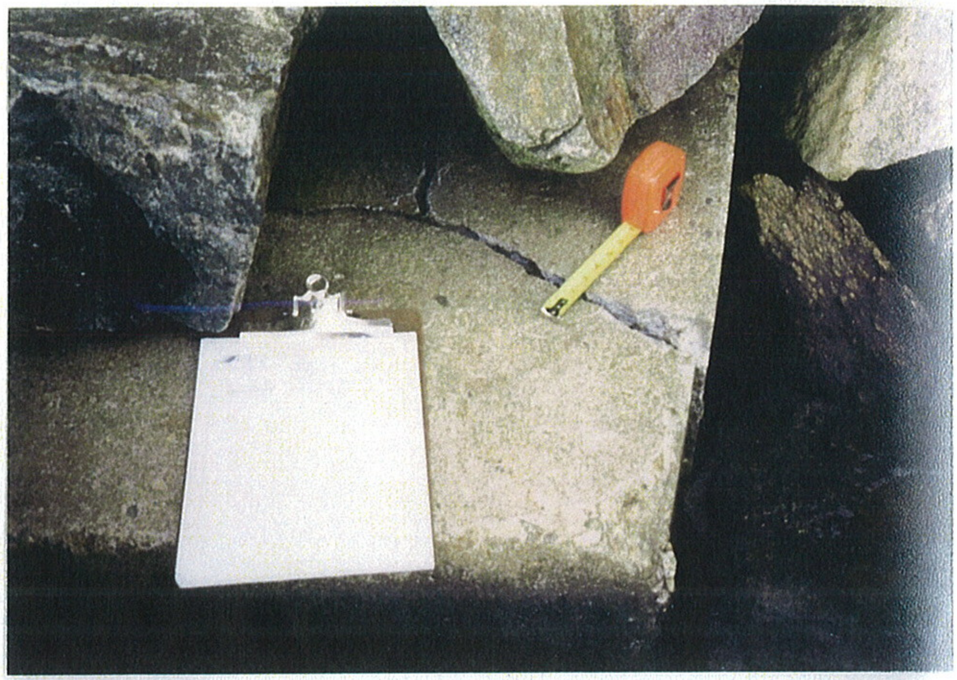
North Side Addition of East Abutment (Photograph 14)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook** **Chatham, Massachusetts** **Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 7

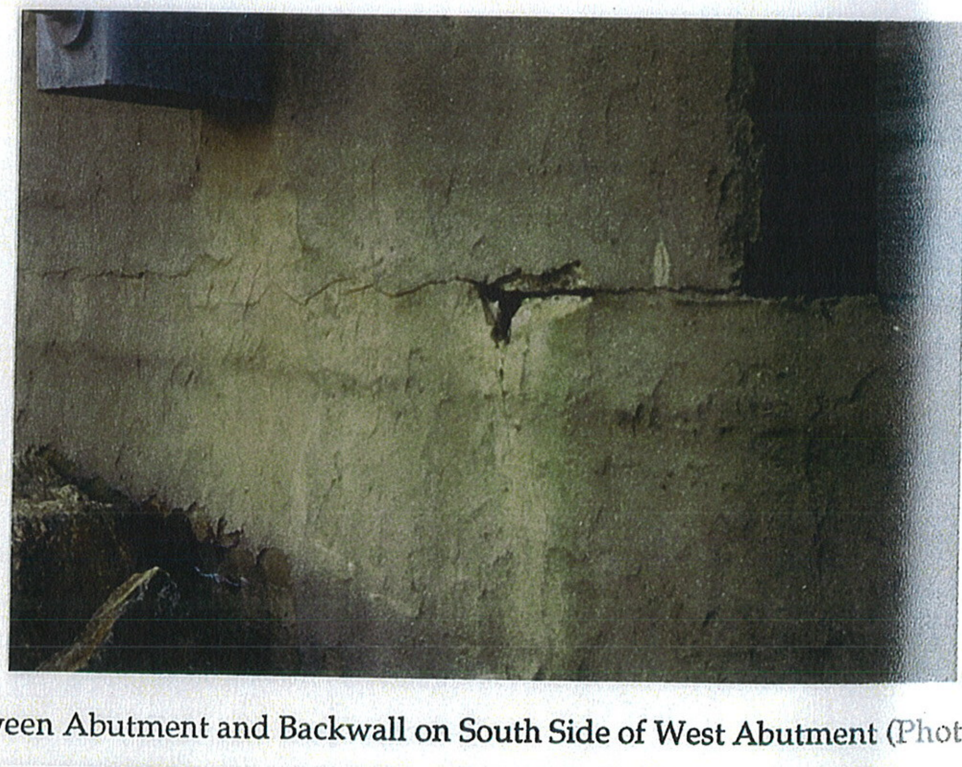
Crack at Back Wall and South East Wingwall
(Photograph 15)

Vertical Crack at the Mid-length of
South East Wingwall
(Photograph 16)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook Chatham, Massachusetts Bridge No. C-07-001 BIN No. 437**	January 1997 / Sheet No. 8



Crack at the South Side of West Abutment Footing (Photograph 17)



Crack Between Abutment and Backwall on South Side of West Abutment (Photograph 18)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook Chatham, Massachusetts Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 9

Bridge Substructure Looking South East (Photograph 19)

Typical Pile Bent Looking East (Photograph 20)

Massachusetts Highway Department	**Bridge Road over Mitchells Brook Chatham, Massachusetts Bridge No. C-07-001 BIN No. 437**	January 1997 Sheet No. 10

Wood Fender at East End of Bascule Span at South (Ocean) Side (Photograph 21)

Typical Pile Bent Bracing (Photograph 22)

Pile Deterioration at the Exterior Pile of West Most Pile Bent No. 11 (Photograph 23)

Typical Rusted and Broken Utility Pipe Bracket (Photograph 24)

APPENDIX D

In-place Preservative Treatments

CHAPTER 14

MAINTENANCE AND REHABILITATION OF TIMBER BRIDGES

14.1 INTRODUCTION

Wood is one of the most durable bridge materials, but over extended periods it may be subject to deterioration from decay, insect attack, or mechanical damage. Timber bridges must be periodically maintained or rehabilitated in order to keep them in a condition that will give optimum performance and service life. Effective bridge maintenance programs improve public safety, extend the service life of the structure, and reduce the frequency and cost of repairs. The objective is not only to repair existing deficiencies, but also to take corrective measures to prevent or reduce future problems. When tied to a competent bridge inspection program, regular maintenance represents the most cost-effective approach for achieving long service life from existing structures. Unfortunately, maintenance is often neglected until critical problems develop that require major restoration or replacement of the structure. In times of declining budgets, the first program reduced as a money-saving measure is often maintenance, when, in fact, reduced maintenance substantially increases long-term costs.

In general terms, bridge maintenance includes those activities necessary to preserve the utility of a bridge and ensure the safety of road users. In practice, all maintenance is either preventative or remedial. Maintenance activities are divided into categories that vary in definition and scope among different agencies. In this chapter, timber bridge maintenance is divided into the three following categories:

1. **Preventative maintenance** involves keeping the structure in a good state of repair to reduce future problems. At this stage, decay or other deterioration has not started, but the conditions or potential are present.
2. **Early remedial maintenance** is performed when decay or other deterioration is present but does not affect the capacity or performance of the bridge in normal service. At this stage, more severe structural damage is imminent unless corrective action is taken.
3. **Major maintenance** involves immediate corrective measures that restore a bridge to its original capacity and condition. Deterioration has progressed to the point where major structural components have experienced moderate to severe strength loss and repair or replacement is mandatory to maintain load-carrying capacity.

Bridge rehabilitation is another form of restoration performed on bridges that are functionally or structurally obsolete. Rehabilitation is similar to maintenance in some ways because it involves many of the same methods and techniques; however, rehabilitation is performed to improve the geometric or load-carrying capacity of an existing bridge, rather than to restore the original capacity. Rehabilitation is most commonly performed on older bridges that were built to lesser geometric or loading standards than those required for today's modern traffic.

This chapter discusses several maintenance and rehabilitation practices and methods that are commonly used for timber bridges. Because deficiencies develop from a variety of causes, it is impractical to address each type of potential problem. Rather, preventative and remedial methods are discussed that can be adapted to the specific circumstances of the structure. These methods include moisture control, in-place preservative treatment, mechanical repair, epoxy repair, and component replacement. Applications of these techniques to actual projects are given in case histories presented in Chapter 15. For additional guidelines and information related to bridge maintenance in general, consult the references listed at the end of this chapter. [1,3,28,37]

14.2 MOISTURE CONTROL

Moisture control is the simplest, most economical method of reducing the hazard of decay in timber bridges. It can be used as an effective and practical maintenance technique to extend the service life of many existing bridges. When exposure to wetting is reduced, members can dry to moisture contents below that required to support most fungal and insect growth (approximately 25 percent). Moisture control was the only method used for protecting many covered bridges constructed of untreated timber, some of which have provided service lives of 100 years or more (Figure 14-1). Although modern timber bridges are protected with preservative treatments, decay can still occur in areas where the preservative layer is shallow or broken. This damage is the major cause of deterioration in timber bridges.

Moisture control involves a common sense approach of identifying areas with visible wetting or high moisture contents, locating the source of water, and taking corrective action to eliminate the source. For example, drainage patterns on approach roadways can be rerouted to channel water away from the bridge rather than onto the deck. Cleaning dirt and debris from the deck surface, drains, and other horizontal components also reduces moisture trapping and improves air circulation (Figure 14-2). One of the most effective approaches to moisture control is restricting or preventing water passage through the deck. Decks that are impervious to moisture penetration will protect critical structural members and

Figure 14-1. - Many covered bridges constructed of untreated timber, such as this one in New Hampshire, have lasted more than 100 years because they were protected from moisture.

substantially reduce the potential for decay. Glulam or stress-laminated decks afford the best protection because they can be placed to form a watertight surface. Leaks between glulam panels or at butt joints in stress-laminated decks can be resealed using bituminous roofing cement.

The deck wearing surface also plays an important role in moisture protection. Wearing surfaces constructed of lumber planks or steel plates provide little protection and often trap moisture under the planks or plates. Lumber running planks are a particular problem because they inhibit drainage on watertight decks and often cause water ponding on the deck surface. When ponding occurs, the only practical option for its removal is to install tubes through the deck to drain water down and away from the deck, rather than onto the deck underside and supporting members (Figure 14-3).

On glulam, stress-laminated, and some nail-laminated decks, the addition of an asphalt wearing surface provides a moisture barrier that protects not only supporting members but also the deck. The effectiveness of the surface protection is increased when the asphalt is placed on geotextile

Figure 14-2. - Dirt and debris on the deck surface can trap moisture and lead to premature deterioration. Material such as this should be removed periodically as part of a good preventative maintenance program.

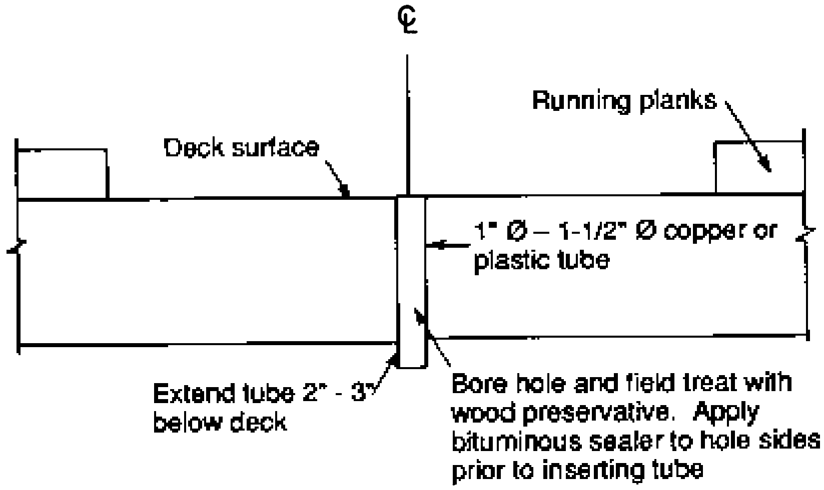


Figure 14-3. - Detail of drain tube for removing trapped water between lumber running planks.

fabric (Chapter 11). All glulam and stress-laminated decks are normally suitable for asphalt surfaces; however, use of asphalt surfaces on nail-laminated decks may be limited by the condition of the deck. Nail-laminated decks commonly show varying degrees of looseness after 5 to 10 years of service under heavy loading. Paving these decks is futile because the separation and movement of laminations will cause the pavement to crack and disintegrate. The best approach to waterproofing a loose nail-laminated deck is to apply stressing to restore deck integrity (discussed later in this chapter), followed by application of an asphalt wearing surface. When this is not practical, deck replacement is usually the only other option.

On bridges with asphalt surfaces, breaks in the surface may develop in service from deck deflections, improper bonding, or poor construction practices. Deficiencies of this type should be repaired as soon as possible to prevent more serious deterioration. Cracking may result from a number of causes but is typically caused by differential deck deflections at panel joints or at bridge ends. Cracks of this type should be thoroughly cleaned with a stiff brush and compressed air, then filled with emulsion slurry or liquid asphalt mixed with sand (Figure 14-4). If pavement is broken or missing, surrounding pavement must be removed to the point where it is sound and tightly bonded to the deck, and a patch must be applied. For best results, the repair area should be cut in a square or rectangular shape with vertical sides, be thoroughly cleaned, and be patched with a dense grade of asphalt pavement.

14.3 IN-PLACE PRESERVATIVE TREATMENT

In-place treating involves the application of preservative chemicals to prevent or arrest decay in existing structures. Two types of treatment are commonly used: surface treatments and fumigants. Surface treatments are applied to prevent infection of exposed wood, whereas fumigants are used to treat internal decay. In-place treating can provide a safe, effective, and economical method for extending the service life of timber bridges. Most of the techniques and treatments were developed for use on railroads or utility poles, for which they have been used effectively for many years. A large number of timber bridges have been treated in-place, extending service life by as much as 20 years or more (see case histories in Chapter 15).

SURFACE TREATMENTS

Surface treatments are applied to existing bridge members to protect newly exposed, untreated wood from decay or to supplement the initial treatment some years after installation. This type of treatment is most effective when applied before decay begins and is commonly used for treating checks, splits, delaminations, mechanical damage, or areas that were field-fabricated during construction. The ease of application and effectiveness of surface treatments as toxic barriers make them useful in preventive maintenance; however, the shallow penetration limits their effectiveness against established internal decay.

Surface treating uses the same basic procedures discussed for field treatment (Chapter 12). Conventional liquid wood preservatives are applied by

Figure 14-4. - (A) Minor cracking in an asphalt wearing surface from differential deck deflections. (B) Sealing the cracks with an asphalt emulsion slurry.

brushing, squirting, or spray-flooding the wood surface (Figure 14-5). Creosote heated to 150 to 200 $^{\circ}$F is probably the most commonly used preservative, but penta and copper naphthenate are also used. The wood surface should be thoroughly saturated with preservative so that all cracks and crevices are treated; however, care must be exercised to prevent excessive amounts from spilling or running off the surface and contaminating water or soil.

Figure 14-5. - Liquid wood preservative is applied to a check in a timber curb by brushing.

In addition to preservative liquids, some preservative compounds are available in semisolid greases or pastes. These preservatives, which generally use sodium fluoride, creosote, or pentachlorophenol as the primary preservative chemical, are useful for treating vertical surfaces or openings. Their primary advantage is that larger quantities of the toxic chemical can be locally applied in heavy coatings that adhere to the wood. Preservative adsorption over an extended period of time can produce deeper penetration than single surface applications of liquid treatments. Semisolid preservatives are commonly used at the groundline of posts, poles, and piling, where they are brushed on the surface from several inches above the groundline to 18 to 24 inches below the groundline (Figure 14-6). After the preservative is applied, the treated portion is wrapped with polyethylene, or other impervious material, to exclude moisture and prevent leaching of the treatment into the surrounding soil.

The effectiveness of surface treatments depends on the thoroughness of application, wood species, size, and moisture content at the time of treatment. Wet wood absorbs less preservative than does dry wood. This factor is significant in timber bridges because many areas requiring treatment are subject to wetting. Tests indicate that improved treatment of wet wood was obtained by using preservatives at double the normal 3- to 5-percent concentration.[17] Although field tests show that surface treatments in aboveground locations can prevent decay infections for up to 20 years or more,[35] it is recommended that treatments used for bridge applications be systematically reapplied at intervals of 3 to 5 years to ensure adequate protection from decay.

Figure 14-6. - Paste wood preservative is applied to a timber pile around the groundline. Note the wrapping material at the upper end of the treated section (photo courtesy of Osmose Wood Preserving, Inc.).

FUMIGANTS

Fumigants are specialized preservative chemicals in liquid or solid form that are placed in prebored holes to arrest internal decay. Over a period of time, the fumigants volatilize into toxic gases that move through the wood, eliminating decay fungi and insects. Fumigants can diffuse in the direction of the wood grain for 8 feet or more from the point of application in vertical members, such as poles. In horizontal members, the distance of movement is approximately 2 to 4 feet from the point of application. The three chemicals most commonly used as liquid fumigants are Vapam (33-percent sodium N-methyldithiocarbamate), Vorlex (20-percent methylisothiocyanate, 80-percent chlorinated C_3 hydrocarbons), and chloropicrin (trichloro-nitromethane). Solid fumigants are available in capsules of methylisothiocyanate (MIT), which is the active ingredient of Vapam and Vorlex. Solid fumigants provide increased safety, reduce the risk of environmental contamination, and permit fumigant use in previously restricted applications.

To be most effective, fumigants must be applied to sound wood. When applied in very porous wood or close to surfaces, some of the fumigant is lost by diffusion to the atmosphere. Before applying fumigants, the condition of the member should be carefully assessed to identify the optimal boring pattern that avoids fasteners, seasoning checks, badly decayed wood, and other openings to the atmosphere. In vertical members such as piles, holes should be bored at a steep downward angle toward the center of the member to avoid crossing seasoning checks (Figure 14-7). It is best to begin by boring almost perpendicular to the member, then quickly raising the drill to a 45 to 60-degree angle once the bit catches in the wood. For horizontal members, holes are bored in pairs straight down to within 1-1/2 to 2 inches from the bottom side. If large seasoning checks are present in horizontal members, holes should be bored on each side of the check to more completely protect the timber (Figure 14-8). The amount of chemical and the size and number of treatment holes depends on the member size and orientation. Table 14-1 gives some examples of the number and size of holes and fumigant dosages required to treat vertical piling. For horizontal members, pairs of holes should not be more than 4 feet apart Additional information and recommended dosages for fumigants may be obtained from the chemical manufacturers.

When solid fumigants are used, they are inserted directly into the prebored holes. Liquid fumigants are applied using commercial equipment but can also be applied from 1-pint polyethylene squeeze bottles (Figure 14-9).[27] When using polyethylene, it is helpful to replace the plastic cap with a reusable cap fastened to a 1-foot length of plastic or rubber tubing. After adding the required dosage of fumigant, the original cap is replaced so the remaining liquid stays in the bottle, and the fumigant is returned to its original container (liquid fumigants should not be stored in plastic bottles for long periods because they can cause the plastic to become brittle and crack). If leaks are observed while applying liquid fumigants, it is

Figure 14-7. - Treating holes for fumigants in vertical members are bored at a steep downward angle (photo courtesy of Jeff Morrell, Oregon State University).

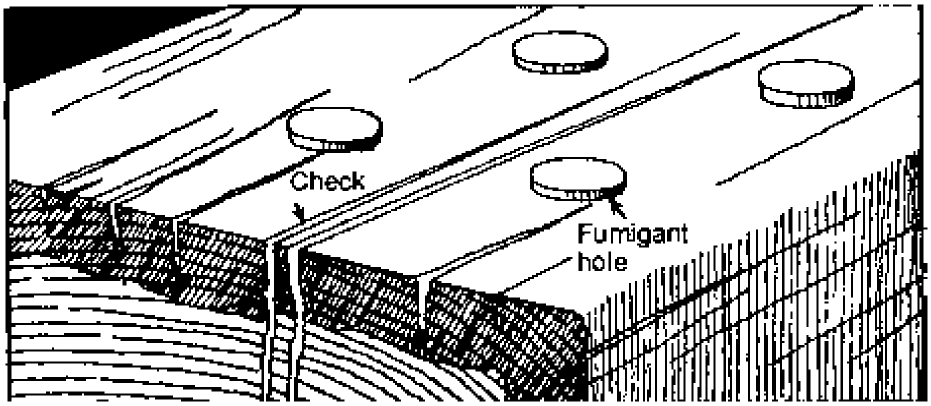


Figure 14-8. - Treating holes for fumigants in horizontal members should be placed on both sides of checks or splits, and be bored to within 1-1/2 to 2 inches of the bottom of the member.

Figure 14-9. - Application of liquid fumigants. (A) Liquid fumigants applied with commercial equipment (photo courtesy of Osmose Wood Preserving, Inc.).

Table 14-1. - Number and size of holes and dosage of fumigant required for piles.

Hole dimensions (in.)		Fumigant dosage (pints per in. of hole)	Numbers of holes for piles of various circumferences (and dosages)		
Diameter	Length[a]		< 32 in. (3/4 pint)	32 – 45 in. (1 pint)	> 45 in. (2 pints)
5/8	15	0.010	6	—	—
	18	0.010	5	—	—
3/4	15	0.015	4	6	—
	18	0.015	—	5	—
	21	0.015	—	4	—
	24	0.015	—	3	6
7/8	21	0.024	—	3	5
	24	0.024	—	—	4

[a] Effective length of treating hole is 3 inches less to allow for a 3-inch treated plug. From Morrell and others.[27]

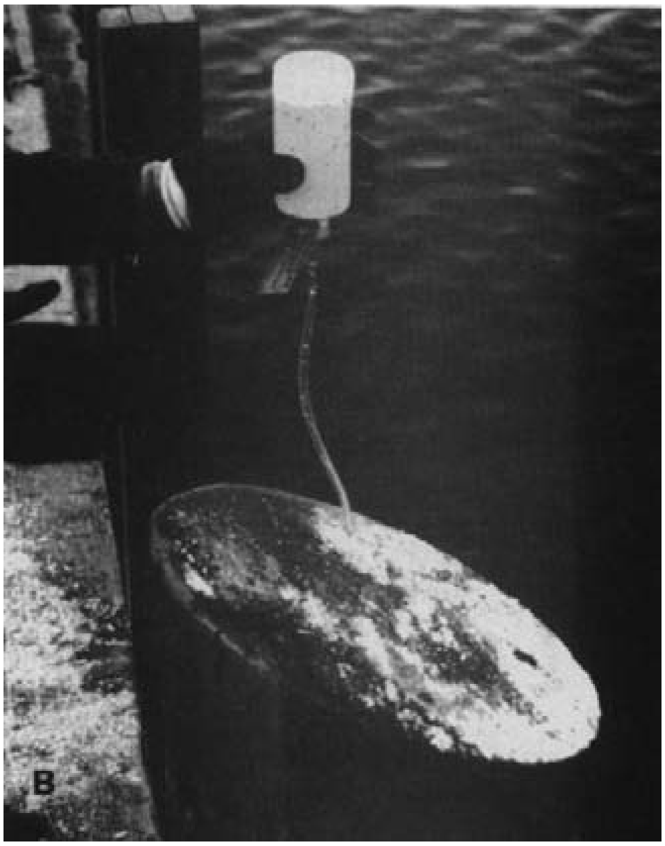


Figure 14-9. - Application of liquid fumigants (continued). (B) Liquid fumigants applied from a polyethylene squeeze bottle (photo courtesy of Jeff Morrell, Oregon State University).

important to stop filling, to plug the hole, and to bore another hole into sound wood. Immediately after placing the chemicals, the hole is plugged with a tight-fitting, treated-wood dowel driven slowly to avoid splitting the wood. For liquid fumigants, sufficient room (1.5 to 2 inches) must be left in the treating hole so the plug can be driven without squirting the chemical.

Fumigants will eventually diffuse out of the wood, allowing decay fungi to recolonize. In properly treated solid wood, Vorlex and chloropicrin will remain effective for 10 to 15 years, while Vapam is somewhat less effective (Figure 14-10). These periods will be reduced when the wood has many fastener holes, splits, checks, or end grain where the chemical can diffuse to the atmosphere. Retreatment can be made at periodic intervals in the same holes used for the initial treatment. The old plug is drilled or pulled, new fumigant is added, and the hole is replugged with a new, treated dowel. Until retreatment cycles are better defined, it is recommended that a 10-year treatment cycle be used with a regular inspection program at 5-year intervals. When inspections indicate the presence of active decay, the protective effects of the fumigant have declined below a toxic threshold, and retreatment is required. It is important to keep accurate records of all in-place treating, including the date and location of the application, the type of chemical, and the dose (such records are required in some States). It may also be beneficial to place a metal tag on the

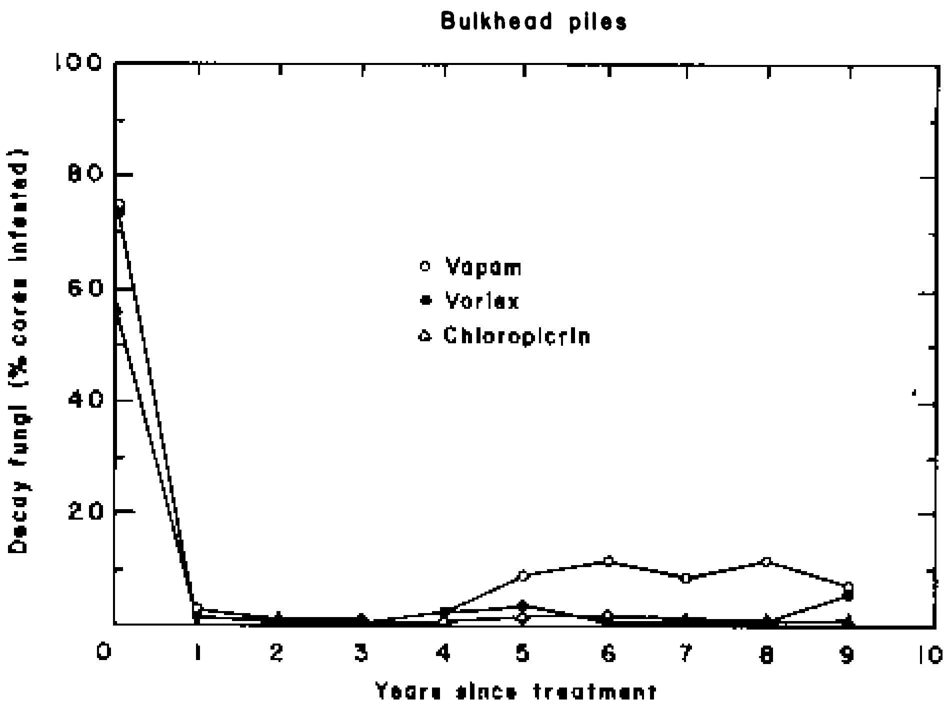


Figure 14-10. - Annual changes in the population of decay fungi isolated from creosoted Douglas-fir piles treated with various fumigants. Each value on the curve represents 60 cores from each of 12 piles. From Morrell and others. [27]

member noting treatment information; however, these tags may be stolen or vandalized and should not be the sole means of recording treatment information.

PRECAUTIONS FOR IN-PLACE TREATING

As with other preservatives and pesticides, wood preservatives and fumigants for in-place treating are toxic to humans and must be used in accordance with State and Federal laws. When properly applied, the treatments pose no environmental or health hazard; however, the potential for environmental damage can be higher in some field locations because of variable conditions and the proximity to streams and other water sources. In-place treatments must be applied only by trained and licensed personnel who fully understand their use and the required safeguards. In addition to the precautions for wood preservatives discussed in Chapter 12, fumigant applicators should also have a gas mask with the appropriate filter available for emergency use. If fumigant vapors are detected by their strong odor or eye irritation, all personnel should move upwind from the treating area and allow vapors to clear. When any form of in-place treatment is used, the procedures, precautions, and contingency for accidental spillage or injury should be well planned before beginning treatment.

In general, in-place treating by local maintenance crews is limited by the scope of the treatment required. For routine maintenance, the amount of treating required is normally minor, and local crews can be used when properly trained and licensed personnel are available. For larger projects involving many members or an entire structure, it is advisable to contract the project to specialists in the field. There are companies that have provided in-place treating services for many years with excellent safety records and results. When selecting a contractor, previous experience and performance histories should be carefully evaluated to ensure that the contractor is qualified to perform the required treating.

14.4 MECHANICAL REPAIR

Mechanical methods of repair use steel fasteners and additional wood or steel components to strengthen or reinforce members. The three methods of mechanical repair discussed in this section are member augmentation, clamping and stitching, and stress laminating.

MEMBER AUGMENTATION

Member augmentation involves the addition of material to reinforce or strengthen existing members. The additional pieces, commonly wood or steel plates attached with bolts, serve to increase the effective section and thus load capacity. The two most widely used methods of member augmentation are splicing and scabbing. Although the distinction between the two is rather vague, splicing generally applies to a defined location where load transfer is restored at a break, split, or other defect (Figure 14-11 A). Scabbing is more frequently associated with strengthening members where existing capacity is insufficient and may involve adding reinforcing pieces over a substantial portion or even over the entire member length (Figure 14-11 B). In both cases, a thorough structural analysis is required to ensure the capacity of the repair and to verify stress distribution in the members. Situations that introduce eccentric loads or tension perpendicular to grain must be avoided. When using splices, it is recommended that the defective member be cut entirely through to more equally distribute loads to splice plates.[3]

In addition to wood or steel augmentation methods, reinforced concrete can be used to strengthen deteriorated timber piling sections (Figure 14-12). Using this procedure, the pile is wrapped with a jacket-type form of fiber-reinforced plastic or fabric that fits the pile like a sleeve. Reinforcing steel is placed around the pile, and the sleeve is filled with concrete. The reinforced concrete increases pile strength and prevents further deterioration, but the pile size is increased and specialized equipment is required for construction.[15,16,20]

CLAMPING AND STITCHING

A typical problem associated with timber members is the development of longitudinal splits. These splits commonly develop in sawn lumber as the member seasons and checks in place. To a lesser degree, splits may also develop in glulam if delamination occurs at the glue lines, although this problem has become very rare with the introduction of waterproof adhesives. In both sawn and glulam members, splits can also develop from overloads or poor design details that introduce tension perpendicular to grain at connections. When splitting is detected it must be determined whether the splits are the result of normal seasoning or the result of a more serious structural problem. Several references are available that provide a good overview of the potential structural effects of splitting in timber members.[3,25]

Clamping and stitching are maintenance operations that use fasteners and steel assemblies to arrest cracks, splits, or delaminations in timber members. These methods are most commonly used for buildings, but also apply to some bridge components, particularly trusses or other structures with a high number of small members or fastened connections. The objective is not to close the split or check, but rather to prevent its further development by drawing the two parts together. Clamping uses bolts with steel-plate assemblies, while stitching uses bolts or lag screws through the member (Figure 14-13). Although both methods have been used effectively, clamping with bolts and steel plates is generally preferable because the section of the member is not reduced. Aside from fastener design requirements discussed in Chapter 5, there are no specific design criteria for clamping and stitching, and the configuration, number, and size of fasteners must be

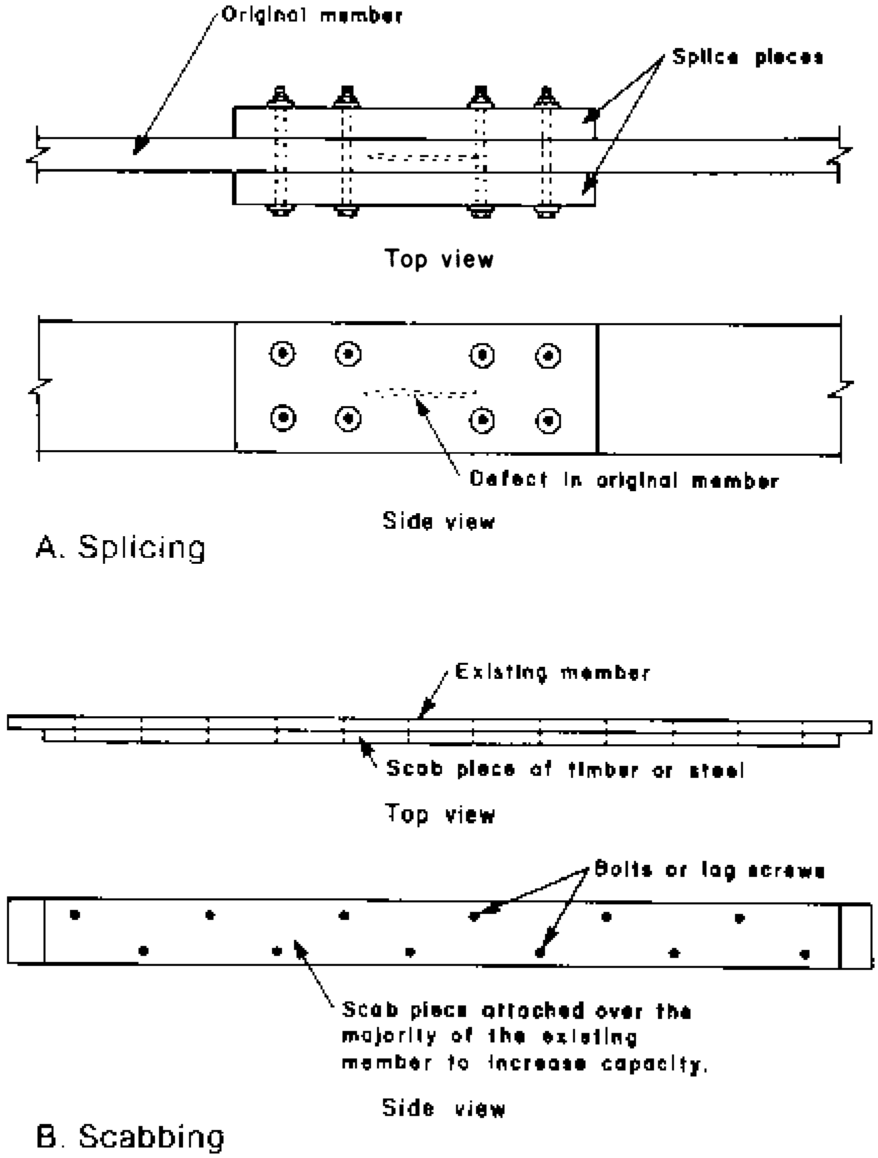


Figure 14-11. - Splicing and scabbing methods of member augmentation.

based on designer judgment on a case by case basis. The following guidelines for stitching are recommended by Ketchum, May, and Hanrahan:[25]

> When used at the end of a piece, stitch bolts should be placed between 2 inches and 3 inches from the end. Small 3/8 or 1/2 inch diameter bolts are suggested. Ordinarily, when bored at a critical stress section of a member, the area of the cross-section removed by the hole for the stitch bolt should not exceed the cross-sectional area occupied by the maximum knot permitted in the structural grade. In drawing up the stitch bolts they should be tightened only to the point where the bolts begin to take tension. No attempt should be made to close a split or check as this may extend the split on the other side of the joint. In servicing structures, stitch bolts should be tightened as well as other bolts.

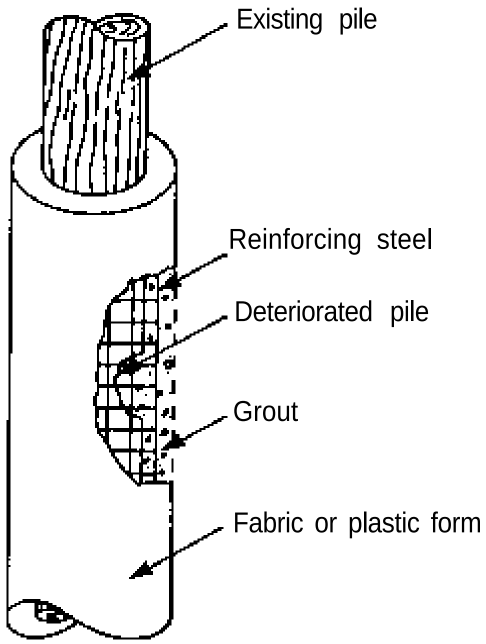


Figure 14-12. - Reinforced concrete jacket for pile augmentation.

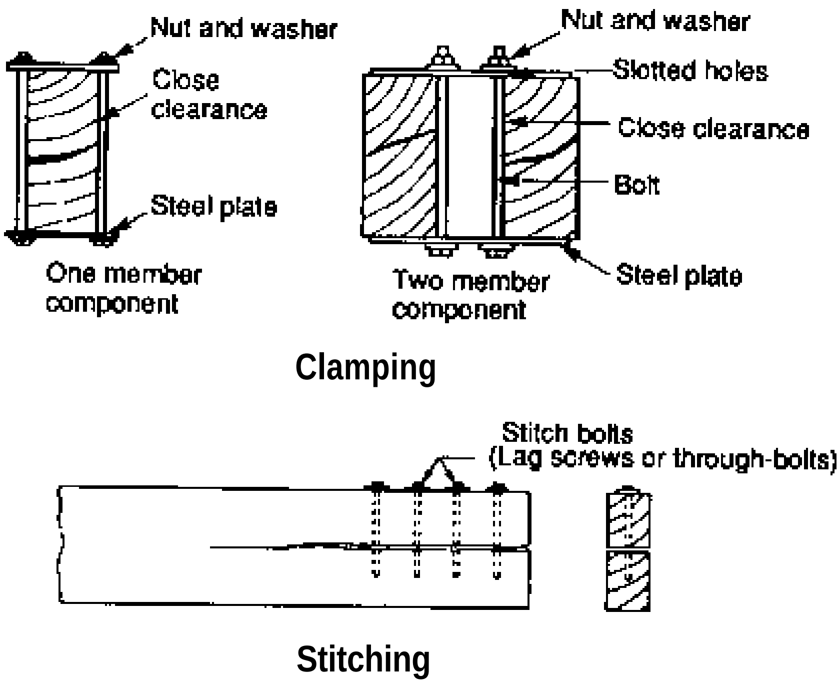


Figure 14-13. - Typical configurations for clamping and stitching timber members.

STRESS LAMINATING

Stress laminating is probably the most effective method for the mechanical repair of existing nail-laminated decks. Such decks frequently separate and delaminate from repeated loading, causing breakup of asphalt wearing surfaces, water penetration through the deck, and a loss in live load distribution width. In these cases, the static strength and condition of the deck is generally maintained, but its serviceability and ability to distribute loads between individual laminations is greatly reduced. In this situation, the laminations no longer act together to distribute loads, and local failures occur. This condition also increases the rate of deterioration, eventually leading to failures that require complete deck replacement.

The system for stress laminating existing nail-laminated decks was originally developed in 1976 by the Ministry of Transportation and Communications in Ontario, Canada. Since that time, it has been successfully used on a number of bridges to restore the integrity of the existing decks.[3,18,36] Using this approach, which uses the same design criteria discussed in Chapter 9, the laminations are stressed with a series of high-strength steel rods applied transverse to the length of the laminations. The stress squeezes the laminations together and greatly increases the load distribution characteristics of the deck. Additionally, the stress seals the deck as the laminations are pressed together, providing a watertight surface.

Stress laminating for existing decks differs in configuration from new construction in that stressing rods are positioned on the outside of the laminations, rather than in holes through the laminations (Figure 14-14). This allows the stressing operation to take place without removing the deck and without costly fabrication operations, while traffic is still using the bridge. It is usually necessary to add laminations to the deck before stressing because the rod force squeezes laminations together, reducing the deck width 10 inches or more, depending on the original width. Stress laminating provides a good long-term solution for repairing existing nail-laminated decks to increase load capacity and substantially extend the service life of the structure. More specific information on stress laminating existing nail-laminated decks is presented in a case history in Chapter 15.

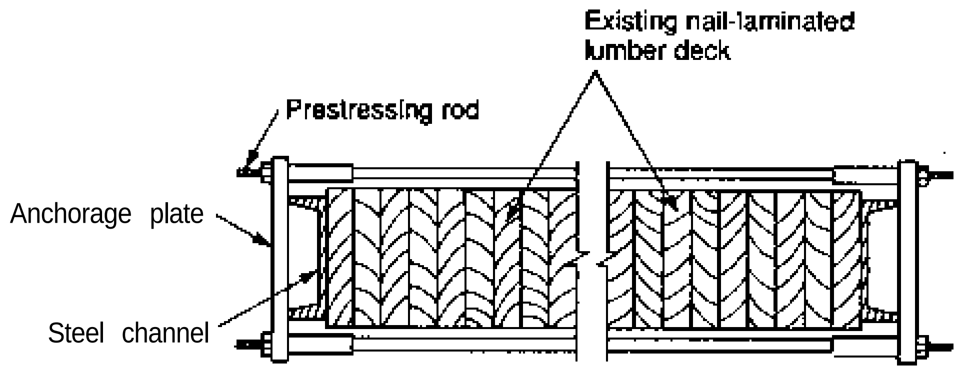


Figure 14-14. - Typical rod and anchorage configuration for stressing existing nail-laminated lumber decks.

14.5 EPOXY REPAIR

Epoxies consist of basic resins and resin-hardening agents that are blended together in a liquid or gel (putty) form. When mixed, the epoxy compounds harden to form a solid, durable material that provides a high degree of adhesion to most clean surfaces. Epoxies were originally developed by the paint and aircraft industries in the 1950's and have been used extensively to repair cracks in concrete since the 1960's. The first reported study on epoxy use for timber repair was presented by Avent[8] in 1976. Since that time there has been a considerable research effort to develop design criteria and to evaluate the effectiveness of epoxy repairs in timber members. Although there are currently no codes or specifications with design criteria or allowable stresses, epoxy repair techniques have been successfully used on timber bridges (some since the early 1960's). The information presented in this section is based on referenced research publications and successful field applications.

TYPES OF EPOXY REPAIRS

Epoxy is used for timber repair as a bonding agent (adhesive) and/or grout (filler) in both structural and semistructural repairs. It is commonly injected under pressure but is also manually applied as a gel or putty. Epoxy is most effective when used as a bonding agent to provide shear resistance between members for structural repairs in dry locations. For semistructural repairs, it is used to fill voids or repair bearing surfaces. Avent[6] describes six basic types of epoxy repairs for structural (Type A) and semistructural (Type B) repairs, as follows:

Type A- 1. Epoxy injection of cracked and split members at truss joints.

Type A-2. Epoxy injection and reinforcement of decayed wood.

Type A-3. Splicing and epoxy injection of broken members.

Type A-4. Epoxy injection of delaminated beams.

Type B-1. Epoxy injection of longitudinal cracks and splits in truss members away from joints.

Type B-2. Repair of bearing surfaces using epoxy gel.

For bridge applications, epoxy repairs can be categorized as grouting, splicing, and pile rehabilitation.

Grouting

As a grouting material, epoxy is used for filling checks, splits, delaminations, insect damage, and decay voids. The epoxy seals the affected area, preventing water and other debris from entering. It can also restore the bond between separated sections, increase shear capacity, and reduce further splitting. In building applications, epoxy has been successfully used in structural repairs to fill splits in truss connections.[2,3,8,9] It has also been used in conjunction with reinforcing rods to replace severely decayed portions of existing members.[3] In bridge applications, its use as a grout has been limited primarily to semistructural or cosmetic repairs involving surface damage or internal insect damage. For surface repairs, voids or other defects are filled with epoxy gel (Figure 14-15). For internal repairs involving splits or insect damage, liquid epoxy must be injected to the inside of the member to fill the void.

Figure 14-15. - Epoxy gel surface repair of a timber pile (photo courtesy of Osmose Wood Preserving, Inc.).

Splicing

Splicing repairs involve the addition of splice pieces that are lapped over the split or deteriorated members and are epoxied in place. In this type of repair, epoxy is used as an adhesive to bond the splices in place. While other types of adhesives are available for wood, epoxies are preferable for field repairs because of their high strength and rapid cure rate. Epoxy splicing has been used mostly in buildings and is not a common type of repair in bridge applications at this time. However, one method of splicing that has been used to a limited degree involves the reconstruction of glulam. In this method, damaged or decayed laminations are cut from the glulam member and replaced with new laminations that are epoxied in place. The laminations in the replacement section are lapped over existing laminations a sufficient distance to develop the required shear strength at the epoxied joint. There is evidence that variations in the moisture content of timber members can in time cause a significant reduction in the bonding strength of epoxy. Therefore, splicing repairs in members exposed to weathering or significant fluctuations in moisture content are not recommended. Also, epoxy splicing should not be used on material treated with oil-type preservatives because of poor bonding between the wood and the epoxy.

Pile Rehabilitation

Pile rehabilitation employs epoxy (using grouting and splicing) for the repair of timber piles loaded primarily in axial compression. The two methods of pile rehabilitation most commonly used are pile posting and pile restoration. In pile posting, the damaged section of pile is completely removed and a new section of similar cross section is installed in its place (Figure 14-16). The new section is positioned with a 1/8- to 1/4-inch gap at the top and bottom and is wedged tightly against the existing pile cutoffs. Following placement of the new section, holes are bored at a steep downward angle above each joint, spaced approximately 90 degrees apart. Steel pins are then driven through the holes to mechanically join the two sections. The sides of the joints are next sealed with epoxy gel, plastic film, or tape, and epoxy is injected into the joints, filling the voids and

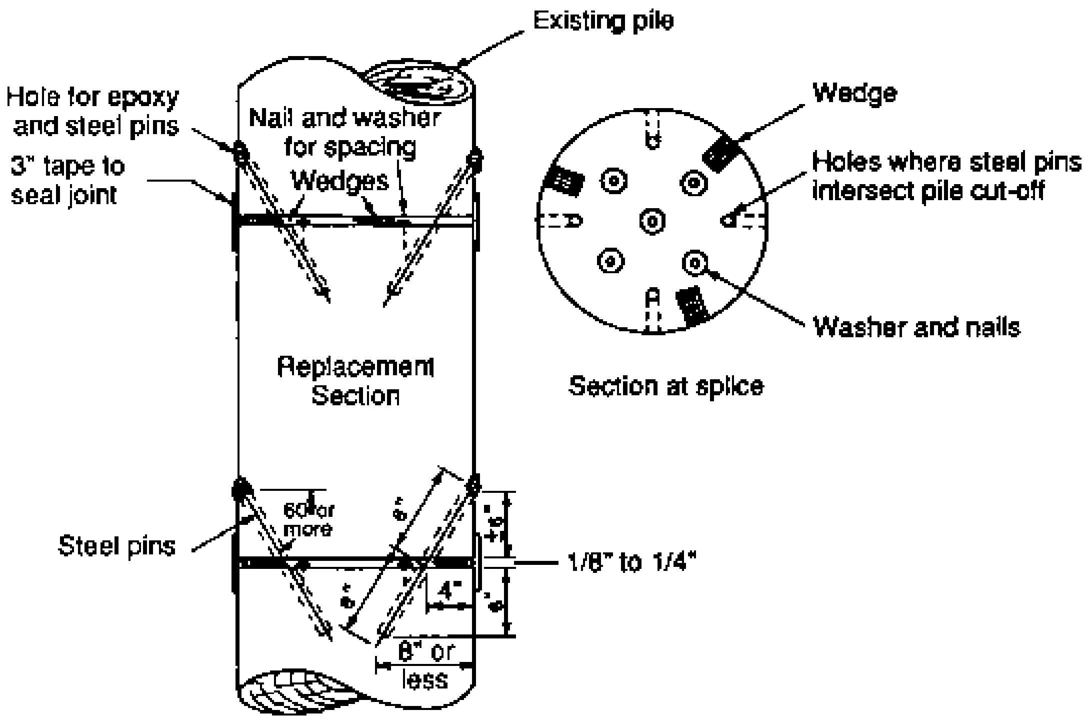


Figure 14-16. - Schematic diagram of pile posting.

bonding the old and new pile sections. This type of repair has proven to be an economical method of substructure repair that effectively restores the compressive strength of deteriorated members. Additional information on pile posting can be found in case histories presented in Chapter 15.

Pile restoration involves the removal and replacement of a vertical wedge-shaped section of piling rather than the entire cross section. This type of repair has been successfully used on piling where localized deterioration occurs in an otherwise sound section. Using this method, a wedge-shaped section is removed from the existing pile by cutting and chiseling (Figure 14-17). A matching replacement section is fabricated from new treated material. The replacement section is fitted to match the removed section, but is slightly smaller in size. After the replacement is fabricated, the contact surfaces of both old and new sections are covered with epoxy gel applied with a putty knife. The new section is placed in position, and metal bands are installed around the section to hold it in place while the epoxy cures. Pile restoration is more expensive than posting and is normally used only when posting is impractical because of limited access.

Figure 14-17. - Pile repair using pile restoration techniques. (A) The deteriorated pile area is removed as a wedge-shaped section. (photos courtesy of Osmose Wood Preserving, Inc.).

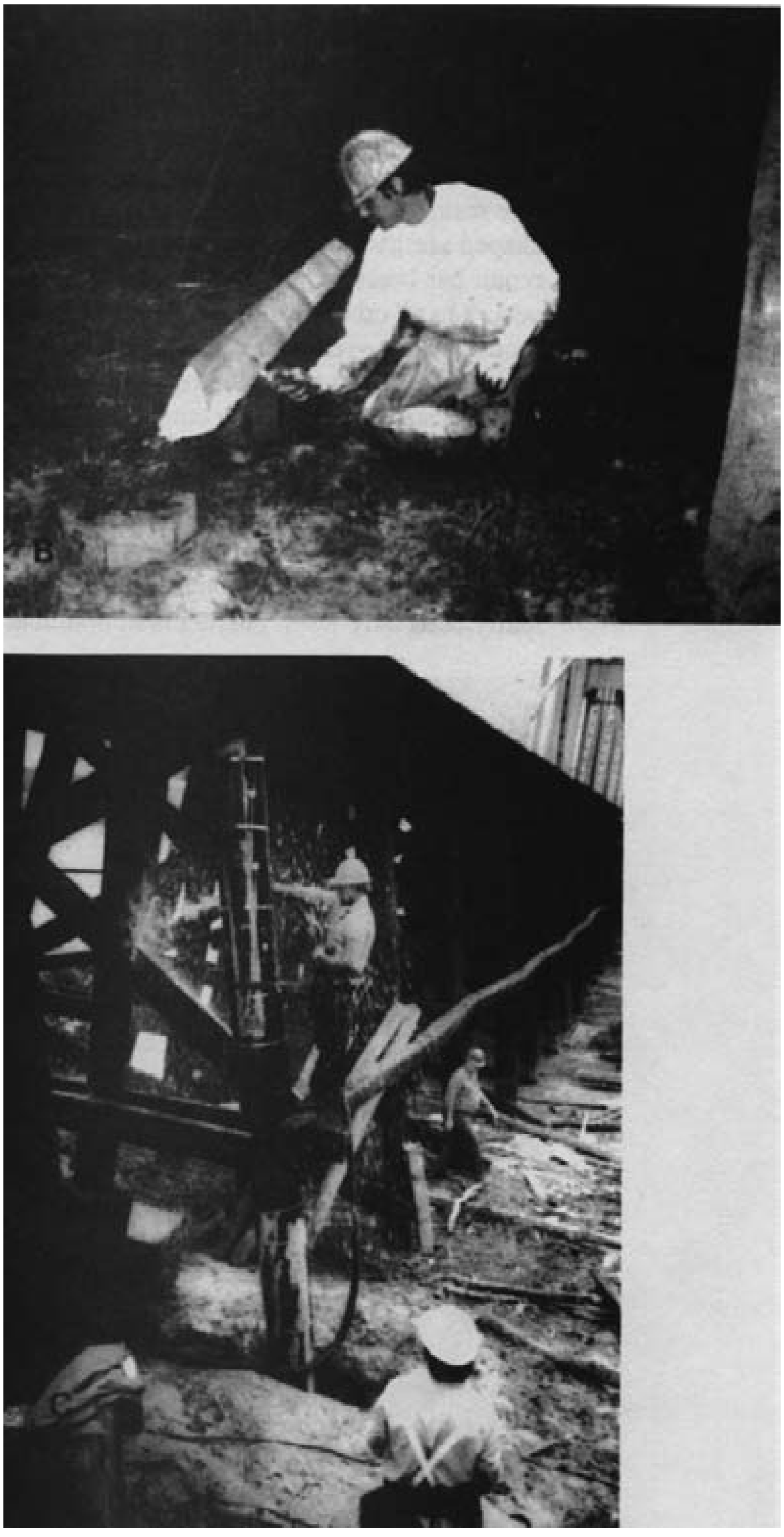


Figure 14-17. - Pile repair using pile restoration techniques (continued). (B) A replacement section is cut, and epoxy gel is applied to the contact surfaces. (C) The replacement section is placed and banded to the existing pile (photos courtesy of Osmose Wood Preserving, Inc.).

GENERAL PROCEDURES FOR EPOXY REPAIR

The procedures for the use of epoxy vary with the type and extent of repair. The basic procedures for epoxy injection can be summarized in four steps: member preparation, port setting and joint sealing, epoxy injection, and finishing.[6] For manual, nonpressure application, port setting and joint sealing are not required. As with all types of repairs, a structural evaluation and analysis of existing components must be made to determine load capacity before and after repair. The cause of the problem should also be identified and corrective measures taken to prevent its recurrence.

Member Preparation

The degree of member preparation required for epoxy repair varies with the type of repair and the wood condition. When the defect or weakness in the original member is the result of decay, actions must be taken to remove the damaged wood, arrest the infections, and prevent renewed damage. If areas to be repaired show early signs of decay, in-place treatment may be sufficient to arrest decay, provided sufficient strength remains in the member. When visible decay is present, the most thorough approach is to remove the infected section. For such cases, the following guidelines are given by Clark and Eslyn:[17]

> The undetectable extensions of the infecting fungi may reach 6 to 12 inches in the grain direction beyond the apparent limits of the decay. A safe rule in removing decayed parts of members is to include the visible decay plus an additional 2 feet of the adjacent wood in the grain direction.

In addition to removing or treating decay areas, the moisture source to the infected member should be identified and eliminated, if possible. When moist wood (greater that 20 percent moisture content) is found, the member should be dried before repairs are made. Although there are epoxies that will bond to moist wood, the presence of moisture levels greater than 20 percent may provide suitable conditions for continued fungal growth and continued deterioration.

As a final preparation step for all epoxy repairs, surfaces must be thoroughly cleaned of all dirt and debris so that a good bond can be achieved between the wood and the epoxy. Areas should be free of excess oil preservatives, which may affect the bond. Although there have been no studies on the bonding strength of epoxies to wood treated with oil-type preservatives, successful piling repairs (compressive loading) have been made on existing members treated with creosote that have been in place for a number of years. Splicing or shear-type repairs are not recommended on surfaces treated with oil-type preservatives because of the questionable bonding to the member surfaces.

Port Setting and Joint Sealing

When epoxy is applied by pressure injection, the repair area must be provided with injection ports and completely sealed before epoxy placement. The injection ports are holes bored into the joint area that permit epoxy injection into interior portions of the repair, vent displaced air as epoxy fills the void, and provide a visual means of observing epoxy distribution. These ports are generally 1/4 to 3/8 inch in diameter and are topped with a small copper or plastic tube that projects from the wood surface. The number and location of ports varies depending on the size and configuration of the repair area. The minimum number of ports is two, one for the injection and one as an escape for displaced air. For most types of repairs, additional ports are added to ensure epoxy penetration to all areas of the joint.

After injection ports are set, areas of the joint must be completely sealed (with the exception of injection port openings). Incomplete sealing allows epoxy to seep from the repair area, wasting material and creating voids in the epoxy that reduce its effectiveness. Methods of joint sealage vary depending on the configuration of the members being repaired. For most repairs, openings can be sealed with an epoxy gel, provided the gel viscosity is sufficiently low to span the distance of the opening. Another common method for sealing piling and other exposed, smooth locations is to staple plastic wraps or tape to the outside of the member (Figure 14-18). With porous wood, it may be beneficial to seal the outside surface with thick epoxy paint to fill hairline cracks and other small openings. These

Figure 14-18. - A joint for a posting-type epoxy repair is sealed with plastic wrap stapled to the members. Small wood strips are then nailed across the plastic to provide an additional seal (photo courtesy of Osmose Wood Preserving Inc.).

openings will allow epoxy to escape even though they may not be evident during visual inspection.

Epoxy Application

Epoxy is applied using manual nonpressure methods or pressure injection, depending on the type of repair. Nonpressure methods are usually limited to exposed surface applications. The two epoxy components are thoroughly mixed in a bowl or other container and are applied with a knife or brush. Surface repairs on angled or vertical surfaces may require a plastic wrap or special tape to keep the epoxy in position as it cures. For pressure injection, the epoxy is applied through one injection port at each joint. As the epoxy fills the voids in the joint, venting ports begin to leak an even flow of epoxy and are progressively sealed. Injection is accomplished using either a caulking gun and tubes of epoxy that are mixed manually before application (Figure 14-19) or an automatic injection gun that mixes the epoxy components in the nozzle. For both techniques, the injection pressure must be sufficient to completely fill the void without breaking joint seals. A maximum injection pressure of 40 lb/in^2 is recommended.[6]

Finishing

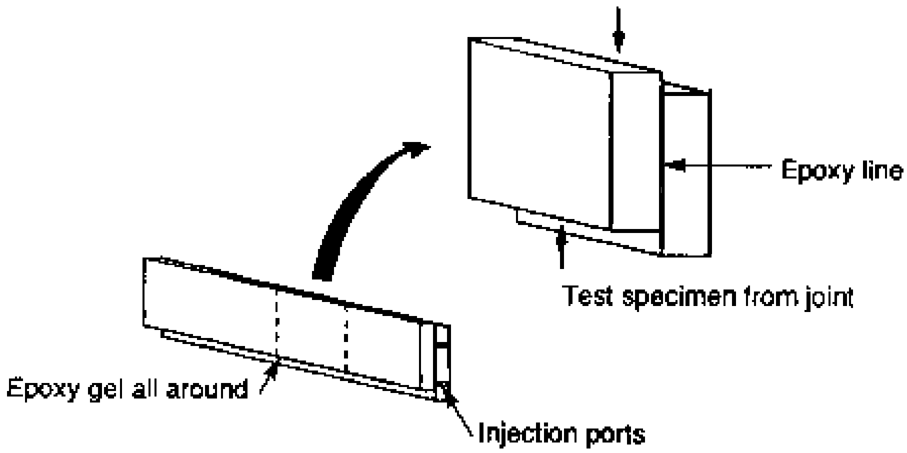
The time required for epoxy to cure to its full strength varies among brands of epoxy and the curing temperature. Most epoxies set in a few hours, but complete curing can take several days. After final curing, the epoxy surface can be finished to meet aesthetic requirements of the site, including removal of projecting injection ports, sanding, and painting of the epoxy surface.

Figure 14-19. - Epoxy is manually injected between a timber pile and cap using a caulking gun (photo courtesy of Osmose Wood Preserving, Inc.).

QUALITY CONTROL FOR EPOXY REPAIRS

A key factor in epoxy effectiveness is the level of quality control provided during the repair process. Although little has been published on this subject, the following guidelines on quality control are given by Avent:[4]

> In many cases laboratory testing is not possible for wood repair in contrast to concrete repair where test cylinders can be taken. For example, lack of quality control can result in serious problems for epoxy repaired members. Many epoxies are very sensitive to mix proportions. The standard injection equipment consists of two positive-displacement pumps driven by a single motor geared to obtain the proper mix. The two epoxy components are mixed at the nozzle; thus a fairly continuous flow prevents hardening of the epoxy in the nozzle. However, crimped lines, malfunctioning pumps, or line blockages can sometimes occur. In severe cases the epoxy will not harden at all, but in other cases the problem may result in soft spots within the joints. Frequent collecting of small samples in containers will verify if the epoxy is hardening as expected, and this is routinely done by contractors on an hourly basis. The detection of weak but hardened material is much more difficult. One method is to inject shear block specimens at the beginning of operations and after the repair of every fifth member. A shear specimen [see Figure 14-20] is cut into four shear blocks after curing and each is tested in single shear. The failure stress level should be approximately equal to the ultimate shear strength of the *wood.* This level of shear strength indicates a high-quality bond.



Joint for quality control tests

Figure 14-20. - Typical shear block specimen for evaluating the strength of an epoxied joint.

Another quality control problem is that of determining epoxy penetration into voids. Special sampling techniques are currently in the development process, but none have proven completely satisfactory as yet. This problem is often heightened because there are two types of repair: structural and non-structural. Non-structural repairs are associated with sealing in applications such as waterproofing, crack sealing to prevent contamination, and cosmetic repairs. Many contractors are familiar only with this type. The approach to non-structural repairs is to inject from port to port without undue concern for complete penetration. Often air voids become trapped by such an approach. The key to successful structural repair is to fill all voids. To ensure complete penetration, it is best to inject from only one port while letting others serve as vents. The successive bleeding and capping of these ports gives a high degree of confidence in the amount of penetration. An average repair often involves at least 12 ports and many have considerably more. However, without close supervision of the injection operation, a contractor may revert to his usual approach for non-structural repairs, especially since the different goals of these types of repair are usually not appreciated. Close supervision thus becomes the primary method of quality control.

14.6 COMPONENT REPLACEMENT

There are situations where a lack of maintenance or other causes leads to deterioration so severe that replacement of the member is the only economically viable alternative. In these cases, the structure must be temporarily supported (when required), the old member removed, and a new one installed in its place. Before replacing members, the cause of deterioration in the original member must be determined and corrected. If the problem is structural, an increased capacity for the replacement may be warranted. If decay is the source of deterioration, corrective measures should be taken to exclude moisture from newly installed members. Whenever a member is replaced, it is advisable to thoroughly inspect all adjacent and contacting components for decay that may not have been apparent when the member was in place. Confirmed or suspected areas of decay should be treated in place before the new member is installed. Remember that failure of the original member resulted from a specific cause that could also cause premature failure or high maintenance costs for the replacement.

On some structures it may be impractical to replace a member because of difficulties with removing the old member or positioning a new member in its place. An alternative solution is to add a sister member that is structurally capable of resisting the loads previously applied to the original member. The use of sister members is most applicable when damage occurs from overloads or other mechanical damage (Figure 14-21). When existing members are decayed, appropriate steps must be taken to eradicate the infection and prevent its spread to the new component. The decayed portions of the member should be removed and the remaining portions treated in place. Again, the source of moisture that provided the suitable decay conditions must also be eliminated.

Figure 14-21. - A sister member in a glulam beam superstructure. The outside beam, which was damaged by a vehicle overload, could not be easily replaced. The sister member was added along the outside of the beam to restore the capacity to the structure.

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Integrated Remedial Protection of Wood in Bridges

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Abstract

While timber bridges can perform well under a variety of conditions, many bridges experience premature internal decay due to poor specification, inadequate preservative treatment or poor construction practices. Arresting deterioration in these bridges poses a major challenge since the wood under attack is normally deep beneath the surface treatments and is highly resistant to impregnation by most conventional liquids. In this report, we discuss the use of fumigants and water diffusible fungicides for arresting these attack and preventing renewed invasion. The benefits of the two chemistries are discussed in relation to the potential for attacks and speed of control required.

Keywords: fumigants, timber bridges, remedial preservation treatment

Introduction

Properly performed preservative treatment of wood produces an excellent barrier against attack by most agents of biological deterioration, however, this barrier is often disrupted during fabrication or as the wood seasons and checks. Nowhere is this problem more acute than in timber bridges. These structures are subjected to extensive design considerations, but often require extensive field fabrication during installation which exposes untreated wood to potential biological attack. In addition, many fasteners are driven through the treated zone into the untreated wood, again exposing the zone beyond the treated shell to entry by moisture and fungal spores. Finally, the larger timbers employed in bridges are generally not completely seasoned to their in-service moisture contents prior to treatment. These timbers can check extensively as they season in service, again exposing untreated wood to fungal and insect attack. The rate of decay in large timbers exposed above ground varies with species and the climate to which the bridge is exposed, but the ultimate result is the development of internal decay which reduces bridge service life (Scheffer, 1971).

These problems have led to a general perception that timber bridges have shorter service lives and require more maintenance than comparable bridges constructed with other materials (Smith et al., 1995; Smith and Bush, 1995).

A variety of methods have been developed to improve the depth of initial treatment to reduce the potential for internal decay (Graham, 1983). These practices include incising, through boring, radial drilling and kerfing, but not all of these activities are compatible with timber used in bridges. In addition, studies have shown that even wood treated using these methods experiences low levels of internal deterioration. As a result, there is a substantial need for field treatments which can be applied to timber in bridges to arrest deterioration and prevent renewed attack (ASHTO, 1983; Ritter, 1990).

Deterioration in large wood members has long posed a major challenge to those charged with prolonging the useful life of a bridge (Ritter and Morrell, 1990). Most oil-based treatments lack the ability to migrate through wood for substantial distances. As a result, they cannot reach the points where decay fungi are actively growing. For many years, the treatment options for deteriorating timbers were limited, but the development of fumigants for wood application in the late 1960's provided a new, highly effective retreatment option (Graham, 1973, 1979). Fumigants are capable of moving as gases through the heartwood of nearly all wood species (Ruddick, 1984; Morrell et al., 1992a).

First developed for use on utility poles, fumigants are applied as liquids to steep angled holes drilled into poles and volatilize to move as gases through the wood. Three chemicals were initially explored for this purpose. Chloropicrin (trichloronitromethane) is a tear gas which has strong lachrymatory properties, Vorlex (20% methylisothiocyanate in chlorinated C_3 hydrocarbons) is a potent nematocide, and metham sodium (32.7 % sodium n-methyl-dithiocarbamate) has a long history of use for treating agricultural fields. Field trials with these chemicals showed that fungi were virtually eliminated from wood poles within one year after treatment (Figure 1). While these results were similar to experiences in soil application, it was the surprising ability of these chemicals to remain in wood for long periods after treatment that made them especially attractive for remedial protection. Fumigants are typically not detectable within 14 days after soil fumigation, yet these same chemicals were detectable in wood at levels which remained inhibitory to fungi for up to 20 years after treatment. Chloropicrin remains detectable at high levels in a number of species for many years after treatment (Morrell and Scheffer, 1985; Schneider et al., 1995). As result of these tests, fumigant usage in wood has steadily risen as utilities seek to extend the useful life of their wood structures (Morrell, 1989). Of the original three fumigants employed for this purpose, chloropicrin and metham sodium continue to be used. Vorlex, which was nearly as effective as chloropicrin, was difficult to apply and was never widely used for this purpose. In addition, a third fumigant, solid methylisothiocyanate (MITC) encapsulated in aluminum for safer application is registered for wood use. While fumigants are widely used by electric utilities, their use in timber bridges is less uniform, despite their potential for substantially extending wood service life. In this report, we will review the properties of the currently registered fumigants, outline the methods for application to timbers, describe newer formulations which are under development and finally, discuss several alternative chemicals which are available for remedial treatment of timber bridges.

Fumigant Application

Fumigants are normally applied to the wood through steeply sloping holes drilled across the grain (Graham and Helsing, 1979). These holes are then plugged with tight fitting wooden dowels which reduce the risk that the vaporizing fumigant will be lost to the outside environment. The goal of the steep sloping hole is to maximize the amount of chemical which can be applied while minimizing the number of strength-reducing holes which must be drilled. In round timbers, the drilling pattern derives from the pattern of inspection holes used to detect internal decay (Graham and Helsing, 1979). In timbers, the chemicals are normally applied through perpendicular holes drilled into the upper face on either side of any checks which might be present. In other areas of a bridge, fumigant application can become more problematic since care must be taken to avoid connectors and since it is sometimes difficult to drill vertically into a timber. At least one fumigant is available in a solid encapsulated formulation which permits application to timbers through holes drilled at almost any angle.

Properties of Existing Fumigants

Chloropicrin and metham sodium are both liquid fumigants. Chloropicrin is highly volatile and its handling properties have generally limited its usage to areas away from inhabited buildings. Applicators must wear full face respirators during application of this chemical, creating considerable public image problems in some areas of the country. There have been a number of attempts to gel or otherwise encapsulate chloropicrin, but none have been commercially successful (Goodell, 1989). One formulation of chloropicrin is available in semi-permeable tubes which slow the release rate for a short period prior to application (Fahlstrom, 1982). These plastic tubes have a permeable membrane on the top which degrades over a several day period, releasing chemical into the

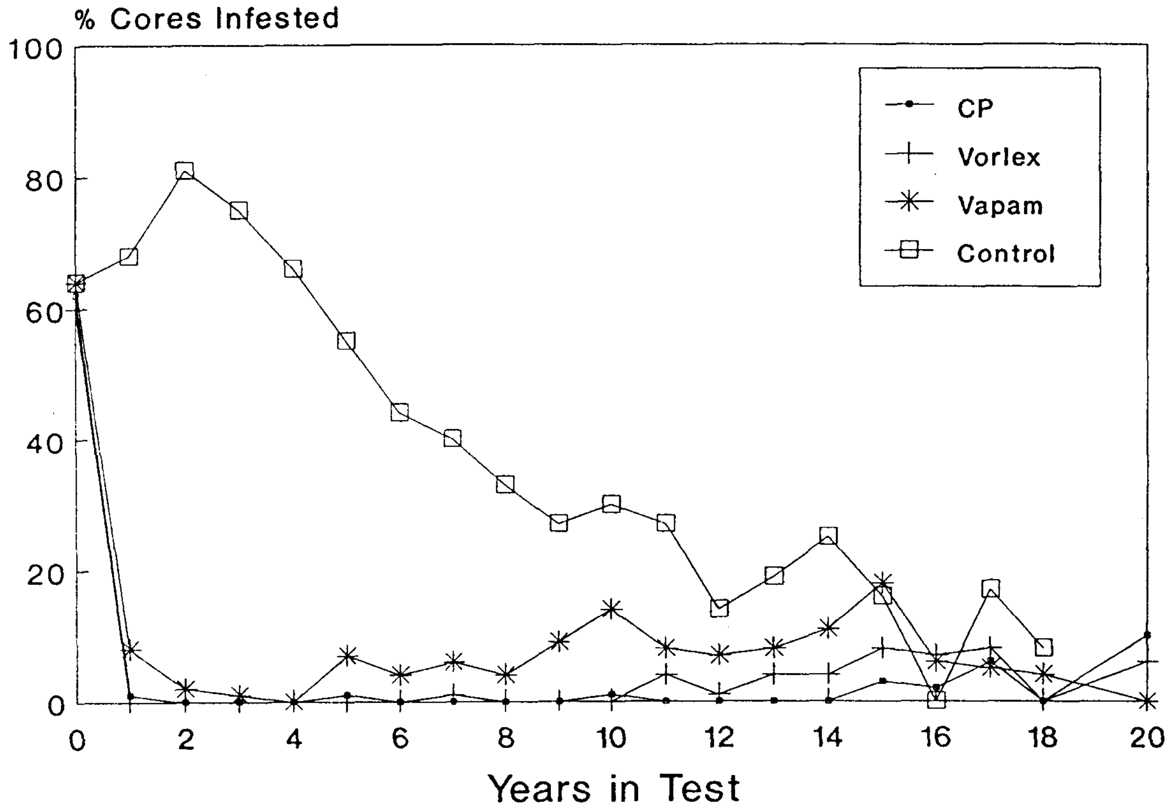


Figure l-Effect of fumigant application on survival of decay fungi in Douglas-fir poles.

wood. Tubes are normally filled at the beginning of a work day. This formulation has found its primary application for remedial treatment of bridges, where the large numbers of contiguous timbers being treated makes the process economical. The system also has some benefits because it permits application farther above the ground than would be possible with liquid chloropicrin. Liquid chloropicrin can leak from checks or other wood defects during application, posing a hazard to workers, while the tubes limit this risk. Despite its drawbacks, chloropicrin remains the most effective of the currently registered fumigants.

Metham sodium is the most widely used fumigant for remedial wood treatment. This compound is not, as applied, a very effective fungicide. Instead, metham sodium decomposes in the presence of organic compounds (such as wood) to produce a variety of fungitoxic compounds including MITC, which was the primary fungicide present in Vorlex (Morrell, 1994). Metham sodium smells like rotten eggs and is caustic, but it is the least toxic of the currently registered wood fumigants. It is has also proven to be the least effective of these chemicals (Figure 1). While chloropicrin has provided up to 20 years of protection, metham sodium eliminates decay fungi within one year, but provides only seven to 10 years of protection in Douglas-fir timbers (Helsing et al., 1984). Part of this differential performance reflects the lower amount of active ingredient applied. Chloropicrin is 96-97% pure, while metham sodium is a 32.7 % solution of the sodium salt. Thus, for a given amount of treatment hole, metham sodium provides much less protective chemical. In addition, studies suggest that the rate of decomposition of metham sodium to MITC is very poor and is sensitive to wood species, moisture content, and temperature (Morrell, 1994). As a result, only about 12% of the total liquid metham sodium applied actually becomes fungicidal. One final drawback of metham sodium is its high toxicity to aquatic life. As a result, metham sodium is not recommended for use in wood near standing water.

A field test of metham sodium in a Douglas-fir timber bridge located near Salem, Oregon shows that the MITC was present at fungitoxic levels at significant distances from the point of application 3 years after treatment (Table 1, 2). These results were similar to those found for Douglas-fir poles treated with equivalent dosages and suggest that fumigant treatment of bridge timbers should provide comparable protection against fungal invasion. Eventually, chemical loss might be expected to increase from bridge timbers; however, since these members have a higher surface to volume ratio. Fumigant is rapidly lost from the wood surface, so increasing the surface area should diminish the protective period provided by a given volatile chemical (Zahora and Morrell, 1989).

The risks of handling volatile, caustic liquids during remedial treatments encouraged the development of MITC as a wood fumigant. MITC is a solid at room temperature and sublimes directly to a gas, but it is also very caustic and must be encapsulated for safe handling (Zahora and Corden, 1986). Field tests in utility poles have shown that MITC is more effective than metham sodium but less effective than chloropicrin in terms of the length of the protective period (Figure 2)(Morrell et al., 1992c). In addition, MITC, as currently packaged, is more costly than either of the other materials, although the encapsulation does improve safety and permits application to wood well above the ground.

In addition to the registered formulations, efforts are underway to develop other, safer fumigants. The simplest strategy is to encapsulate an existing liquid fumigant to reduce the risk of spills and worker exposure. This strategy has recently been employed by encapsulating chloropicrin in various polymers to slow the release rate and reduce the risk of worker exposure during application. Preliminary field trials suggest that release may occur over a six to 10 year period (Love et al., 1996). When coupled with the tendency of wood to retain chloropicrin, this release rate creates the potential for longer protective periods than those afforded by current treatment technologies. Considerable effort remains to demonstrate the validity of these assumptions. This formulation is currently undergoing registration with the U.S. Environmental Protection Agency.

The other alternative to the currently registered fumigants is to identify solid chemicals which decompose to produce volatile fungicides in the presence of wood. There are a number of compounds which could potentially be used for this purpose, but the most likely candidate is Basamid (Forsyth and Morrell, 1995). Basamid is a crystalline material whose cyclic structure decomposes to produce MITC. Field trials have shown that this material decomposes too slowly to be of use as a remedial treatment (Highley and Eslyn, 1989), but the rate of decomposition can be accelerated by addition of buffers or metals. Field trials, again in utility poles, suggest that incorporating copper into Basamid prior to application produces decomposition at levels which would control fungi already present and limit the risk

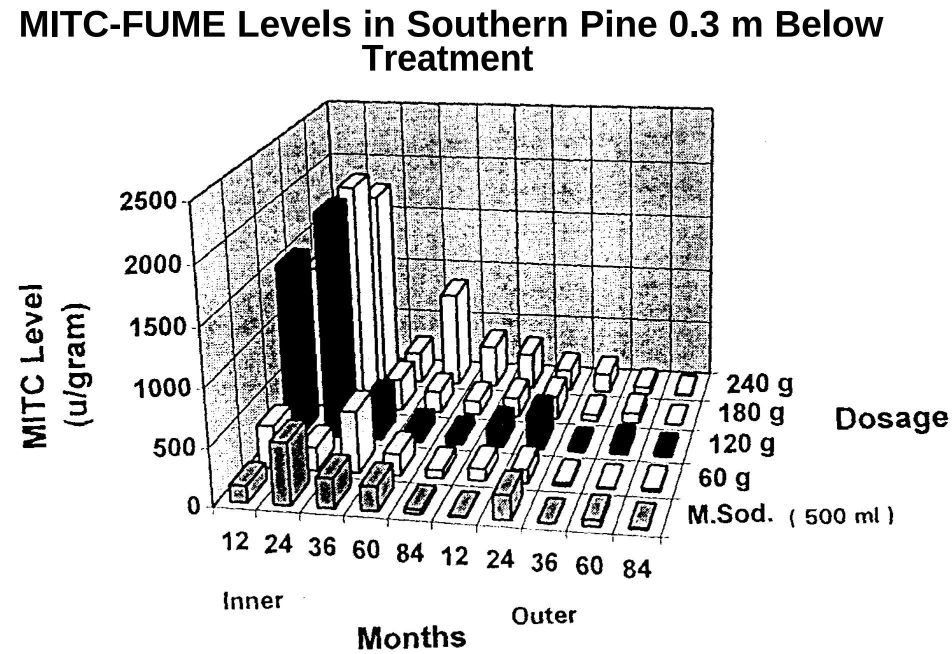
Table 1- **Residual MITC content in Douglas-fir bridge stringers one or two years after metham sodium treatment as determined by gas chromatographic analysis of ethyl acetate extracts of wood samples.**

		µg MITC/OD g wood					
		Inner			Outer		
Structure #	Stringer Position	1 year	2 years	3 years	1 year	2 years	3 years
5	Top	4.3	52.3	9.7	0.00	27.6	3.3
	Bottom	59.7	34.7	31.1	24.5	112.4	84.1
10	Top	40.2	136.1	71.3	53.2	60.3	76.4
	Bottom	75.8	114.9	43.0	39.9	59.4	116.3
15	Top	27.3	66.1	46.4	37.4	59.5	145.4
	Bottom	16.0	99.7	17.8	24.3	112.9	43.4
20	Top	26.2	115.5	58.2	65.4	130.6	44.6
	Bottom	82.7	42.6	67.7	23.2	19.9	163.1
25	Top	26.5	80.2	40.7	13.1	44.4	52.5
	Bottom	33.4	83.3	86.0	65.5	95.4	32.1
30	Top	73.2	126.8	77.5	100.3	98.5	70.2
	Bottom	83.6	40.8	83.3	75.8	63.7	49.3
35	Top	44.1	74.1	108.7	60.6	120.8	56.5
	Bottom	14.0	75.1	19.2	9.2	42.4	8.8
40	Top		50.1			140.4	
	Bottom		92.1			56.7	
Average	Top	34.5	87.7	58.9	47.1	85.3	64.1
	Bottom	52.3	72.9	49.7	37.5	70.4	71.0

Table 2- **Levels of colonization by Douglas-fir timbers one to three years after application of metham sodium as measured by culturing increment cores.**

		Cores With Decay Fungi (%)[a]		
Structure #	**Stringer Position**	**1 year**	**2 years**	**3 years**
5	Top	0	0	0
	Bottom	0	0	0
10	Top	0	0	0
	Bottom	0	0	0
15	Top	17	0	0
	Bottom	0	0	0
20	Top	0	0	0
	Bottom	0	0	0
25	Top	17	0	0
	Bottom	0	0	0
30	Top	0	0	0
	Bottom	0	0	0
35	Top	17	0	0
	Bottom	0	0	0
Average	Top	7.3	0	0
	Bottom	0	0	0

[a]Values represent means of 6 cores/treatment



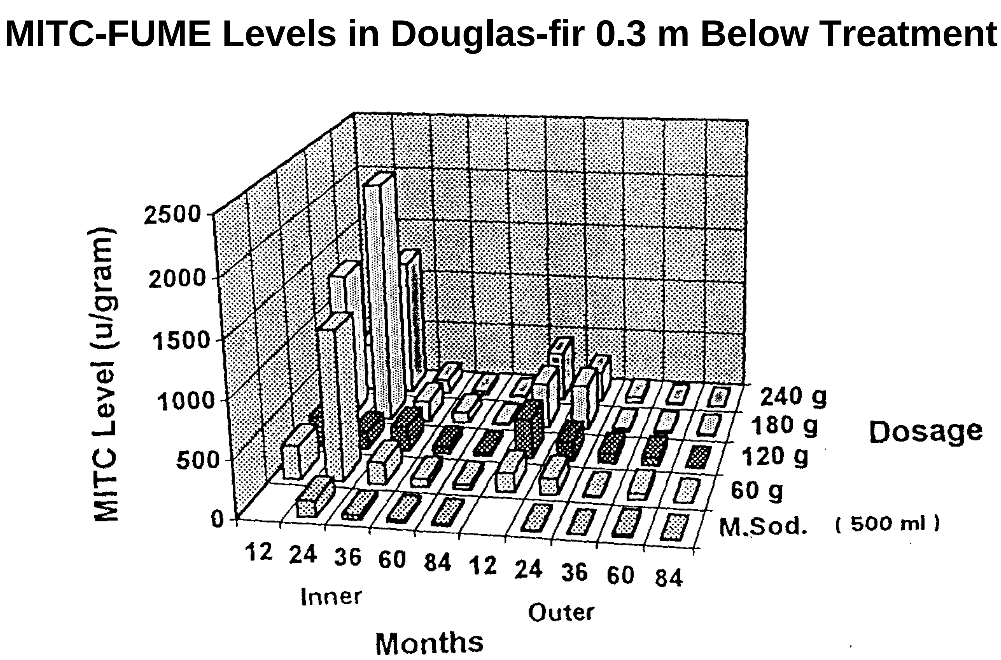


Figure 2-Residual levels of MITC in Douglas-fir and southern pine poles one to seven years after application of MITC-Fume.

of reinvasion (Forsyth and Morrell, 1993). One other advantage of this chemical is its existing registration for application to non-food crops, making it far easier to register for wood application.

Ultimately, strategies utilizing solid fumigants which can decompose slowly over a several year period can provide a safer method for preventing internal decay using volatile chemicals.

Alternative to Fumigants

While fumigants have proven to be highly effective, their handling properties have encouraged a search for less toxic decay control strategies. One alternative to fumigants are water diffusible fungicides including boron and fluoride. These compounds do not volatilize like fumigants, but they are able to diffuse from areas of high to low concentrations whenever free water is present in the wood. Both boron and fluoride have been used for many years for protecting a variety of products from decay, but their use for internal decay control in large timbers in North America is a relatively recent development (Becker, 1976). Boron is highly effective against most decay fungi and insects, although the levels required for control can vary quite widely. Typically, a target boron retention between 0.25 and 0.5% by weight is required for wood protection. Levels required for preventing wood attack where the Formosan termite is present are many times higher. Fluoride is generally only used for controlling decay fungi. In a number of studies, boron and fluoride have moved well through moist wood, but move very little when the moisture content falls below 30% (Smith and Williams, 1969). Proponents of these systems have pointed out that substantial fungal decay does not occur when the moisture content falls below 30%, therefore, it should not matter if the diffusible compound does not move in dry wood since no decay can occur under these conditions. However, this approach ignores the fact that wood moisture contents can vary widely along the length of large timbers. As a result, the boron or fluoride may be applied to a dry zone, where no movement will occur, while an adjacent wet area contained actively growing decay fungi. Judicious application can help overcome some of this limitation, but there remains the risk that the improperly placed chemical will not diffuse to the points where it is needed.

Two formulations of boron and fluoride are labeled for wood use in the U.S. Fused boron rods are produced by heating boron to high temperatures and pouring this molten material into molds. The boron cools and hardens into a glass-like rod which is applied to the same steep angled holes used for fumigant treatment. Boron diffuses from the rods in the presence of moisture (Morrell et al., 1990) and moves well through a variety of North American wood species (Morrell et al., 1992b). Sodium fluoride is available in rod form and has a long history of use in railroad ties, but has only recently been labeled for other wood uses. Field trials are currently underway to evaluate the performance of these materials in larger timbers. An additional formulation which is not currently labeled in the U.S. is composed of both fluoride and boron in a rod form (Preschem Ltd., Cheltenham, Australia). Field trials with this formulation suggest that the rate of chemical movement from the rods remains slower than that found with fumigants (Table 3).

Field trials of boron in fused boron rods have shown that boron diffusion away from the application point in Douglas-fir poles takes up to 3 years to achieve chemical levels which can provide effective fungal control (Table 4)(Morrell and Schneider, 1995). Since decay continues while this diffusion occurs, the user takes a risk that the timber will deteriorate to an unsafe condition before boron levels are sufficient to effect fungal control. Trials with southern pine poles have proven more successful, perhaps reflecting the more permeable nature of this wood species (Zahora et al., 1996). Trials with a fluoride/boron rod have shown that boron has moved more rapidly than the fluoride over a 2 year period. These results are interesting since a prior trial of groundline preservative pastes containing fluoride and boron showed the opposite effect in Douglas-fir posts (Morrell et al., 1994).

A final diffusible preservative system available for timber in bridges is a water soluble copper naphthenate/boron paste. Limited field trials with this formulation indicate that the boron moves well from the point of application, while the copper naphthenate moves to only a limited extent (Forsyth and Morrell, 1992). As a result, this treatment might be useful for treating the inner surface of large voids, where the copper naphthenate would coat the surface of the void, while the boron would diffuse further into the wood. This treatment, however, would be unlikely to completely eliminate established decay fungi.

Selecting Remedial Treatments

Bridge maintenance specialists have a variety of options for arresting internal decay in their bridges. Each chemical has certain pros and cons which may make it especially attractive for specific applications. For example, where decay is actively occurring in a bridge located away from inhabited structures, chloropicrin

Table 3- **Residual boron and fluoride at selected locations above or below the groundline in Douglas-fir poles one year after treatment with fluoride/boron rods.**

Dosage (g)	Application Pattern (Degrees)[a]	Residual Chemical (%F or BAE)[b]											
		Distance from Treatment Zone											
		-300 mm				300 mm				600mm			
		Outer		Inner		Outer		Inner		Outer		Inner	
		F	BAE	F	BAR	F	BAE	F	BAE	F	BAE	F	BAE
70.5	90	0.02	0.10	0.11	0.63	0.08	0.54	0.11	0.51	<0.01	0.03	0.01	0.02
	120	0.01	0.06	0.03	0.26	0.02	0.09	0.06	0.49	<0.01	0.04	<0.01	0.05
141.0	90	0.01	0.28	0.07	0.06	0.02	0.07	0.07	0.36	0.01	0.03	0.01	0.05
	120	0.04	0.09	0.12	0.67	0.03	0.10	0.04	0.20	0.01	0.04	0.01	0.05
0.00	-		0.01	-	0.08	-	0.04	-	0.01	-	0.01	-	0.01

[a] **Values represent composite analyses of 5 poles/treatment. BAE represents boric acid equivalent.**
[b]**Application patterns were holes at 90 or 120" intervals around the pole.**

Table 4 -- **Residual boric acid equivalent (BAE) at selected locations in Douglas-fir poles 1 or 3 years after treatment with borate rods with and without supplemental moisture.**

Borate Dosage (%)	Water Added	Residual Boron Concentration (%BAE) by position[a]											
		Groundline				300 mm above Groundline				900 mm above Groundline			
		Outer		Inner		Outer		Inner		Outer		Inner	
		Year 1	Year 3	Year 1	Year 3	Year 1	Year 3	Year 1	Year 3	Year 1	Year 3	Year 1	Year 3
120	-	0.02	0.17	0.02	0.34	ND[b]	0.20	ND	0.32	ND	0.02	ND	0.02
	+	0.02	0.49	0.02	0.72	ND	0.11	ND	0.16	ND	0.03	ND	0.04
240	-	0.02	0.45	0.02	0.75	ND	0.13	0.02	0.10	ND	0.05	ND	0.04
	+	0.01	0.38	0.02	0.54	ND	0.14	ND	0.22	ND	0.03	ND	0.04

[a]**Values represent composite analyses of 5 pole sections.**
[b]**ND signifies boron levels <0.0l % BAE.**

might represent the best option, while a similar bridge near houses might be better suited to treatment with metham sodium or MITC. In instances where there is no visible evidence of decay, the use of water-diffusible boron or fluoride may be appropriate since the risk of deterioration while the chemical diffuses through the wood is minimal.

Timber bridge inspectors contemplating the use of diffusible boron or fluoride must carefully weigh the benefits of safer chemical application against the need for rapid decay control. In instances where the timbers contain active decay fungi, fumigants may provide the fastest control, thereby preventing further deterioration of the bridge capacity. In some instances, inspection may show that a bridge has only minor decay problems. In these cases, the preventative application of diffusible chemicals may prevent the inception of decay. One advantage of boron or fluoride is the unrestricted classification of these compounds. Fumigants are generally restricted use pesticides and, even where they are not, considerable care must be taken during application. The diffusibles are more easily handled and may be more suitable in locations where extensive training of the inspection crew in chemical handling is not desirable or cost effective.

The long term protective effect of diffusibles remain under study, so users of these technologies would be strongly advised to consider some form of monitoring of the chemical levels in their structures to determine when retreatment is necessary.

Conclusions

The wide array of treatment options provide a variety of opportunities for prolonging the useful life of timber in bridges. Along with the obvious safety and economic benefits, these treatments also conserve our valuable forest resources.

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APPENDIX E

Commercial Timbers of the Caribbean

Present and Potential

Commercial Timbers of The Caribbean

With Special Reference to

- The West Indies
- The Guianas
- And British Honduras

by

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Agriculture Handbook No. 207

U.S. Department of Agriculture
Washington, D.C.

Forest Service
March 1962
Approved for reprinting July 1971

Present and Potential Commercial Timbers of The Caribbean

INTRODUCTION

The steady improvement of social and economic conditions in the Caribbean countries has brought about a comparable increase in the consumption of timber and other wood products. Although the Caribbean region includes man millions of acres of forests containing untold billions of cubic feet of timber, most of the increased demand is met by imports from outside the region. Softwoods are imported principally from the United States; hardwoods, from Europe, Africa, and the Philippines. Many hundred, even thousands of different timbers are available in the Caribbean forests; many of them are qualified for the uses filled by imported timbers, yet the intra-Caribbean trade in this commodity is limited to a few species. The present wood consumption in a large art of the region consists mainly of imported softwood (coniferous) species for construction work and a limited use of homegrown hardwoods (broadleaf) for furniture, construction, posts, and fuel.

Hardwood timber is, in general, plentiful throughout the continental area of the Caribbean and on a number of the West Indies islands. But, some areas, including Puerto Rico, Jamaica, Barbados, and some of the smaller islands of the Lesser Antilles, are handicapped by a scarcity of both hardwood and softwood species.

The coniferous resources of the region are largely confined to British Honduras, Honduras, Nicaragua, and Mexico on the continent, and to a limited supply in Haiti, Cuba, Dominican Republic, and the Bahamas in the West Indies. Excepting British Honduras, all Caribbean countries are importers of softwood timber, though British Guiana's requirements are nearly met by local hardwoods. The Caribbean area is considered- in this work to include the three Guianas and the northern part of Venezuela and Colombia, Central America, southern Mexico? the southern tip of Florida, and the West Indies from Cuba and the Bahamas to Trinidad and Tobago. An increasing proportion of the softwood lumber imports is coming from within the Caribbean region. Nevertheless? the volume of the softwood resources is so limited that the bulk of future requirements will have to be supplied from the outside, largely from the United States.

In British Honduras the pine industry has reached its full development, and further expansion must be based on the utilization of lesser known timbers. In fact,, the best pine stands in Central America are being consumed so rapidly that a sharp decline is predicted within the next two or three decades. But in the Guianas the volume of exportable timbers is increasing with advancement in the timber production industry. In this area, vast tracts of unexploited hardwood forests remain untouched.

Many hundreds, even thousands, of different woods are available in the forests of the Caribbean countries. Yet the local commerical production and utilization and the exportation of timbers from the area over the past, 300 years, and even today, are confined to a relatively few of these woods. Less than twenty timbers are of importance in the present export market. Consequently, many of the smaller islands and Central American countries import, and use softwood timbers where indigenous hardwood species would be satisfactory. Also, many local hardwood timbers, if well manufactured and if properly marketed in quantity, could satisfy similar needs in other countries in the region.

Furthermore, it is reasonable to assume that among the immense number of unused timbers are many with qualities equal or superior to the relatively few native hardwood timbers presently accepted. Some probably possess outstanding beauty, durability, resistance to insects or marine organisms, or have such high strength properties that they would be readily accepted by the local and export trade.

In view of the expanding market and the uncertainty of the present resources of the small number of timbers being utilized, the need for using the lesser known species is of first importance. This applies both to the areas having abundant timber supplies and to the islands having insufficient forest, reserves, yet many unused timbers.

Lack of knowledge, particularly by the consumer, seems the principal deterrent to the utilization of lesser known woods. Needed is information on physical and mechanical properties, as well as knowledge of air seasoning, kiln drying, durability, machining characteristics, and resistance to insects and marine organisms. Prospective users should also have the benefit of reliable recommendations on the acceptable uses for the different timbers and an estimate of their present and potential availability.

In view of the above considerations, the Fourth Session of the West Indian Conference held in 1950 recommended that a future conference be convened to consider the agricultural potentialities of the Caribbean area, with special reference to developing the timber trade. Later, the objective was restricted to a study of the present and potential timber trade. The conference, held at Port of Spain, Trinidad, in April 1953, was attended by representatives from most countries and islands of the Caribbean area.

Conference delegates agreed on the need for compiling and publishing a list of the timbers of present and potential regional importance. They also agreed that this document should cover the entire Caribbean, including the independent republics, and should contain all available information on the selected timbers. The principal timbers described in the text were selected largely by member countries of the Caribbean Commission and do not necessarily include all timbers of present or potential importance in the entire Caribbean region.

Countries represented in the selection of timbers are as follows: British Guiana, French Guiana, Surinam, and British Honduras on the continent; Jamaica, Dominican Republic, and Puerto Rico in the Greater Antilles; Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent, Grenada, Trinidad, and Tobago in the Lesser Antilles. Although Cuba and Haiti are not included in this group, they are well represented by the selections made for other islands in the Greater Antilles. But important timbers in other parts of the Caribbean area are not discussed in detail unless they are also presently or potentially important in the above countries or islands.

The conference by resolution directed the Secretariat of the Caribbean Commission to ask the Tropical Forest Research Center of the U.S. Forest Service for assistance in the project. In answer to that request., this publication was prepared. It presents, to the best of the author's knowledge, a summary of all available and worthwhile information on the 71 important timbers in that part of the Caribbean area described above.

SELECTION OF IMPORTANT CARIBBEAN TIMBERS

Foresters and other representatives of the Government attending the 1953 Timber Conference in Port of Spain, Trinidad, selected an initial list of 54 timbers of present or potential commercial importance. The number was later increased to 71 as additional timbers were suggested. This number will surely increase in the years ahead : Remote areas will become more accessible to improved markets, and further studies will be made of the quantity and quality of many woods, currently little known. The final selection of timbers covered in this work and the species chosen are essentially as suggested by the participating governments. The timbers are listed by their preferred trade and botanical names in table 1.

TABLE 1.—*Present and potential commercial timbers of the Caribbean*

Trade name	Scientific name	Page
Angelin	*Andira inermis* (W. Wright) H.B.K.	27
	A. spp.	27
Angelique	*Dicorynia guianensis* Amsh.	28
Aromata	*Clathrotropis macrocarpa* Ducke	30
	C. brachypetala (Tul.)Kleinh.	30
Baboen	*Virola surinamensis* (Rol.) Warb.	30
Bagasse	*Bagassa guianensis* Aubl.	33
	B. tiliaefolia (Desv.) R. Ben.	33
Balata	*Manilkara bidentata* (A. DC.) Chev.	34
Balsa	*Ochroma pyramidale* (Cav.) Urban	36
Banak	*Virola koschnyi* Warb.	30
Baromalli	*Catostemma commune* Sandw.	38
	C. fragrans Benth.	38
Bethabara	*Tabebuia serratifolia* (Vahl) Nicholson	39
Bois gris	*Licania ternatensis* Hook. f.	41
Broadleaf	*Terminalia latifolia* Sw.	42
Bullhoof	*Drypetes brownii* Standl.	43
Bustic	*Dipholis salicifolia* (L.) A. DC.	44
	D. spp.	44
Cedar, Central American	*Cedrela mexicana* M. J. Roem.	45
	C. odorata L.	45
	C. guianensis A. Juss.	45
Courbaril	*Hymenaea courbaril* L.	47
	H. davisii Sandw.	47
Crabwood	*Carapa guianensis* Aubl.	49
Dakama	*Dimorphandra conjugata* (Splitg.) Sandw.	52
Determa	*Ocotea rubra* Mez	53

TABLE 1.—*Present and potential commercial* timbers of the Caribbean—Continued

Trade name	Scientific name	Page
Dukali	*Parahancornia amapa* (Huber) Ducke	54
Encens	*Protium attenuatum* (Rose) Urban	55
Gommier	*Dacryodes excelsa* Vahl	55
Greenheart, Demerara.	*Ocotea rodiaei* (R. Schomb.) Mez	57
Gronfoeloe	*Qualea rosea* Aubl.	60
	Q. coerula Aubl.	60
	Q. albiflora Warm.	60
Gumbo-limbo	*Bursera simaruba* (L.) Sarg.	62
Haiari	*Alexa imperatricis* (Schomb.) Baill.	63
	A. leiopetala Sandw.	63
Hura	*Hura crepitans* L.	64
Inyak	*Antonia ovata* Pohl	65
Kauta	*Licania laxiflora* Fritsch	66
	L. mollis Benth.	66
	L. persaudii Fanshawe & Maguire	66
Kautaballi	*Licania venosa* Rusby	66
	L. majuscula Sagot	66
Kereti silverballi	*Ocotea wachenheimii* R. Ben.	68
	O. puberula Nees	68
Kopie	*Goupia glabra* Aubl.	69
Kurokai	*Protium crenatum* Sandw.	70
	P. decandrum March.	70
	P. sagotianum March.	70
	P. schomburgkianum Engl.	70
Kwarie	*Vochysia guianensis* Aubl.	72
	V. tomentosa DC.	72
Lignumvitae	*Guaiacum officinale* L.	73
	G. sanctum L.	73
Magnolia	*Talauma dodecapetala* (Lam.) Urban	75
Mahoe	*Hibiscus elatus* Sw.	76
Mahogany, Honduras.	*Swietenia macrophylla* King	76
Mahogany, West Indies.	*Swietenia mahagoni* Jacq.	79
Manbarklak	*Eschweilera longipes* (Poit.) Miers	81
	E. subglandulosa (Steud.) Miers	81
Manni	*Symphonia globulifera* L. f.	82
Manniballi	*Inga alba* Willd.	84
Marblewood	*Marmaroxylon racemosum* (Ducke) Killip	85
Marish	*Licania buxifolia* Sandw.	66
	L. densiflora Kleinh.	66
	L. macrophylla Benth.	66
	L. micrantha Miq.	66
Mora	*Mora excelsa* Benth.	86
	M. gonggrijpii (Kleinh.) Sandw.	86
Nargusta	*Terminalia amazonia* (J. F. Gmel.) Exell	86
Pakuri	*Platonia insignis* Mart.	90
Parakusan	*Swartzia jenmanii* Sandw.	92
	S. polyphylla DC.	92
	S. schomburgkii Benth.	92
Pine, Caribbean	*Pinus caribaea* Morelet	92
Podocarp	*Podocarpus coriaceus* L. C. Rich.	95
	P. guatemalensis Standl.	95
Purpleheart	*Peltogyne pubescens* Benth.	96
	P. porphyrocardia Griseb.	96
	P. venosa (Vahl) Benth. var. *densiflora* (Spruce) Amsh.	96
Resolu	*Chimarrhis cymosa* Jacq.	99
Roble	*Tabebuia rosea* (Bertol.) DC.	99
	T. heterophylla (DC.) Britton	99
Rosewood, Honduras.	*Dalbergia stevensonii* Standl.	101
Saman	*Pithecellobium saman* (Jacq.) Benth.	102
Santa-maria	*Calophyllum brasiliense* Camb.	104
	C. lucidum Benth.	104
Sara	*Vouacapoua macropetala* Sandw.	106
Simarouba	*Simarouba amara* Aubl.	107
	S. glauca DC.	107
Snakewood	*Piratinera guianensis* Aubl.	108
Sterculia	*Sterculia pruriens* (Aubl.) K. Schum.	110
	S. caribaea R. Br.	110
	S. rugosa R. Br.	110
Suradan	*Hyeronima laxiflora* (Tul.) Muell.-Arg.	112
	H. alchorneoides Fr. Allem.	112
	H. caribaea Urban	112
	H. clusioides (Tul.) Griseb.	112
Tabebuia, white	*Tabebuia insignis* (Miq.) Sandw. var. *monophylla* Sandw.	114
	T. stenocalyx Sprague & Stapf	114
Tatabu	*Diplotropis purpurea* (Rich.) Amsh.	115
Tauroniro	*Humiria balsamifera* (Aubl.) J. St. Hil.	116
Teak	*Tectona grandis* L. f.	118
Tonka	*Dipteryx odorata* (Aubl.) Willd.	120
Wacapou	*Vouacapoua americana* Aubl.	121
Wallaba	*Eperua falcata* Aubl.	123
	E. grandiflora (Aubl.) Benth.	123
	E. jenmanii Oliver	123
	E. schomburgkiana Benth.	123
Wamara	*Swartzia leiocalycina* Benth.	125
	S. benthamiana Miq.	125
Yemeri	*Vochysia hondurensis* Sprague	126
Yokewood	*Catalpa longissima* (Jacq.) Sims	128

Timbers of similar characteristics are commonly marketed in many parts of the world under a common trade name. Examples of such group marketing are the commercial white oak, hickory, and black gum timbers of the United States, which commonly include from two to ten or more different species. Individual species of these and many other timbers are not available separately on the commercial market. In the Caribbean area where several hundred species reach saw-log size, the opportunities for group marketing are not only more favorable but almost, imperative for the successful exploitation of the tropical forests. Consequently, species have been grouped in this work according to the present marketing practices in the countries concerned when available knowledge justifies such a grouping. Many additional species are excluded for lack of information on their physical and mechanical properties. The presently accepted groups will undoubtedly be enlarged with added research and more practical experience.

There is probably less variation between species in any one limber group than is accepted in the usual trade groupings used in other areas. Hence, additional species can eventually be listed in many of the commercial groups without, exceeding the accepted range of variability in commercial timber. In some instances, species listed as secondary in importance can be included with the principal species now listed under the accepted trade name.

NOMENCLATURE

The timber trade names in this work were selected principally by members of the interested governments. The author made only a few changes or modifications to clarify the origin of certain timbers or to separate them more clearly from others with similar trade names. Trade names used in the principal country of export are preferred unless subject to confusion with the names of other timbers. The trade names accepted in this work are generally in agreement with those adopted by the British Standards Institute as listed in its "Nomenclature of Commercial Timbers Including its Sources of Supply" *(36).*[1]

Most tropical timbers are known by different common names in each country or territory of origin and often by several names even within each territory. These names are sometimes variations of connotations of the tree's form, fruit, or other morphological characteristics, the uses for its wood and other parts, or certain characteristic features of the tree or its products. Many of these local names are misleading. Some are used repeatedly for different species throughout the Caribbean area. They are, on the whole, unreliable and only of local value, but are listed in this work to assist the reader in identifying local timbers with the preferred trade and accepted botanical names.

The scientific names, including those mentioned incidentally, have been checked and conform to current usage under the International Code of Botanical Nomenclature. Synonyms in use are also listed in the text and index. Further taxonomic studies of tropical trees and woods may result in slight revision of the nomenclature.

DISTRIBUTION AND HABITAT

Most tropical American tree species and timbers of related species are not uniformly distributed throughout the Caribbean area but may be arranged into several geographical groups. Timbers found in one country may be absent from a nearby country. Several examples will illustrate the main patterns of tree distribution of the timbers described here.

[1] Italic numbers in parentheses refer to Bibliography, p. 131.

Balsa (*Ochroma pyramidale*) is found widely in tropical America, including West Indies, Central America, and northern South America. Some species, such as gommier (*Dacryodes excelsa*), are confined to the West Indies, and a few, such as one kind of magnolia (*Talauma dodecapetala*), are known from only one or a few islands. Others, such as Honduras rosewood (Dalbergia *stevensonii*), are restricted to Central America? or occur also in the West Indies, as does Caribbean pine (*Pinus caribaea*).

The trees and timbers of the Guianas and other parts of northern South America for the most part are different from those of Central America and the West Indies. Many timbers described here are limited to South America (*Catostemma, Eperua, Goupia, Qualea,* etc.). In the Guianas are found many trees of the Amazon rain forest. Trinidad, which is within sight of the continent. has trees of South American relationship, not West Indian. However, some South American trees extend slightly northward into Central America and the southern West Indies.

The section on Distribution and Habitat. of the one or more species providing each timber is based on published information. For many species this section is not complete and may be subject to certain revisions as additional botanical classifications are made. Further botanical exploration will likely extend the distribution or range of many timbers and bring about some reclassification or combination of species. Many "species" have already been combined to increase the range of certain timbers. Further published accounts of species occurrence and habitat will also allow the correction of present knowledge.

TREE DESCRIPTIONS

The section under each timber headed The Tree should be of special interest to the forester and other technicians. It will help them correlate the other descriptive material with the botanical species where tree identity is in doubt. To the nontechnical reader, this information can provide a measure of the potential size and the quality of products available from the trees. For example. it should be clear to the reader that snakewood (*Piratinera guianensis*), although moderately resistant to marine borers, does not grow to sufficient size, length, or in suitable form for use as marine piling. Similarly, it is evident that Demerara greenheart (*Ocotea rodiaei*) is generally of adequate size for this use.

The text also shows the variation in tree size between countries and, to some extent, localities and sites. Most writers tend to quote the upper size limits of trees growing on good sites rather than the average or common size at maturity. Detailed botanical descriptions of trees do not appear justified in a text primarily for the reader interested in timber products. This information is available in other publications dealing especially with the subject.

DESCRIPTION OF THE WOOD

Description of the physical characteristics of each timber covered in this text is largely confined to those macroscopic characteristics and other superficial features easily seen by the unaided eye and easily understood by the average wood user. Each timber's description is for the average of that species or group of species. The wood of any species commonly varies between countries of origin, from one locality to another, from tree to tree, and even within the individual tree. Color and grain are the most variable characteristics.

The description of the wood of each timber is a summary of the published information on that timber. Where differences between published references exist, the most logical and generally accepted description was used. As would be expected, disagreement concerning color and texture occurs most often. This is attributable in part to variation in the timber and in part to the lack of established standards for judging these properties.

Descriptions frequently refer to tangential or radial surfaces and transverse or end grain. Tangential surfaces of boards or other specimens are those more or less parallel or tangent to the growth rings of the trees. Radial surfaces are at right angles to the growth rings. Transverse or end-grain surfaces are perpendicular to the main axis of the tree. Thus, if a board is cut from the perimeter of a log, parallel to the growth rings, the wide surface of the board will be termed the tangential surface, the edges of the board will be radial surfaces, and both ends will show transverse or end-grain surfaces, sometimes called the cross-sectional surfaces.

Correspondingly, boards cut parallel to the perimeter or growth rings of the tree are termed "flat-grained," "flat-sawed," or "plainsawed." Those cut across or at right angles to the growth rings are termed "quartersawed" or "edge-grained" lumber. Certain advantages and disadvantages are inherent in either plainsawed or quartersawed lumber *(242)*. The principal differences are as follows:

1. Flat-sawed lumber generally reveals better figure patterns resulting from growth rings than quartersawed stock.
2. Flat-sawed lumber is less subject to loss of surface appearance and reduction in strength by round or oval knots or shakes and pitch pockets.
3. Flat-sawed boards shrink less in thickness and more in width than quartersawed boards.
4. Flat-sawed stock is less subject to collapse in drying than quartersawed lumber.
5. Quartersawed lumber cups and twists less in drying than flat-sawed lumber.
6. Quartersawed lumber shows up figures resulting from pronounced rays, interlocked grain, and wavy grain more clearly than flat-sawed lumber.
7. Quartersawed lumber is generally more costly to produce from the log.
8. Quartersawed lumber will surface-check and split less in seasoning than flat-sawed lumber.
9. Quartersawed boards wear more evenly and often hold paint better than flat-sawed boards.

Two other terms commonly used in wood descriptions are texture and grain. Texture is a term that describes the size of the vessels or pores; degrees of texture are very coarse, coarse, medium, fine, or very fine. Grain is a description of the direction of the wood elements. The grain may be straight, wavy, or interlocked. When the grain is straight, the fibers run parallel to the main axis of the tree and generally more or less straight to the length of sawed lumber. Wavy grain, sometimes termed curly grain, undulates back and forth across the surface of lumber. In interlocked or roey-grain timber, the. direction of the fiber alinement alternates at intervals, resulting in a ribbon figure on the quartersawed surface. Splitting specimens having interlocked grain reveals an uneven surface on the radial plane.

WEIGHT AND SPECIFIC GRAVITY

Solid wood with all air and moisture excluded is about 1.5 times the weight of water, regardless of the species. The fact that the dry wood of most species floats in water demonstrates that a large part of wood consists of cell cavities and pores. Consequently, variations in the size of cell openings and in the thickness of cell walls result in some species having more wood substance than others and, thereby, a higher specific gravity or weight. Specific gravity is thus a direct index of the amount of wood substance a piece of dry wood contains.

Specific gravity is defined as the ratio of the weight of a given volume of wood to that of an equal volume of water. The weight and volume of wood change with the shrinkage and swelling caused by changes in moisture content. The weight changes with moisture content both above and below the fiber saturation point (around 30 percent). However, volume changes only in wood below the fiber saturation point, as shrinkage does not begin until this point is reached. Hence, a figure for the specific gravity of wood is meaningless unless it includes the moisture content at which the weight and volume of the wood were determined in arriving at the specific gravity figure.

Specific gravity is commonly calculated on two bases: (1) True specific gravity; and (2) nominal specific gravity. True specific gravity is generally based on the volume and weight of wood in either the air-dry or the green condition. Nominal specific gravities are usually based on volumes when green and weights when ovendry. This specific gravity is based on conditions that could never occur simultaneously. However, true specific gravity can be calculated from nominal specific gravity with perfect accuracy for wood of any moisture content above the fiber saturation point, (green timber), and with fair accuracy between the fiber saturation point and air-dry by simply increasing it by a percentage corresponding to the moisture content in question. Thus, by quoting the nominal specific gravity based oh green volume and ovendry weight, the reader is able to compute the true specific gravity for wood at any moisture content.

The weight of wood per cubic foot is determined by multiplying true specific gravities by 62.4, or by multiplying nominal specific gravities by the product of 62.4 times the sum of one plus the moisture content, of the specimen at the time of test. The weight per cubic foot for each timber when air dry at about 12 percent moisture content and when green is given in table 2.

TABLE 2.— *Specific gravity and weight of Caribbean timbers*

Trade name	Scientific name	Specific gravity based on—		Weight per cubic foot	
		Green volume and ovendry weight	Air-dry volume and weight	Green	Air dry
				Pounds	
Angelin	*Andira inermis*	0.63	0.76	74	
Angelique	*Dicorynia guianensis*	.60	.72	67	
Aromata	*Clathrotropis brachypetala*	----------	1.10	--------	
	C. macrocarpa	----------	1.00	--------	
Baboen	*Virola surinamensis*	.42	.51	51	
Bagasse	*Bagassa guianensis*	.68	.80	67	
Balata	*Manilkara bidentata*	.85	.89	76	
Balsa [1]	*Ochroma pyramidale*	----------	.16	--------	
Banak	*Virola koschnyi*	.44	.53	51	
Baromalli	*Catostemma commune*	.45	.60	70	
Bethabara	*Tabebuia serratifolia*	.92	1.10	75	
Bois gris	*Licania ternatensis*	----------	1.12	--------	
Broadleaf	*Terminalia latifolia*	----------	.65	--------	
Bullhoof	*Drypetes brownii*	----------	.74	--------	
Bustic	*Dipholis salicifolia*	.86	.95	77	
Cedar, Central American	*Cedrela mexicana*, *C. odorata*, *C. guianensis*	.40	.48	44	
Courbaril	*Hymenaea courbaril*	.70	.84	70	
	H. davisii	.67	.84	70	
Crabwood	*Carapa guianensis*	.56	.64	56	
Dakama	*Dimorphandra conjugata*	----------	1.06	--------	
Determa	*Ocotea rubra*	.52	.62	59	
Dukali	*Parahancornia amapa*	----------	.60	--------	
Encens	*Protium attenuatum*	----------	.52	--------	
Gommier	*Dacryodes excelsa*	.53	.64	52	
Greenheart, Demerara	*Ocotea rodiaei*	.88	1.04	78	
Gronfoeloe	*Qualea rosea*	.53	.62	60	
	Q. coerula	----------	.58	60	
	Q. albiflora	.49	.59	79	
Gumbo-limbo	*Bursera simaruba*	.30	.34	38	
Haiari	*Alexa imperatricis*, *A. leiopetala*	----------	.48	--------	
Hura	*Hura crepitans*	.38	.46	40	
Inyak	*Antonia ovata*	----------	.53	--------	
Kauta	*Licania laxiflora*, *L. mollis*, *L. persaudii*	----------	1.20	--------	
Kautaballi	*Licania venosa*, *L. majuscula*	----------	1.15	--------	
Kereti silverballi	*Ocotea wachenheimii*, *O. puberula*	----------	.53	--------	
Kopie	*Goupia glabra*	.70	.83	73	

See footnote at end of table.

TABLE 2.— *Specific gravity and weight of Caribbean timbers*— Continued,

Trade name	Scientific name	Specific gravity based on—		Weight per cubic foot	
		Green volume and ovendry weight	Air-dry volume and weight	Green	Air dry
				Pounds	*Pounds*
Kurokai	*Protium decandrum*	0.53	0.64	50	40
	P. schomburgkianum	.48	.53	56	33
Kwarie	*Vochysia guianensis*	.40	.54	67	34
	V. tomentosa	----	.43	67	27
Lignumvitae	*Guaiacum officinale*, *G. sanctum*	----	1.28	----	80
Magnolia	*Talauma dodecapetala*	.59	.64	72	44
Mahoe	*Hibiscus elatus*	----	.75	----	47
Mahogany, Honduras:	*Swietenia macrophylla*				
Forest-grown	----	.45	.53	44	33
Plantation-grown	----	.42	.50	40	31
Mahogany, West Indies	*Swietenia mahagoni*	.56	77	68	48
Manbarklak	*Eschweilera subglandulosa*	.87	1.08	78	67
Manni	*Symphonia globulifera*	.58	.72	67	44
Manniballi	*Inga alba*	----	.57	----	36
Marblewood	*Marmaroxylon racemosum*	----	1.15	----	72
Marish	*Licania buxifolia*	.88	1.09	75	68
	L. macrophylla	.76	.93	71	58
Mora	*Mora excelsa*	.78	1.00	77	62
	M. gonggrijpii	----	1.03	----	64
Nargusta	*Terminalia amazonia*	.66	.80	71	50
Pakuri	*Platonia insignis*		.80	----	50
Parakusan	*Swartzia jenmanii*, *S. polyphylla*, *S. schomburgkii*	----	.78	----	49
Pine, Caribbean	*Pinus caribaea*	.65	.77	57	48
Podocarp	*Podocarpus coriaceus*	----	.51	41	32
Purpleheart	*Peltogyne pubescens*	.74	.87	75	54
	P. venosa var. *densiflora*	.75	.87	77	54
Resolu	*Chimarrhis cymosa*		.75	----	47
Roble	*Tabebuia rosea*	.49	.58	56	36
	T. heterophylla	.58	.67	59	42
Rosewood, Honduras	*Dalbergia stevensonii*	----	1.00	----	62
Saman	*Pithecellobium saman*	.48	.56	51	35
Santa-maria	*Calophyllum brasiliense*	.52	.61	51	38
Sara	*Vouacupoua macropetala*	----	.93	----	58
Simarouba	*Simarouba amara*, *S. glauca*	.38	.44	40	27
Snakewood	*Piratinera guianensis*	----	1.20	----	75
Sterculia	*Sterculia pruriens*	.44	.59	53	37
Suradan	*Hyeronima laxiflora*	.65	.79	74	49
Tabebuia, white	*Tabebuia insignis* var. *monophylla*	.55	.68	65	42
Tatabu	*Diplotropis purpurea*	.78	.93	78	58
Tauroniro	*Humiria balsamifera*	.66	.80	67	50
Teak:	*Tectona grandis*				
Forest-grown	----	----	.68	62	42
Plantation-grown	----	----	.69	63	43
Tonka	*Dipteryx odorata*	.89	1.08	81	67
Wacapou	*Vouacapoua americana*	.79	.95	75	59
Wallaba	*Eperua falcata*	.78	.93	76	58
Wamara	*Swartzia leiocalycina*	.87	1.06	75	66
	S. benthamiana		.88	----	55
Yemeri	*Vochysia hondurensis*	.37	.45	67	28
Yokewood	*Catalpa longissima*	----	.80	----	50

[1] Wood selected for export generally weighs 7 to 10 pounds per cubic foot air-dry with a specific gravity of 0.11 to 0.18 based on air-dry volume and weight.

Table 2 also carries both the nominal specific gravity based on green volume and ovendry weight of wood and the true specific gravity based on the air-dry volume and weight of the timber. Several different specific gravity values are often reported in the literature for each timber, and sometimes cover a considerable range. This is to be expected as many factors are included that influence the density of wood, Density often varies considerably between sites and country of orgin and, as many of the timbers have extensive distribution, a covsiderable range in density is expected. The specific gravities and weights in table 2 are, therefore, the averages of the individual published results from the areas included,

Most specific gravities and weights per cubic foot quoted in the tables and text for air-dry wood are based on a moisture content of 12 percent. The change between 12 and 15 percent moisture content is so minor that no reference is made to the few data based on the higher moisture content.

Some difficulty is encountered in listing specific gravities and weight per cubic foot for the wood of those timbers with two or more species. Where the difference between species is great, the gravity and weight are cited for each species. In other cases, these are combined and represent the timber group. Where this information is available for only one or two species of a trade group, it is stated for the individual species rather than the entire group.

SEASONING

Wood can be air-seasoned in the open or kiln-seasoned in dry kilns using artificial heat and humidity. Few dry kilns are available in the Caribbean area so most lumber is air-seasoned. Because of their diffuse porous nature, tropical hardwoods generally season with less defect than most ring porous woods in the temperate zones.

The tropical climate of the Caribbean area presents both favorable and unfavorable conditions for air-seasoning. One combination bringing about favorable conditions is high temperature and relative humidity throughout the year that allow continuous and uniform drying. This reduces the possibility of serious surface checking, end splitting, cup, bow, and other seasoning defects.

On the other hand, lumber piles should be roofed or under some cover for successful air-seasoning; otherwise, the frequent tropical rains may prevent any appreciable amount of drying during the rainy season or, for that matter, any time of the year. When properly protected from ram, lumber will season through out the year in most areas of the American tropics. Under cover, lumber 1¼ inches thick will usually air-season in 2 to 6 months. Lumber will normally air-season to a moisture content between 15 and 20 percent, depending on the species, location, and time of year.

Table 3 groups the different timbers according to their ease of air-seasoning. The timbers, divided into three groups, are rated on the time required for each to season and the amount and severity of defects that normally occur. Of necessity, only a small number of groups are used. Thus, where two timbers are quite similar, one may fall in the bottom of one c ass and the other in the top of the next lower class. This is unavoidable. To a marked extent, the grouping presents the average air-seasoning; it does not cover the possibilities of improving the seasoning qualities of the different timbers by bettering seasoning practices.

Many timbers are degraded during seasoning because of an excessive rate of drying. This can be largely overcome by reducing air circulation; that is, by closer piling, by use of thinner stickers, and by placing shields or covers on one or more sides of the lumber stacks. Other factors such as sticker spacing, width of lumber stacks, and exposure to sun or rain are important in the drying rate and amount of seasoning defect.

End splitting and end checking occur during the seasoning of some timbers. But these faults may be prevented by coating the ends of boards with a moisture-resistant paint, pigments, waxes, or other material to prevent the over-rapid loss of moisture at these places. A commercial mixture of asphalt and plastic roof coating has been used by the Tropical Forest Research Center with excellent success; when end-coated with this material, 60 species of tropical hardwoods were seasoned with no appreciable end defect. The nailing of end cleats or narrow wooden strips to the ends of boards or planks is of only limited value in air-seasoning; during kiln-seasoning this practice can even cause end splits to develop or extend.

The humidity and temperature conditions in the Caribbean area are very favorable for the development of sap-stain fungi in logs and lumber. The best ways to prevent this type of damage are early conversion of logs after felling or storage of logs under water. The application of antiseptic sprays to ends and places from which the bark is removed will also protect most species of logs for 1 or 2 months if wood-infesting insects are not prevalent. Unfortunately, insects are a problem in tropical areas. To prevent their entry into logs and the transmission of fungi to the wood, applying an insecticide to the log is also necessary. In some species, adding an end coating is also required to prevent seasoning checks through which insects or fungi can enter *(242).*

Molds and stains are confined largely to the sapwood; their colors vary. Molds are not responsible for much staining. The discoloration caused by them is mostly superficial and largely due to the cottony or powdery surface growths easily removed by brushing or light surfacing.

TABLE 3.—*Caribbean timbers grouped as to their ease of air-seasoning*

Trade name	Scientific name
EASY TO SEASON	
Angelin	*Andira* spp. *A. inermis*
Bagasse	*Bagassa guianensis*
Bethabara	*Tabebuia serratifolia*
Cedar, Central American.	*Cedrela guianensis* *C. mexicana* *C. odorata*
Encens	*Protium attenuatum*
Gommier	*Dacryodes excelsa*
Gumbo-limbo	*Bursera simaruba*
Kereti silverballi	*Ocotea wachenheimii* *O. puberula*
Magnolia	*Talauma dodecapetala*
Mahogany, Honduras.	*Swietenia macrophylla*
Mahogany, West Indies.	*Swietenia mahagoni*
Manni	*Symphonia globulifera*
Podocarp	*Podocarpus coriaceus* *P. guatemalensis*
Roble	*Tabebuia heterophylla* *T. rosea*
Saman	*Pithecellobium saman*
Simarouba	*Simarouba amara* *S. glauca*
Tabebuia, white	*Tabebuia insignis* var. *monophylla* *T. stenocalyx*
Teak	*Tectona grandis*
Tonka	*Dipteryx odorata*
MODERATELY DIFFICULT TO SEASON	
Angelique	*Dicorynia guianensis*
Baboen	*Virola surinamensis*
Banak	*Virola koschnyi*
Baromalli	*Catostemma commune* *C. fragrans*
Bois gris	*Licania ternatensis*
Bullhoof	*Drypetes brownii*
Courbaril	*Hymenaea courbaril*
Crabwood	*Carapa guianensis*
Determa	*Ocotea rubra*
Greenheart, Demerara	*Ocotea rodiaei*
Gronfoeloe	*Qualea rosea* *Q. coerula* *Q. albiflora*
Hura	*Hura crepitans*
Kauta	*Licania laxiflora* *L. mollis* *L. persuadii*
Kautaballi	*Licania venosa* *L. majuscula*
Kopie	*Goupia glabra*
Kurokai	*Protium crenatum* *P. decandrum* *P. sagotianum* *P. schomburgkianum*
Kwarie	*Vochysia guianensis* *V. tomentosa*
Manbarklak	*Eschweilera longipes* *E. subglandulosa*
Manniballi	*Inga alba*
Marish	*Licania buxifolia* *L. macrophylla* *L. densiflora* *L. micrantha*
Nargusta	*Terminalia amazonia*
Pine, Caribbean	*Pinus caribaea*
Purpleheart	*Peltogyne pubescens* *P. perphyrocardia* *P. venosa* var. *densiflora*
Resolu	*Chimarrhis cymosa*
Rosewood, Honduras	*Dalbergia stevensonii*
Santa-maria	*Calophyllum brasiliense* *C. lucidum*
Sara	*Vouacapoua macropetala*
Sterculia	*Sterculia pruriens* *S. caribaea* *S. rugosa*
Suradan	*Hyeronima laxiflora* *H. alchorneoides* *H. caribaea* *H. clusioides*
Tatabu	*Diplotropis purpurea*
Tauroniro	*Humiria balsamifera*
Wacapou	*Vouacapoua americana*
Wallaba	*Eperua falcata* *E. grandiflora* *E. jenmanii* *E. schomburgkiana*
Wamara	*Swartzia leiocalycina* *S. benthamiana*
Yemeri	*Vochysia hondurensis*
DIFFICULT TO SEASON	
Balata	*Manilkara bidentata*
Balsa	*Ochroma pyramidale*
Courbaril	*Hymenaea davisii*
Haiari	*Alexa imperatricis* *A. leiopetala*
Lignumvitae	*Guaiacum sanctum* *G. officinale*
Mora	*Mora excelsa* *M. gonggrijpii*

Stains resulting from sap-staining fungi penetrate into the sapwood (not heartwood) and cannot be removed by surfacing. The discoloration of the wood is visible as specks, spots, streaks, or patches. At times it can be seen throughout the entire sapwood layer. Shortly after the lumber is cut from the logs, it may become infected by airborne fungi. Stains develop rapidly and noticeable discoloration may be evident within 24 hours after conversion.

Stain may be controlled by piling products immediately after conversion., so that the wood's surface dries rapidly. This is often impractical, or results in excessive seasoning degrade from the too rapid loss of moisture during the early stages of drying. Stain may also be controlled by dipping, spraying, or brushing the wood with antiseptic solutions, such as chlorinated phenols, organic mercury compounds, and borax. Numerous commercial products are also on the market for this use. Early treatment is imperative : once sap stain is established it cannot be controlled by treating the wood surface with chemicals. Rapid air-seasoning or kiln-drying below 20 percent moisture content is the most effective control measure once sap stain is present.

Most information on kiln-seasoning of Caribbean timbers has been developed by the Forest Products Research Laboratory in England. Frequeut reference is made in this text to the kiln schedules recommended for different, timbers in their "Kiln Operator's Handbook" *(222)*. One of their more recent publications, No. 42, provides new schedules for faster drying and more severe kiln conditions. Any reader interested in kiln-seasoning of tropical American timbers should acquire these publications for details on kiln schedules and recommended operating techniques. The U.S. Forest Products Laboratory, Madison, Wis., also lists kiln schedules in its report D-1791 that may be used for tropical hardwoods by experienced kiln operators.

SHRINKAGE AND MOVEMENT

Freshly sawed lumber contains from 30 to more than 300 percent water, based on the ovendry weight of the wood. The percentage of moisture varies according to species. In the green condition, dense, close-grained wood contains less moisture than open-grained, less dense wood. As an example, very heavy woods often contain 30 to 40 percent moisture in the green condition, compared to as much as 300 percent or more in some very light woods such as balsa.

Water is present in wood in two forms; as free water in the cell cavities and intercellular spaces of the wood and as absorbed water held in the walls of the wood elements. When the free water is removed but all the absorbed water remains in the cell walls, the wood is said to hare reached the fiber saturation point. This condition occurs at about 30 percent moisture content but may vary considerably between species. Shrinkage does not occur in wood until this point has been reached. However, as a piece of wood dries, the outer part is reduced to a moisture content below the fiber saturation point sooner than the interior. Consequently, the whole piece may show some shrinkage near the surface before the average moisture content reaches the fiber saturation point.

Wood shrinks as it loses moisture below the fiber saturation point. Wood that, has reached the air-dry condition at. 15 percent moisture content has undergone about half the shrinkage possible. For each 1 percent loss of moisture-below the fiber saturation point (30 percent moisture content), wood shrinks about, one-thirtieth of the total possible shrinkage. Shrinkage values are normally calculated and reported as the total shrinkage from green to ovendry wood, and expressed as a percent, of the original green volume.

For Caribbean timbers, shrinkage values are presented on this basis in table 4, and in the sections discussing shrinkage of the timbers in the text. Shrinkage from green to 15 percent moisture content (the air-dry moisture content often used for timbers in this area) amounts to half the total shrinkage. Shrinkage to 10 percent and 20 percent moisture contents amounts to $^2/_3$ and $^1/_3$ of the total shrinkage respectively.

Wood generally shrinks about twice as much in the direction of growth rings (tangential) as across the growth rings (radial) and very little along the grain (longitudinal). Consequently, wood that contains cross grain (interlocked) or irregular grain will shrink more longitudinally than straight-grained wood because of the tangential and radial surfaces. The total shrinkage in all directions quoted as one sum is termed volumetric shrinkage.

The relationship of radial shrinkage to tangential shrinkage is often an indication of the inherent tendency of a wood to cup and otherwise distort during seasoning. Generally, woods that have a low ratio of tangential to radial shrinkage season with less cupping and other defects than woods with a higher ratio. Likewise, because of the greater shrinkage in the direction of the growth rings, "flat-sawed" or "plainsawed" boards are more a t to cup and surface check than "quartersawed" or "edge-grained" boards. Flat-sawed boards are also subject to greater shrinkage across the surface and less in thickness than quartersawed boards.

In genera!, heavier pieces of wood shrink more than lighter pieces of the same species. There are, however, many exceptions where heavy species shrink less than those that weigh less and where lightweight woods have large shrinkage values. Recent studies at. Yale University *(250)* show that tropical woods, with few exceptions, undergo lower shrinkage than United States woods of similar density. They found no correlation between volumetric shrinkage and specific gravity, indicating something other than weight was the dominant factor controlling shrinkage.

Shrinkage during drying is to some extent a criterion of subsequent shrinkage and swelling that will occur in the wood as a result of changes in atmospheric conditions. Wood is exposed to continuous daily and seasonal changes in relative humidity. Its tendency to absorb or give off moisture to come into balance with the surrounding air is accompanied by swelling or shrinking of the wood. This movement may be in the same proportions as the initial shrinkage in seasoning. In the absence of specific movement values, it IS reasonable to assume a dimensional change of one-thirtieth of the shrinkage from green to ovendry for each l-percent change in moisture content. However, recent studies at the Forest Products Research Laboratory in England show that all woods do not undergo dimensional changes in response to changed atmospheric conditions in proportion to their initial shrinkage values (108). They found that some woods shrink appreciably in drying, yet may undergo comparatively small dimensional changes in use.

TABLE 4.— *Shrinkage properties of Caribbean timbers*

Trade name	Scientific name	Shrinkage-green to ovendry			
		Radial	Tangential	Longitu-dinal	Volumetric
		Percent	*Percent*	*Percent*	*Percent*
Angelin	*Andira inermis*	3. 6	7. 1	0. 24	10. 6
Angelique	*Dicorynia guianensis*	4. 6	8. 2	. 16	14. 0
Baboen	*Virola surinamensis*	5. 3	12. 4	....	17. 6
Bagasse	*Bagassa guianensis*	5. 2	6. 6	. 09	10. 2
Balata	*Manilkara bidentata*	6. 3	9. 4	. 23	16. 9
Balsa (17 lbs./cu. ft.)	*Ochroma pyramidale*	3. 0	7. 6	. 47	10. 8
Banak	*Virola koschnyi*	4. 8	13. 4	....	....
Baromalli	*Catostemma fragrans*	5. 4	11. 7	....	17. 1
Bethabara	*Tabebuia serratifolia*	6. 6	8. 0	. 16	13. 2
Cedar, Central American	{*Cedrela guianensis*				
	C. odorata	4. 1	4. 9	....	8. 9
	C. mexicana				
Courbaril	{*Hymenaea courbaril*	4. 5	8. 5	. 27	12. 7
	H. davisii	4. 1	7. 6	. 51	14. 8
Crabwood	*Carapa guianensis*	3. 1	7. 6	. 10	10. 4
Determa	*Ocotea rubra*	3. 7	7. 6	. 26	10. 4
Gommier	*Dacryodes excelsa*	4. 1	6. 4	. 24	10. 5
Greenheart, Demerara	*Ocotea rodiaei*	8. 2	9. 6	....	16. 8
Gronfoeloe	{*Qualea rosea*	4. 4	8. 4	. 08	11. 4
	Q. coerula	3. 7	7. 9	....	....
	Q. albiflora	4. 0	7. 7	. 14	12. 7
Gumbo-limbo	*Bursera simaruba*	2. 3	3. 6	....	8. 6
Hura	*Hura crepitans*	2. 7	4. 5	. 48	7. 3
Kereti silverballi	*Ocotea wachenheimii*	3. 6	7. 2	....	....
Kopie	*Goupia glabra*	4. 5	8. 0	8. 18	12. 6
Kurokai	*Protium schomburgkianum*	4. 2	6. 8	....	10. 7
Kwarie	{*Vochysia guianensis*	4. 8	8. 2	. 07	15. 4
	V. tomentosa	2. 5	8. 8	....	....
Mahogany, Honduras:	*Swietenia macrophylla*				
Forest-grown	....	3. 1	4. 2	....	7. 6
Plantation-grown	....	2. 4	4. 2	. 42	6. 6
Mahogany, West Indies	*Swietenia mahagoni*	4. 6	5. 4	....	6. 9
Manbarklak	*Eschweilera subglandulosa*	5. 8	10. 3	. 28	15. 9
Manni	*Symphonia globulifera*	5. 7	9. 7	. 15	15. 6
Manniballi	*Inga alba*	3. 1	7. 2	....	....
Marblewood	*Marmaroxylon racemosum*	....	....	....	14. 3
Marish	{*Licania buxifolia*	7. 5	11. 7	. 21	17. 2
	L. macrophylla	6. 8	10. 6	. 31	16. 2
Mora	*Mora excelsa*	6. 9	9. 8	. 36	18. 8
Nargusta	*Terminalia amazonia*	4. 8	7. 9	. 18	12. 7
Pakuri	*Platonia insignis*	....	....	....	17. 3
Pine, Caribbean	*Pinus caribaea*	6. 3	7. 8	....	12. 9
Purpleheart	*Peltogyne pubescens*	5. 8	8. 4	....	13. 2
Roble	{*Tabebuia rosea*	3. 6	6. 1	. 16	9. 5
	T. heterophylla	4. 1	5. 5	. 28	9. 7
Rosewood, Honduras	*Dalbergia stevensonii* [1]	2. 9	4. 6	. 34	7. 2
Saman	*Pithecellobium saman*	2. 9	4. 4	. 26	7. 1
Santa-maria	*Calophyllum brasiliense*	4. 8	7. 1	. 03	12. 3
Simarouba	*Simarouba amara*	2. 3	5. 0	. 27	8. 0
Sterculia	*Sterculia pruriens*	5. 7	9. 2		13. 6
Suradan	*Hyeronima laxiflora*	5. 3	9. 4	. 34	14. 4
Tabebuia, white	{*Tabebuia insignis* var. *monophylla*}	5. 8	7. 7		13. 7
	T. stenocalyx				
Tatabu	*Diplotropis purpurea*	4. 6	7. 0	. 15	11. 8
Tauroniro	*Humiria balsamifera*	7. 2	9. 7	. 09	15. 7
Teak:					
Forest-grown	*Tectona grandis*	2. 3	4. 2		6. 8
Plantation-grown	*Tectona grandis*	2. 1	4. 6	. 37	5. 1
Tonka	*Dipteryx odorata*	5. 0	7. 6	. 13	12. 0
Wacapou	*Vouacapoua americana*	4. 9	6. 9	. 12	13. 0
Wallaba	*Eperua falcata*	3. 6	6. 9	. 17	10. 0
Wamara	*Swartzia benthamiana*	....	....		13. 3
Yemeri	*Vochysia hondurensis*	2. 0	8. 0	. 17	9. 8

[1] From *Dalbergia* sp.

Several factors may be responsible for this phenomenon; the most apparent is the difference in the fiber saturation point between species. Those woods having a low fiber saturation point are likely to shrink or swell more than woods having a high fiber saturation point. Another factor is the range in moisture content of the different woods at any given range of atmospheric moisture conditions. The method of seasoning may also affect. the initial shrinkage. It may cause collapse or honeycombing, and thereby change the wood structure enough so that subsequent movements do not correspond to the initial shrinkage values. Other minute but important cellular changes may also occur in seasoning that may alter the wood's response to changes in moisture content.

Shrinkage and movement values have practical application in determining the proper moisture content for woods used in different conditions. Movement values are often important in the selection of wood for certain uses. The preference for teak for ship decking is a prime example of this.

STRENGTH PROPERTIES

The uses for many timbers are based largely on their strength or mechanical properties. Tests of mechanical properties have been conducted on most of the Caribbean timbers discussed in this report. Tables 10 and 11 in the appendix present results of tests for green and air-dry wood for most of the timbers covered in the text. For comparison, data for a number of well-known woods from Europe and the United States are also included.

Tests were made on small clear specimens 2 by 2 inches or smaller in cross section and of specific lengths, according to the test specifications. Standard testing procedures of the American Society for Testing Materials or the "Monnin System" as used in most European countries were followed *(13).* Actually, these values are not safe working stresses because they were obtained for material free from all defects, such as knots, checks, shakes, and distorted grain that have an appreciable effect on the strength of seasoned timber.

Anyone designing timber structures will find table 12 in the appendix of some value, as it shows the maximum allowable stresses for certain tropical timbers under different circumstances. Data for these tables were taken from J. Ph. Pfeiffer's "De Houtsoorten Van Surinam" (Surinam Timbers), v. 2, pp. 192-193 (175). The conversion from kilograms per cubic inch to pounds per cubic inch was computed in the Central Secretariat of the Caribbean Commission (50). Any changes in species botanical names from those listed by Pfeiffer were made in accordance with a more recent publication by the Surinam Forest Service.

As it dries, wood increases in strength *(260)* but not until the fiber saturation point is reached. However, not all strength properties are increased with a decrease in moisture content. In fact, toughness or shock resistance, which is dependent upon both strength and pliability, sometimes decreases as the wood dries. This is largely due to the inability of dry wood to bend as far as green wood before failure, even though it will sustain a greater load.

In general, the strength of wood increases about in proportion to the increase in specific gravity. Thus, in most woods, the heavier of two pieces or species at the same moisture content will be superior in most strength properties. Yet there may be marked differences in certain specific properties between timbers of the same weight due to differences in the structure of the wood. This point is illustrated by the toughness of ash compared to other woods of similar weight.

Strength tests of 126 tropical American hardwoods, conducted at Yale University *(250),* show that tropical timbers in the green condition are usually superior in bending strength, crushing strength, and a number of other properties to hardwoods of similar density growing in the United States. After seasoning, however, the tropical woods generally show less improvement in most strength properties than domestic woods. As a result, tropical woods lose much of their superiority in strength over woods from the United States after air-drying. Also tropical woods are commonly lower in cleavage and tension perpendicular to the grain when air-dried than when green.

The strength properties cited in the tables and discussed later in the timber descriptions are listed below. The descriptions are largely from the Wood Handbook *(242)* and Technical Bulletin 479 *(160)* prepared by the U.S. Forest Products Laboratory.

Fiber stress at proportional limit in static bending.– This property is the measure of the computed stress at, which the strain (or deflection) becomes no longer proportional to the stress (load). It is, therefore, the stress load) at which the load-deflection curve departs from a straight line. This is the upper limit to the stresses or loads that can be used in. the design of permanent structures.

Modulus of rupture in static bending.– This is a measure of the capacity of a beam to support a slowly applied load for a short time. Of particular importance in timbers subject to transverse bending, it is used to determine the safe working stresses (loads) for timbers of different species and with certain defects.

Modulus of elasticity in static bending.– A measure of stiffness or rigidity. In a beam, the modulus of elasticity is a measure of its resistance to deflection (bending); hence, the greater the stiffness the less the deflection. It is useful for computing the deflection of beams, joists, and stringers under loads that do not cause stresses beyond the proportional limit. It, is also used in computing the load that can be carried by a long column.

Work to proportional limit in static bending.` A measure of the energy absorbed by *a* beam when it is stressed to the proportional limit. While the values cannot, be used directly in strength calculations. they are a comparative measure of the toughness of a piece to the elastic limit. It is also a value by which different species can be compared in their ability to absorb shock without permanent damage.

Work to maximum load in static bending.– The ability of timber to absorb shock with some permanent deformation and more or less injury to the timber. It is a measure of combined strength and toughness of wood under bending stresses, and is of particular importance where timbers are subjected to considerable bending under heavy loads.

Fiber stress at proportional limits in *compression parallel to the* grain.-The greatest stress at which the compressive load remains proportional to the shortening of the specimen. This property helps to determine safe working stresses for short columns as well as design values for bolted joints and similar values.

Maximum crushing strength in compression parallel to the grain.– The maximum capacity of a short, piece to withstand loads applied on the end grain. It is a means to estimate the endwise crushing of wood in short structural timbers, design of bolted joints, and other similar uses in the development of safe working stresses. It is of considerable importance where short columns or props are to be used.

Modulus of elasticity in compression parallel to the grain.– A measure of stiffness useful in calculating the strength of long columns.

Hardness.– Represents the resistance of wood to wear and marring. Values are presented for end-grain surfaces and side-grain surfaces. Side-grain values are the calculated average for the radial and tangential surfaces combined. Hardness is important when timber is used for such purposes as flooring, furniture, paving blocks, bearing blocks, and railway ties.

Compression perpendicular to grain-fiber stress at proportional limit.– The maximum across-the-grain stress of a few minutes duration that can be applied through a plate covering only part of a timber surface without causing injury to the timber. It is especially useful in deriving safe working stresses for computing the bearing area for beams, stringers, and joists and in comparing species for railway ties.

Tension perpendicular to grain.– An expression of the average maximum stress sustained across the grain by the wood. It is useful in comparing species and for estimating the resistance of timber to forces acting across the grain.

Shear (parallel to the grain) .– A measure of the ability of timber to resist slipping of one part upon another along the grain. It is an important property in beams, where the stress tends to cause the upper half of the beam to slide upon the lower and in timbers fastened by bolts and other connectors.

Cleavage.–The maximum load required to cause splitting. It is an important factor where timbers are nailed or bolted. However, a low cleavage value can be advantageous where timbers must, be split prior to use.

Toughness.– A measure of the ability of a wood to withstand shock or impact loads. It is a means of comparing species and of selecting stock of known properties, particularly when used in conjunction with specific gravity.

WORKING PROPERTIES

The working properties of the different timbers are often an important factor in their selection for specific uses. These properties are important when either hand or machine tools are used, for timbers vary in their workability as they do in other properties. The section on working properties for each timber summarizes the published information concerning the various operations in woodworking. Unless otherwise stated, the descriptions are for air-dry timber, ordinarily from 12 to 18 percent moisture content. One general exception are the tests at the U.S. Forest. Products Laboratory in which wood was seasoned to 6 percent moisture before testing (68).

Table 5 lists the different timbers by their working qualities, including the ease with which the timbers can be sawed or machined, as well as the quality or grade of the machined surface. A wood that works with considerable ease but produces many defective pieces would not be classed as a timber that is "easy to work." However, the more dense woods tend to be more difficult to machine.

In the absence of a specific method for rating the different working properties, the ratings are based on the general opinion and experience of woodworkers and research technicians as reported in various publications. Consequently, a timber at the bottom of one class may not be much different from one in the top of the next lower class.

The machining tests on Caribbean timbers hare usually been made under standard working conditions on commercial machines. Ordinarily developed for timber of average properties, these working conditions are often not entirely suitable for very dense or light timber, or for those woods having a particular machining problem. Consequently, the working properties of many timbers can be improved under different or special ma-

TABLE 5.– *Classification of Caribbean timbers as to their working properties*

Trade name	Scientific name
EASY TO WORK	
Angelin	*Andira* spp. *A. inermis*
Angelique	*Dicorynia guianensis*
Baboen	*Virola surinamensis*
Bagasse	*Bagassa guianensis* *B. tiliaefolia*
Balsa	*Ochroma pyramidale*
Banak	*Virola koschnyi*
Broadleaf	*Terminalia latifolia*
Bustic	*Dipholis* spp.
Cedar, Central American.	*Cedrela guianensis* *C. mexicana* *C. odorata*
Crabwood	*Carapa guianensis*
Determa	*Ocotea rubra*
Dukali	*Parahancornia amapa*
Encens	*Protium attenuatum*
Gommier	*Dacryodes excelsa*
Gumbo-limbo	*Bursera simaruba*
Haiari	*Alexa imperatricis* *A. leiopetala*
Hura	*Hura crepitans*
Inyak	*Antonia ovata*
Kereti silverballi	*Ocotea wachenhemii* *O. puberula*
Kurokai	*Protium crenatum* *P. decandrum* *P. sagotianum* *P. schomburgkianum*
Magnolia	*Talauma dodecapetala*
Mahoe	*Hibiscus elatus*
Mahogany, Honduras.	*Swietenia macrophylla*
Mahogany, West Indies.	*Swietenia mahagoni*
Manni	*Symphonia globulifera*
Manniballi	*Inga alba*
Parakusan	*Swartzia jenmanii* *S. polyphylla* *S. schomburgkii*
Pine, Caribbean	*Pinus caribaea*
Podocarp	*Podocarpus coriaceus* *P. guatemalensis*
Resolu	*Chimarrhis cymosa*
Roble	*Tabebuia heterophylla* *T. rosea*
Saman	*Pithecellobium saman*
Santa-maria	*Calophyllum brasiliense* *C. lucidum*
Sara	*Vouacapoua macropetala*
Simarouba	*Simarouba amara* *S. glauca*
Sterculia	*Sterculia pruriens* *S. caribaea* *S. rugosa*
Tabebuia, white	*Tabebuia insignis* var. *monophylla* *T. stenocalyx*
Teak	*Tectona grandis*
Yokewood	*Catalpa longissima*
MODERATELY DIFFICULT TO WORK	
Aromata	*Clathrotropis brachypetala* *C. macrocarpa*
Balata	*Manilkara bidentata*
Baromalli	*Catostemma commune* *C. fragrans*
Bethabara	*Tabebuia serratifolia*
Bullhoof	*Drypetes brownii*
Courbaril	*Hymenaea courbaril* *H. davisii*
Dakama	*Dimorphandra conjugata*
Greenheart, Demerara.	*Ocotea rodiaei*
Gronfoeloe	*Qualea rosea* *Q. albiflora*
Kopie	*Goupia glabra*
Mora	*Mora excelsa* *M. gongrijpii*
Nargusta	*Terminalia amazonia*
Pakuri	*Platonia insignis*
Purpleheart	*Peltogyne pubescens* *P. porphyrocardia* *P. venosa* var. *densiflora*
Suradan	*Hyeronima laxiflora* *H. alchorneoides* *H. caribaea* *H. clusioides*
Tatabu	*Diplotropis purpurea*
Tauroniro	*Humiria balsamifera*
Wacapoua	*Vouacapoua americana*
Wallaba	*Eperua falcata* *E. grandiflora* *E. jenmanii* *E. schomburgkiana*
Wamara	*Swartzia leiocalycina* *S. benthamiana*
DIFFICULT TO WORK	
Bois gris	*Licania ternatensis*
Kauta	*Licania laxiflora* *L. mollis* *L. persaudii*
Kautaballi	*Licania venosa* *L. majuscula*
Kwarie	*Vochysia guianensis* *V. tomentosa*
Lignumvitae	*Guaiacum officinale* *G. sanctum*
Manbarklak	*Eschweilera longipes* *E. subglandulosa*
Marblewood	*Marmaroxylon racemosum*
Marish	*Licania buxifolia* *L. macrophylla* *L. densiflora* *L. micrantha*
Rosewood, Honduras.	*Dalbergia stevensonii*
Snakewood	*Piratinera guianensis*
Tonka	*Dipteryx odorata*
Yemeri	*Vochysia hondurensis*

chining conditions. Changing the cutting angle, feed rate, spindle or rim speed, or using special cutters or saw blades can often improve the machinability of a timber. Tests at the U.S. Forest Products Laboratory have indicated that "in general the tropical hardwoods machined as well as do our native hardwoods and with most of them at least. it seems unlikely that machining difficulties would restrict their use much" (*68*).

RESISTANCE TO DECAY

The ability to resist decay is important when woods are selected for certain uses, but it is of little consequence where the wood will not be subject to conditions favorable for decay. Decay is an ever-present hazard in the tropics where the conditions of moisture and temperature are ordinarily ideal for the development of fungi. Unless preservative treatment is applied, only timbers with considerable decay resistance should be used for posts, poles, railway ties, foundations, and other uses. where the timber may become damp or wet. Decay resistance is not important where wood is used for furniture, cabinetwork, millwork, and other interior or protected uses. Then too, wood will not ordinarily decay in exterior uses where it is subject to frequent wetting, unless the construction is such that the wood is prevented from drying out after each wetting.

Most decay occurs in wood with a moisture content above the fiber saturation point–about 30 percent moisture content. On the other hand, wood that is continuously water soaked or continuously dry will not decay. Thus, the underwater portion of piling and bridgework or air-dry timber at 20 percent or less moisture content is safe from damage. Wood kept at the air-dry moisture content of 15 to 20 percent in the Caribbean area is, consequently, in no danger of decay. However, decay is almost certain to occur if the construction allows any part of a board or timber to remain wet for long periods of time.

The description in the text of the decay resistance of each timber is based on the durability of untreated heartwood, which is more durable than sapwood. It is doubtful if the sapwood of any species is durable without preservative treatment. Information on durability was available from published results of graveyard tests, pure culture laboratory tests, and from published observations on the durability of the different woods while in use.

Information derived from graveyard tests, in which untreated heartwood posts of tropical species (either round or square) are set in the ground and inspected periodically for decay, is available from Surinam, British Guiana, Trinidad, St. Lucia, Panama, Puerto Rico, England, and the United States. The results sometimes vary between countries but are generally in good agreement.

In pure culture tests small heartwood specimens are exposed to fungal attack under closely controlled laboratory conditions, and the relative durability of different woods is determined on the basis of the loss in weight through decay. The results of these tests at Yale University and the U.S. Forest Products Laboratory are in very good agreement. However, the results of graveyard tests and pure culture tests are not in agreement for some timbers. When this occurs, the laboratory tests generally show the higher decay resistance. It appears that the laboratory tests conducted under closely controlled conditions may be the most reliable. In the laboratory, it is not difficult to distinguish heartwood from sapwood; but in graveyard tests, it is sometimes very difficult in timbers without, well-defined heartwood to be certain whether the posts used contain heartwood or sapwood. This may be the reason for some of the discrepancies between different graveyard tests.

Table 6 lists the timbers by durability classes, according to the published results of field and laboratory tests. Four classifications are used: Very resistant, resistant, moderately resistant, and nonresistant. When authors report differences in tests and results, the most consistent or reliable rating is used. Timbers reported to be quite variable in durability and those rated on the basis of general reputation alone are indicated by footnotes.

RESISTANCE TO ATTACK BY TERMITES AND OTHER INSECTS

The sections on durability in the timber descriptions contain a brief summary of the published information on damage by wood-attacking insects. Unfortunately, very little information is available concerning insect attack on the Caribbean timbers except for the comprehensive laboratory tests conducted by G. N. Wolcott (*262, 263*) on the resistance of woods to attack by the West Indian dry-wood termite (*Cryptotermes brevis* Walker) and a less comprehensive study of damage by subterranean termites of Trinidad timbers *(39).* Most information on other insect damage to logs and sawed products is based on casual observations and experience which, although generally reliable, is often influenced by local conditions peculiar to a small area.

The most common wood-attacking insects in the Caribbean region are the ambrosia beetles (Scolytidae and Platypodidae), both dry-wood and subterranean termites (Order Isoptera), and powder-post beetles (Bostrychidae and Lyctidae). Ambrosia beetles, more often called pinhole borers, are a common menace in green logs and lumber and sometimes attack living trees. Both unseasoned sapwood or heartwood may be attacked. Attack by these insects is evidenced by numerous holes $^{1}/_{50}$ to $^{1}/_{8}$ inch in diameter, according to the species of pinhole borer responsible. Entry of pinhole borers is often associated with staining of the wood around the holes. Damage by this insect is liable to be severe if logs are not converted soon after felling or if they are not protected by insecticide sprays.

Attack ceases when the timber is seasoned. Damage can be prevented in freshly sawed lumber or living beetles destroyed by dipping the product in a water solution containing 0.2 percent of gamma benzene hexachloride. It is also a common practice to include in the same solution an ingredient to prevent sap stain and keep the lumber bright.

TABLE 6.—*Classification of Caribbean timbers as to their resistance to decay*

Trade name	Scientific name
VERY RESISTANT TO DECAY	
Bagasse	*Bagassa guianensis* *B. tiliaefolia*
Balata	*Manilkara bidentata*
Bethabara	*Tabebuia serratifolia*
Greenheart, Demerara.	*Ocotea rodiaei*
Haiari	*Alexa imperatricis* *A. leiopetala*
Lignumvitae	*Guaiacum officinale* *G. sanctum*
Mahogany, West Indies.	*Swietenia mahagoni*
Manbarklak	*Eschweilera longipes* *E. subglandulosa*
Rosewood, Honduras	*Dalbergia stevensonii*
Snakewood	*Piratinera guianensis*
Tatabu [1]	*Diplotropis purpurea*
Tonka	*Dipteryx odorata*
Wacapou	*Vouacapoua americana*
Wallaba	*Eperua falcata* *E. grandiflora* *E. jenmanii* *E. schomburgkiana*
Wamara	*Swartzia leiocalycina* *S. benthamiana*
RESISTANT TO DECAY	
Angelin	*Andira* spp. *A. inermis*
Angelique	*Dicorynia guianensis*
Bois gris [2]	*Licania ternatensis*
Bustic [2]	*Dipholis* spp.
Cedar, Central American.[1]	*Cedrela mexicana* *C. odorata* *C. guianensis*
Courbaril	*Hymenaea courbaril* *H. davisii*
Determa	*Ocotea rubra*
Kopie	*Goupia glabra*
Mahoe [2]	*Hibiscus elatus*
Mahogany, Honduras.	*Swietenia macrophylla*
Manni	*Symphonia globulifera*
Marblewood [2]	*Marmaroxylon racemosum*
Mora	*Mora excelsa* *M. gonggrijpii*
Nargusta	*Terminalia amazonia*
Pakuri [2]	*Platonia insignis*
Pine, Caribbean	*Pinus caribaea* (also moderately resistant).
Podocarp	*Podocarpus coriaceus* *P. guatemalensis*
Purpleheart	*Peltogyne pubescens* *P. porphyrocardia* *P. venosa* var. *densiflora*
Resolu [2]	*Chimarrhis cymosa*
Roble	*Tabebuia heterophylla* *T. rosea*
Saman	*Pithecellobium saman*
Santa-maria [1]	*Calophyllum brasiliense* *C. lucidum*
Suradan	*Hyeronima laxiflora* *H. alchorneoides* *H. caribaea* *H. clusioides*
Teak	*Tectona grandis*
Yokewood [2]	*Catalpa longissima*
MODERATELY RESISTANT TO DECAY	
Aromata	*Clathrotropis brachypetala* *C. macrocarpa*
Broadleaf	*Terminalia latifolia*
Bullhoof	*Drypetes brownii*
Cedar, Central American.[1]	*Cedrela mexicana* *C. odorata* *C. guianensis*
Crabwood [1]	*Carapa guianensis*
Dakama [2]	*Dimorphandra conjugata*
Gommier	*Dacryodes excelsa*
Gronfoeloe	*Qualea rosea* *Q. coerula* *Q. albiflora*
Hura	*Hura crepitans*
Inyak	*Antonia ovata*
Kautaballi	*Licania venosa* *L. majuscula*
Kereti silverballi	*Ocotea wachenheimii* *O. puberula*
Kwarie [1]	*Vochysia guianensis* *V. tomentosa*
Magnolia [2]	*Talauma dodecapetala*
Marish	*Licania macrophylla* *L. densiflora* *L. micrantha*
Parakusan [2]	*Swartzia jenmanii* *S. polyphylla* *S. schomburgkiana*
Pine, Caribbean	*Pinus caribaea* (also resistant)
Sara	*Vouacapoua macropetala*
Tabebuia, white	*Tabebuia insignis* var. *monophylla* *T. stenocalyx*
Tauroniro	*Humiria balsamifera*
Yemeri [1]	*Vochysia hondurensis*
NONRESISTANT TO DECAY	
Baboen	*Virola surinamensis*
Banak	*Virola koschnyi*
Balsa	*Ochroma pyramidale*
Baromalli	*Catostemma fragrans* *C. commune*
Dukali [1]	*Parahancornia amapa*
Encens	*Protium attenuatum*
Gumbo-limbo	*Bursera simaruba*
Kauta	*Licania laxiflora* *L. mollis* *L. persaudii*
Kurokai	*Protium crenatum* *P. decandrum* *P. sagotianum* *P. schomburgkianum*
Manniballi	*Inga alba*
Simarouba [1]	*Simarouba amara* *S. glauca*
Sterculia	*Sterculia pruriens* *S. rugosa* *S. caribaea*

[1] Variable in decay resistance. [2] Based on reputation for durability; not substantiated by research.

Subterranean termites are a more widespread menace in the Caribbean area than the dry-wood termite. Subterranean termites develop and maintain their colonies in the ground, but reach their food supply by building tunnels through the earth and over obstructions to the wood above. The must keep contact with the ground or perish for lack of moisture. Although this insect often works in obscure locations, the presence of the above-ground tunnels signifies their presence. Termites can be controlled by thoroughly poisoning the soil beneath and adjacent to wooden structures, by placing barriers or shields between the ground and wooden members, or by using treated or termite-resistant wood.

Dry-wood termites are more difficult to control than subterranean termites because they are able to exist concealed in either damp or dry wood without contact with the ground. Consequently, their depredations are often severe before their presence is noted; and once found, they are still difficult to exterminate except by thorough fumigating. Most control methods, such as dipping infested wood in insecticides and injecting poisonous dust or solutions into the nests or tunnels, are not successful in the Caribbean areas, where these insects are the most active.

Attack by the winged adults can be controlled by full-length treatment of all wood with wood preservatives or insecticides or by using wood having a. high natural resistance to their attack. However, the slow volatization of many preservatives eventually reduces their toxicity to a point where the termites can survive. In the absence of other treatments, a heavy unbroken coverage of paint or other similar material will normally prevent the entrance of dry-wood termites.

The timbers are rated in table 7 according to their resistance to attack by both dry-wood and subterranean termites. These ratings are based largely on work by Wolcott in Puerto Rico (*262*, 263) and Brooks, Adamson, Baker, and Crowdy in Trinidad *(39)*. Ratings not substantiated b research are so indicated. In all woods examined, their respective ratings are based on the resistance of heartwood to termite attack as the sapwood of all species is considerably more susceptible to attack than the heartwood. Where the published information indicates a difference in a timber's resistance to dry-wood and subterranean termites, the lower rating was usually accepted. These differences are generally discussed in the sections on insect attack of the respective timbers.

Powder-post beetles attack either freshly cut or seasoned wood of both softwoods and hardwoods, but generally prefer the sapwood of timber having pores of sufficient size for the female to deposit her eggs. Larvae emerging from these eggs burrow through the wood, leaving tunnels $^{1}/_{16}$ to $^{1}/_{12}$ of an inch in diameter, which are packed with a fine powder. The packed, fine powder serves as a means of identification. Later, small holes are left in the surface of the wood when the winged adults emerge. Powder-post infestations can be prevented or controlled by sterilizing the wood with steam or by soaking it in DDT, pentachlorophenol, or other suitable insecticide.

Tropical hardwoods may also be attacked by wood-boring grubs, roundheaded borers, flatheaded borers, and other wood-boring insects. As a rule, they are considerably less destructive than the insects discussed above.

RESISTANCE TO MARINE BORERS

No timber is known to be entirely resistant to marine borers or teredo. A number of Caribbean timbers do exhibit a high resistance to these marine animals. However, the service life of these timbers is often influenced by local conditions and the particular species of marine borers present. Of course, resistance of timbers to marine boring animals is important only when the timber is used in salt or brackish waters. Timbers that show high resistance to teredo in Caribbean waters are sometimes far less resistant along the Atlantic coast of the United States or in the vicinity of Hawaii. Similarly, timbers may vary in their resistance between salt and brackish waters. These differences are considered to be the result of different types and species of marine borers from one place to another.

The silica content of the wood may be important in resistance to marine borers as many of the most resistant woods contain appreciable amounts of silica. One explanation may be that the high silica content wears down or blunts the teeth of the boring apparatus of the mollusk, thereby preventing his penetration into the wood. However, some nonsilicious woods exhibit considerable resistance to marine borers, indicating other factors may also have an effect on a timber's natural resistance.

The most practical protection for piling and other timbers used in sea water is heavy treatment with coal-tar creosote or creosote-coal-tar solution. Concrete casing or metal armor that prevents the marine borers from attaching themselves to the wood is also used with success.

Resistance of the different timbers to marine borers is covered in the sections on durability and is summarized in table 8, in which the timbers are rated by classes of resistance-high, moderate, and low. This information was principally available from recent tests made in Hawaii, the Canal Zone, and along the Atlantic coast of the United States. Also identified in the table are timbers rated by reputation rather than by research, and those that exhibit considerable variability in resistance to marine borers. Further research may change many of these ratings.

TABLE 7.– *Classification of Caribbean timbers as to their resistance to termite attack*

Trade name	Scientific name
VERY RESISTANT TO TERMITES	
Balata	*Manilkara bidentata*
Bethabara	*Tabebuia serratifolia*
Courbaril	*Hymenaea courbaril* *H. davisii*
Greenheart, Demerara.	*Ocotea rodiaei*
Lignumvitae	*Guaiacum officinale* *G. sanctum*
Mahogany, West Indies.	*Swietenia mahagoni*
Manbarklak	*Eschweilera longipes* *E. subglandulosa*
Mora	*Mora excelsa* *M. gonggrijpii*
Purpleheart	*Peltogyne pubescens* *P. porphyrocardia* *P. venosa* var. *densiflora*
Snakewood	*Piratinera guianensis*
RESISTANT TO TERMITES	
Angelin	*Andira* spp. *A. inermis*
Bois gris [1]	*Licania ternatensis*
Cedar, Central American.	*Cedrela mexicana* *C. odorata* *C. guianensis*
Kauta [1]	*Licania laxiflora* *L. mollis* *L. persaudii*
Kautaballi [1]	*Licania venosa* *L. majuscula*
Kopie	*Goupia glabra*
Marblewood	*Marmaroxylon racemosum*
Marish	*Licania buxiflora* *L. macrophylla* *L. densiflora* *L. micrantha*
Nargusta	*Terminalia amazonia*
Pakuri	*Platonia insignis*
Pine, Caribbean [2]	*Pinus caribaea*
Resolu [1]	*Chimarrhis cymosa*
Saman	*Pithecellobium saman*
Tatabu	*Diplotropis purpurea*
Tauroniro	*Humiria balsamifera*
Teak	*Tectona grandis*
Wacapou	*Vouacapoua americana*
Wallaba	*Eperua falcata* *E. grandiflora* *E. jenmanii* *E. schomburgkiana*
Wamara	*Swartzia leiocalycina* *S. benthamiana*
MODERATELY RESISTANT TO TERMITES	
Angelin	*Andira inermis*
Angelique	*Dicorynia guianensis*
Aromata	*Clathrotropis brachypetala* *C. macrocarpa*
Broadleaf [1]	*Terminalia latifolia*
Bullhoof	*Drypetes brownii*
Determa	*Ocotea rubra*
Gronfoeloe	*Qualea rosea* *Q. coerula* *Q. albiflora*
Kereti silverballi	*Octotea wachenheimii* *O. puberula*
Kwarie	*Vochysia guianensis* *V. tomentosa*
Mahogany, Honduras.	*Swietenia macrophylla*
Magnolia [1]	*Talauma dodecapetala*
Manni	*Symphonia globulifera*
Suradan	*Hyeronima laxiflora* *H. alchorneoides* *H. caribaea* *H. clusioides*
Yokewood	*Catalpa longissima*
VERY SUSCEPTIBLE TO TERMITES	
Baboen	*Virola surinamensis*
Balsa	*Ochroma pyramidale*
Banak	*Virola koschnyi*
Baromalli	*Catostemma commune* *C. fragrans*
Dukali [1]	*Parahancornia amapa*
Encens [1]	*Protium attenuatum*
Gommier	*Dacryodes excelsa*
Gumbo-limbo	*Bursera simaruba*
Hura	*Hura crepitans*
Kopie	*Goupia glabra*
Kurokai	*Protium crenatum* *P. decandrum* *P. sagotianum* *P. schomburgkianum*
Manniballi	*Inga alba*
Roble	*Tabebuia heterophylla* *T. rosea*
Santa-maria	*Calophyllum brasiliense* *C. lucidum*
Simarouba	*Simarouba amara* *S. glauca*
Sterculia	*Sterculia pruriens* *S. caribaea* *S. rugosa*
Tabebuia, white	*Tabebuia insignis* var. *monophylla* *T. stenocalyx*
Yemeri	*Vochysia hondurensis*

[1] Rating based on reputation or resistance of closely related species.

[2] Resistance dependent on resin content in wood.

PERMEABILITY

The preservative treatment of wood, especially that, used in the ground or in damp or exposed locations, often lengthens the life of the wood as much as five times. However, the treatment value depends primarily on the kind of preservatives used, the depth to which it penetrates into the wood, and the amount'of the preservative retained in the wood after treatment.

Thus, the resistance of a wood to impregnation by preservatives is of primary importance. Unfortunately, this property cannot be determined from the superficial appearance of the timber, but must be gotten by carefully controlled tests in the laboratory.

Little, is known concerning the resistance of the different Caribbean timbers to the penetration of preservatives. Available information on this subject is included in the timber descriptions

TABLE 8.—*Classification of Caribbean timbers as to their resistance to marine borers*

Trade name	Scientific name
HIGH RESISTANCE	
Kauta	*Licania laxiflora* *L. mollis* *L. persaudii*
Kautaballi	*Licania venosa* *L. majuscula*
Lignumvitae	*Guaiacum officinale* *G. sanctum*
Manbarklak	*Eschweilera longipes* *E. subglandulosa*
Marish	*Licania buxifolia* *L. macrophylla* *L. densiflora* *L. micrantha*
Suradan	*Hyeronima laxiflora*
Wacapou	*Vouacapoua americana*
MODERATE RESISTANCE	
Angelin	*Andira* spp. *A. inermis*
Angelique	*Dicorynia guianensis*
Bagasse	*Bagassa guianensis* *B. tiliaefolia*
Bois gris [1]	*Licania ternatensis*
Bustic [1]	*Dipholis salicifolia* *D.* spp.
Crabwood [1]	*Carapa guianensis*
Determa	*Ocotea rubra*
Greenheart, Demerara.[2]	*Ocotea rodiaei*
Snakewood	*Piratinera guianensis*
Suradan	*Hyeronima clusioides*
LOW RESISTANCE	
Baboen	*Virola surinamensis*
Balata	*Manilkara bidentata*
Balsa	*Ochroma pyramidale*
Banak	*Virola koschnyi*
Bethabara	*Tabebuia serratifolia*
Broadleaf [1]	*Terminalia latifolia*
Cedar, Central American.	*Cedrela mexicana* *C. odorata* *C. guianensis*
Courbaril	*Hymenaea courbaril* *H. davisii*
Dukali [1]	*Parahancornia amapa*
Encens [1]	*Protium attenuatum*
Gommier	*Dacryodes excelsa*
Gronfoeloe [1]	*Qualea rosea* *Q. coerula* *Q. albiflora*
Hura [1]	*Hura crepitans*
Kereti silverballi	*Ocotea wachenheimii* *O. puberula*
Kopie	*Goupia glabra*
Kwarie [1]	*Vochysia guianensis* *V. tomentosa*
Mahogany, Honduras.	*Swietenia macrophylla*
Mahogany, West Indies.	*Swietenia mahagoni*
Manni [1]	*Symphonia globulifera*
Manniballi [1]	*Inga alba*
Marblewood	*Marmaroxylon racemosum*
Mora	*Mora excelsa* *M. gonggrijpii*
Nargusta [1]	*Terminalia amazonia*
Pine, Caribbean	*Pinus caribaea*
Purpleheart	*Peltogyne pubescens* *P. porphyrocardia* *P. venosa* var. *densiflora*
Roble	*Tabebuia heterophylla*
Santa-maria	*Calophyllum brasiliense* *C. lucidum*
Simarouba	*Simarouba amara* *S. glauca*
Sterculia	*Sterculia pruriens* *S. caribaea* *S. rugosa*
Tabebuia, white	*Tabebuia stenocalyx* *T. insignis* var. *monophylla*
Tatabu	*Diplotropis purpurea*
Tauroniro	*Humiria balsamifera*
Teak	*Tectona grandis*
Wallaba	*Eperua falcata* *E. grandiflora* *E. jenmanii* *E. schomburgkiana*
Wamara	*Swartzia leiocalycina* *S. benthamiana*
Yemeri	*Vochysia hondurensis*

[1] Rating based on published reputation or rating of closely related species rather than research results.

[2] Resistance varies according to location. Recent tests indicate this timber is not highly resistant in many areas.

under Permeability. Wherever possible, reference is made to the ease with which a timber absorbs preservatives under both open-tank (nonpressure) and pressure treatments. The absence of a section on permeability in the timber descriptions indicates that reliable information is not available.

Heartwood ordinarily resists preservative treatment more than sapwood, although the sapwood of some timbers is also extremely resistant to preservatives. And when a sapwood resists preservatives, the wood is virtually eliminated from use where decay is a problem, for sapwood is always more susceptible to decay than heartwood. On the other hand, posts and poles with wide easily impregnated sapwood can give good service after thorough treatment, even though the heartwood may be only moderately resistant to decay.

Preservatives are applied by either pressure or nonpressure methods. The various nonpressure processes include the following : (1) Superficial application of preservatives to the wood with brushes or a spray nozzle or by a brief dipping; (2) soaking in preservative oils or steeping in water solutions; (3) diffusion process using waterborne preservatives; (4) various adaptations of the hot-and-cold-bath process; (5) vacuum treatment; and (6) a number of other miscellaneous nonpressure processes. The superficial application of preservatives with brushes or by momentary dips is used to some extent in the Caribbean area and, with an oilborne preservative, may add from 1 to 3 years to the life of wood placed in the ground. However, exposure to the weather or contact with soil or water will quickly leach out a waterborne preservative applied by brush. Such superficial treatments are most successful in those timbers that have little resistance to impregnation.

Other nonpressure methods are used with considerable success, depending on the preservative, the permeability of the timber, and the use of the treated material. Wood can be impregnated as successfully with the hot-and-cold-bath processes, cold soaking and steeping, or some of the other nonpressure methods, as with the pressure processes, if the wood has a low resistance to treatment. The value of preservative treatment depends on the retention and penetration achieved and not on the process used. But, if the wood resists treatment, one of the pressure processes will give better results for they have the advantage of giving more uniform and dependable treatment.

Many preservatives are used with good results. Coal-tar creosote, the most important and most extensively used, is considered the best preservative for general outdoor use in structural timbers and for marine use, but it is not adapted for material that will be painted or where its odor is objectionable. Where creosote is unsuitable, pentachlorophenol and copper napthenate in petroleum oil solutions are substituted extensively. Pentachlorophenol in mineral spirits or other volatile light-colored solvents is gellerally used for window sash, millwork, interior trim, and other material requiring clean, paintable surfaces. Copper naphenate and pentachlorophenol in various grades of petroleum oil are also used extensively for the commericial treatment of lumber, posts, and poles. Both preservatives provide a high degree of protection against decay and termites, but are less effective than creosote against marine borers.

Paintability of wood is affected by the type of petroleum oil used in the treating solutions; usually, the heavier oils of low volatility give the best preservative service but are most likely to interfere with painting. The use of "bloom" preservatives, such as ester gum, is required when pentachlorophenol solutions are used with volatile solvents; bloom preservatives prevent the formation of crystals on the surface of the wood after treatment.

In the United States, several water-repellent preservatives are sold under various trade names for the treatment of millwork and other interior work. Containing either pentachlorophenol or copper napthenate, they are valued for retarding moisture changes in wood and for protection against decay and insects.

Wood preservatives used in water solution are also effective against insects and decay, but are acceptable only n-here the wood will not come in contact with the ground or water. Preservatives of this type include zinc chloride, chromated zinc chloride, Tanalith (Wolman Salts), acid copper chromate (Celcure), and chromated zinc arsenate (Greensalt or Erdalith). These preservatives leave the surfaces clean, paintable, and free from any objectionable odor, but, in general, they are more subject to leaching when exposed to the elements than the oilborne preservatives. However. they are generally more acceptable for inside use than creosote and other preservatives in heavy petroleum oils, and give long service when not exposed to the elements.

WOOD USES

The most common uses for each timber in the countries of origin and in the importing countries when applicable are included in the timber descriptions. The recommended uses for each timber are also discussed in the descriptions and summarized in table 9. These recommendations are made on the basis of the timber's combined physical, mechanical, and machining properties. Only those timbers most suited for each use are cited. although other Caribbean species could be utilized for the same purposes with some success.

The use made of timbers in the countries of their origin is generally a good indication of their usefulness and qualities, but often includes uses for which they are not suited and may omit others for which they are most suited. Timbers are often utilized for many purposes simply because they are readily available in good quantity at moderate prices. Despite the many species growing in most areas of the Caribbean, relatively few are produced in commercial quantities. As a result, some woods are used for certain purposes only, because other timbers better qualified for those uses are not readily available. Nevertheless, the local acceptance of a timber for any specific use over a long period indicates reasonably good service given for that purpose.

SUPPLY

The paragraph on supply in each timber description is based largely on information furnished by interested governments in the Caribbean area. This in no way implies that the timbers are not available from other Central and South American countries. Countries or areas having exportable quantities of the different timbers are listed in this section. Moderate quantities of some timbers many become available from certain other Caribbean islands and countries as the export demand develops, but these are not listed as exportable at this time.

TABLE 9.—*Present and potential uses for Caribbean timbers based on their physical and mechanical properties and accepted uses*

AGRICULTURAL IMPLEMENTS

Angelique Balata Bethabara Bullhoof Bustic Courbaril	Gronfoeloe Kopie Kurokai Mora Parakusan Pine, Caribbean	Purpleheart Roble Santa-maria Sara Suradan Tabebuia, white	Tatabu Tonka Tauroniro Wamara Yokewood

BENT PARTS OR ITEMS

Balata Courbaril	Determa Kopie	Manni Nargusta	Tatabu Tonka

BOAT AND SHIP CONSTRUCTION

Keel and Underwater Structural Parts

Angelique Aromata Bagasse Balata Bethabara Bois gris Courbaril Determa	Greenheart, Demerara [1] Kauta Kautaballi Kopie Lignumvitae Manbarklak [1] Marish Mora	Pine, Caribbean Purpleheart Santa-maria Suradan Tabebuia, white Tatabu Teak Tonka	Wacapou Yokewood

Frames and *Timbers*

Angelin Angelique Aromata Bagasse Balata Bethabara Courbaril	Determa Greenheart, Demerara Mahoe Manni Mora Nargusta Pakuri	Pine, Caribbean Purpleheart Roble Santa-maria Suradan Tabebuia, white Tatabu	Tauroniro Teak Tonka Wamara Yokewood

Planking

Angelique Bagasse Cedar, Central American	Courbaril Determa Mahogany, Honduras	Nargusta Pine, Caribbean Roble	Saman Santa-maria Tabebuia, white Teak

Decking

Angelique Bagasse Courbaril	Nargusta Purpleheart	Roble Tabebuia, white	Teak Wacapou

Finish and Trim

Cedar, Central American Courbaril	Crabwood Mahogany, Honduras	Mahogany, West Indies Purpleheart	Rosewood Santa-maria

BOXES AND CRATES

Baboen Banak Baromalli Crabwood Dukali Encens	Gommier Gumbo-limbo Haiari Hura Inyak Kereti silverballi	Kwarie Manni Manniballi Pakuri Pine, Caribbean Podocarp	Roble Simarouba Sterculia Yemeri

See footnote at end of table.

FRAME CONSTRUCTION

Framing Members for Walls, Floors, Roofs, etc.

Angelin	Determa	Manniballi	Simarouba
Angelique	Dukali	Marish	Sterculia
Aromata	Gommier	Mora	Suradan
Bagasse	Gronfoeloe	Nargusta	Tabebuia, white
Baromalli	Gumbo-limbo	Pine, Caribbean	Tatabu
Bois gris	Haiari	Podocarp	Tauroniro
Broadleaf	Kereti silverballi	Purpleheart	Teak
Bulletwood [Bustic]	Kopie	Resolu	Wacapou
Bullhoof	Kurokai	Roble	Wallaba
Cedar, C. A.	Kwarie	Saman	Wamara
Courbaril	Mahoe	Santa-maria	Yokewood
Crabwood	Manni	Sara	

Exterior Siding, Sheathing, and *Other Exposed Uses*

Angelique	Gumbo-limbo	Pine, Caribbean	Suradan
Aromata	Haiari	Podocarp	Tabebuia, white
Baromalli	Inyak	Purpleheart	Tatabu
Broadleaf	Kereti silverballi	Resolu	Tauroniro
Cedar, C. A.	Kwarie	Roble	Teak
Crabwood	Manni	Saman	Wallaba
Determa	Manniballi	Santa-maria	Yemeri
Dukali	Mora	Simarouba	Yokewood
Gommier	Nargusta	Sterculia	

Inside Sheathing

Baboen	Dukali	Kopie	Santa-maria
Banak	Gommier	Kurokai	Simarouba
Baromalli	Gumbo-limbo	Manni	Sterculia
Broadleaf	Haiari	Manniballi	Suradan
Cedar, C. A.	Hura	Nargusta	Tabebuia, white
Crabwood	Inyak	Pine, Caribbean	Yemeri
Determa	Kereti silverballi	Resolu	

HEAVY CONSTRUCTION (general)

Angelin	Courbaril	Manbarklak	Tatabu
Angelique	Crabwood	Manni	Tauroniro
Aromata	Dakama	Marish	Teak
Bagasse	Determa	Mora	Tonka
Balata	Greenheart, Demerara	Pakuri	Wacapou
Bethabara	Gronfoeloe	Pine, Caribbean	Wallaba
Bois gris	Kauta	Roble	Wamara
Bullhoof	Kautaballi	Santa-maria	Yokewood
Bustic	Kopic	Suradan	

COOPERAGE, SLACK

Baboen	Banak	Manni	

COOPERAGE, TIGHT

Angelique	Broadleaf	Manni	Tauroniro
Baromalli	Determa	Pakuri	Wallaba

FURNITURE AND CABINETWORK

First Grade

Angelin	Crabwood	Mahoe	Saman
Angelique	Determa	Mahogany, Honduras	Santa-maria
Baboen	Encens	Mahogany, W. I.	Tabebuia, white
Bagasse	Gommier	Manni	Tatabu
Balata	Gronfoeloe	Marblewood	Tauroniro
Banak	Hura	Nargusta	Teak
Bethabara	Kopie	Purpleheart	Wacapou
Cedar, C. A.	Kurokai	Roble	Wamara
Courbaril	Magnolia	Rosewood, Honduras	Yokewood

Utility Grade

Baromalli	Kereti silverballi	Manniballi	Simarouba
Dukali	Kwarie	Podocarp	Yemeri

FLOORING

Angelique	Gronfoeloe	Mora	Tabebuia, white
Aromata	Hura	Nargusta	Tatabu
Balata	Kopie	Pine, Caribbean	Teak
Bethabara	Magnolia	Purpleheart	Tonka
Broadleaf	Mahoe	Resolu	Wacapou
Courbaril	Manni	Roble	Yokewood
Crabwood	Manniballi	Santa-maria	
Greenheart, Demerara	Marblewood	Sara	

INTERIOR TRIM AND FINISH

Angelique	Determa	Kurokai	Purpleheart
Baboen	Encens	Magnolia	Roble
Banak	Gommier	Mahoe	Rosewood, Honduras
Baromalli	Gronfoeloe	Mahogany, Honduras	Saman
Broadleaf	Gumbo-limbo	Mahogany, W. I.	Santa-maria
Cedar, C. A.	Haiari	Manni	Simarouba
Courbaril	Hura	Manniballi	Tabebuia, white
Crabwood	Kereti silverballi	Marblewood	Teak
			Yokewood

INSTRUMENTS

Bethabara	Podocarp	Rosewood, Honduras	Wamara
Nargusta	Purpleheart	Simarouba	

MARINE PILING AND CONSTRUCTION (UNDERWATER)

Teredo Infested Waters [1]

Angelique	Determa	Manbarklak	Suradan
Bagasse	Greenheart, Demerara	Marish	Wacapou
Bois gris	Kauta	Pine, Caribbean (with treatment)	
Bustic	Kautaballi		

Nonteredo Waters

Angelin	Bustic	Manbarklak [2]	Tatabu
Angelique [2]	Courbaril	Manni	Tauroniro
Aromata	Determa [2]	Marish	Teak
Bagasse [2]	Greenheart, Demerara [2]	Mora	Tonka
Balata	Gronfoeloe	Pakuri	Wacapou [2]
Bethabara	Kauta [2]	Pine, Caribbean	Wallaba
Bois gris [2]	Kautaballi [2]	Santa-maria	Wamara
Bullhoof	Kopie	Suradan [2]	Yokewood

See footnotes at end of table.

MARINE AND BRIDGE CONSTRUCTION (ABOVE WATER)

Angelique Aromata Bagasse Balata Bethabara Bois gris Bustic	Courbaril Crabwood Dakama Determa Greenheart, Demerara Gronfoeloe Kopie Manbarklak	Manni Mora Nargusta Pine, Caribbean Purpleheart Santa-maria Suradan Tatabu	Tauroniro Teak Tonka Wacapou Wallaba Wamara Yokewood

MILLWORK

Angelique Baboen Banak Baromalli Broadleaf Cedar, C.A. Courbaril Crabwood Determa	Dukali Encens Gommier Gronfoeloe Haiari Hura Inyak Kereti silverballi Kurokai	Magnolia Mahoe Mahogany, Honduras Mahogany, W.I. Manni Manniballi Pine, Caribbean Podocarp Purpleheart	Roble Saman Santa-maria Simarouba Sterculia Tabebuia, white Teak

MUSICAL INSTRUMENTS

Balata Cedar, C. A. Courbaril	Mahogany, Honduras Mahogany, W.I. Purpleheart	Rosewood, Honduras Simarouba Snakewood	Wamara

PATTERNMAKING

Cedar, C.A. Gumbo-limbo	Mahogany, Honduras Mahogany, W.I.	Podocarp Saman	Simarouba

POSTS AND SHORT POLES

Angelin Angelique Bagasse Balata Bethabara Bois gris Bustic Cedar, C.A.	Courbaril Determa Greenheart, Demerara Haiari Kopie Mahoe Mahogany, Honduras Manbarklak	Manni Mora Nargusta Pine, Caribbean Resolu Roble Saman Santa-maria	Suradan Tatabu Teak Tonka Wacapou Wallaba Wamara

SHINGLES

Broadleaf Cedar, C.A. Crabwood	Gommier Mahoe Roble	Santa-maria Simarouba Wallaba	Yokewood

SPORTING AND ATHLETIC ITEMS

Bagasse Balata Balsa Baromalli	Bethabara Courbaril Greenheart, Demerara Lignumvitae	Parakusan Purpleheart Roble Rosewood, Honduras	Snakewood Tabebuia, white Tonka

TOOL HANDLES

Balata Baromalli Bethabara	Courbaril Parakusan Purpleheart	Roble Rosewood, Honduras Tabebuia, white	Tatabu Tonka Wamara

TURNING

Angelin Balata Bethabara Bullhoof Courbaril Crabwood	Greenheart, Demerara Lignumvitae Mahogany, Honduras Mahogany, W.I. Marblewood Nargusta	Pakuri Parakusan Purpleheart Roble Rosewood, Honduras Snakewood	Tatabu Tonka Wamara

UTILITY POLES

Balata Bethabara	Bulletwood [Bustic] Manbarklak	Pine, Caribbean Suradan	Wallaba

VENEER AND PLYWOOD

Decorative

Angelin Baboen Banak Cedar, C.A. Courbaril Crabwood Determa	Gommier Gumbo-limbo Hura Kurokai Mahogany, Honduras Mahogany, W.I. Manni	Nargusta Purpleheart Roble Rosewood, Honduras Saman Santa-maria Suradan	Tabebuia, white Tauroniro Tonka Wacapou

Utility Grade

Baromalli Bullhoof Dukali Gronfoeloe	Haiari Inyak Kereti silverballi Kopie	Kwarie Manniballi Pakuri Pine, Caribbean	Podocarp Simarouba Yemeri

Core Stock

Baboen Banak Cedar, C.A.	Crabwood Gumbo-limbo Haiari	Hura Inyak Kereti silverballi	Kwarie Podocarp Simarouba Yemeri

[1] Timbers with known resistance to marine borers. Other timbers require preservative treatment for optimum use.
[2] Also suitable for use in teredo infested waters because of varying degrees of resistance to marine borers.

APPENDIX F

FRP Pile Jackets

Repair of Wood Piles Using Prefabricated Fiber-Reinforced Polymer Composite Shells

Roberto Lopez-Anido, M.ASCE[1]; Antonis P. Michael, S.M.ASCE[2]; Thomas C. Sandford, M.ASCE[3]; and Barry Goodell[4]

Abstract: An effective method for combined environmental protection and structural restoration of wood piles in waterfront facilities is not available. The objective of the study presented in this paper is to survey the available methods for wood pile protection and structural restoration with the intent of developing an effective method. In addition to reviewing the available repair methods, a field inspection of a harbor in Maine was conducted to assess existing technologies. A wood pile repair method that utilizes bonded fiber-reinforced polymer (FRP) composite shells and a grouting material is proposed. Fiber, resin, adhesive, coating, and grouting materials are systematically analyzed to deliver the required system performance. Two fabrication methods for the FRP composite shells are discussed based on the experience gained in the fabrication of laboratory prototypes. Then a step-by-step procedure amenable for field installation is proposed, and a preliminary cost analysis is conducted to assess the feasibility of the proposed system.

DOI: 10.1061/(ASCE)0887-3828(2005)19:1(78)

CE Database subject headings: Wooden piles; Composite materials; Waterfront structures; Shells; Fiber reinforced polymers.

Introduction

Scope and Objective

No effective method for both protection and structural restoration of wood piles in waterfront facilities is discussed in the literature, nor is such a method available in practice. Understanding the cause and characterizing the extent of wood pile deterioration is the first step in designing a repair method for damaged piles, as well as in devising a protection strategy to prevent further attack from marine organisms (Lopez-Anido et al. 2004c). The objective of the study described in this paper is to survey the available methods for wood pile protection and structural restoration with the intent of developing an effective repair method.

Attaining this objective required both a literature review and a field inspection of a harbor. A wood pile repair method that utilizes fiber-reinforced polymer (FRP) composite prefabricated shells, shear connectors, and grouting material is proposed to address both the protection and the structural restoration needs. This repair system provides shear transfer capability between the wood pile and the encasing FRP composite shells, which strengthens the damaged pile portion (Lopez-Anido et al. 2003, 2004a). The FRP composite repair system can also reduce the rate of future deterioration by introducing a barrier that protects the wood pile from marine borer attack. In this method, prefabricated shells are bonded together in situ with an underwater-curing epoxy adhesive to form the FRP composite shield or jacket that encases the wood pile specimen. The performance of the underwater-curing epoxy after exposure to freezing and thawing cycles was investigated (Lopez-Anido et al. 2004b).

Two fabrication methods for the FRP composite shells are presented and compared based on the experience gained fabricating laboratory prototypes. Then a step-by-step procedure amenable for field installation is proposed, and a preliminary cost analysis is conducted to assess the feasibility of the proposed system.

Background

Marine borers cause extensive damage to wood piles used to support piers, marinas, or other waterfront structures, and in many cases replacement of these piles has been the only alternative (Goodell et al. 2003; Lopez-Anido et al. 2004c). Preservative treatments prolong the life of wood piles for many years and have previously been used extensively to protect piles in wooden waterfront structures. However, environmental concerns regarding the preservatives used for this purpose have resulted in restrictions on their use.

For this reason some states, such as Maine, have effectively banned the use of creosote in marine waters. Creosote has been one of the most common and effective preservatives used for the protection of wood piles from marine borers. The lack of an effective preservative to protect against marine degradation has aggravated the problem of wood pile deterioration. Another preservative chemical used in wood piles, chromated copper arsenate (CCA), contains heavy metals, and questions have been raised

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Note. Discussion open until July 1, 2005. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on August 2, 2002; approved on March 24, 2003. This paper is part of the ***Journal of Performance of Constructed Facilities***, Vol. 19, No. 1, February 1, 2005. ©ASCE, ISSN 0887-3828/2005/1-78–87/$25.00.

about its hazard to human health. The federal government has recently placed restrictions regarding the use of CCA preservative in residential applications, and some states have banned its use for noncommercial applications entirely. Some marina owners and state department of transportation officials have also expressed concern over the use of CCA-treated piles because of perceived brittleness of the pile after treatment. A study on CCA leaching of treated wood piles in seawater and fresh water estimated the long-term release of chemical elements (Lebow et al. 1999).

The service life of deteriorated marine wood piles can be prolonged in some instances by repairing the piles. Repair methods include encasing the damaged wood pile with some type of jacket or sheeting (e.g., plastic, steel, or concrete) or removing the damaged portion and replacing it with a new piece that is spliced with the old wood pile. For example, a method for repairing damaged creosote-treated wood piles using a wire-mesh reinforced shotcrete jacket has been proposed (Chellis 1961). A method for ground repair of wood poles has also been presented that involves screwing a metal sleeve around the base of the pole and filling the space between the sleeve and the pole with aggregates and resin (Douglas 1986; Shepard 1987).

The Unified Facilities Criteria (UFC) handbook for operation and maintenance of waterfront facilities presents six repair methods for damaged wood piles (USACE 2001). The first method discusses protection of wood piles by wrapping them with polyvinyl chloride or polyethylene wraps. A second method proposes partial posting of a damaged wood pile by joining a new pile butt with bolted pretreated timber fish plates. The third method discusses repair of wood piles by concrete encasement. Two types of concrete forms can be used: (1) flexible forms (sea form fabric form), and (2) split fiberboard forms. These forms have no structural significance but are used to keep the concrete contained until it hardens. The fourth method addresses the repair or retrofit of timber piles with an underwater-curing epoxy and fiber-reinforced wraps in which the fabrics are saturated with the epoxy and then applied to the wood pile. The fifth repair strategy considers replacement of the damaged wood pile with a new wood pile. Finally, the sixth repair strategy proposes replacing the damaged wood pile with a new concrete pile.

Available Methods for Protection of Wood Piles

One strategy for protection of wood piles from marine borer attack is encasing new piles with a plastic wrap or jacket (Baileys 1995; U.S. Navy 1987). Most of the available methods are suitable only for protection and provide no structural restoration capabilities, and therefore, can only be used to protect new piles or piles with minimal damage and adequate structural properties. Master Builders, Inc., of Cleveland, Ohio, developed a process (APE, advanced pile encapsulation) for protection of piles, risers, jackets, and other marine structures. This method employs a molded fiberglass outer jacket that is used as a form for containing the grout. The grout used in this process is an aggregate epoxy mix that is pumped through injection ports from the bottom of the form (ADCI 1996; Master Builders 2001). This method uses an epoxy grout that is usually expensive and a nonstructural fiberglass jacket that is expensive and offers no structural restoration.

Tapecoat Company, of Evanston, Illinois, has developed a modular encapsulation system that provides protection to marine structures. The product trade name is TC Enviroshield and the series T is used for wood piles. This system consists of a flexible outer jacket that wraps the pile and restrains the flow of water. The modular encapsulation system is reported to reduce the levels of dissolved oxygen content of the water inside the wrap by preventing the exchange of oxygenated water with that trapped in the jacket. Even though complete water exchange may not be prevented, use of the jacket is believed to kill existing borers in the wood pile and prevent new larval forms from settling on and attacking the pile (ADCI 1996; Tapecoat 2001). This product can only be used to protect structurally sound wood piles, since it cannot restore structural capacity.

Denso North America, of Houston, has also developed a line of products used for protection of wood piles. These include Denso's SeaShield Series 100, which encapsulates the pile and seals out oxygen and water, providing protection from marine borers for timber piles. Denso has also developed jackets that are used as forms for concrete or epoxy encasement to structurally restore wood piles (ADCI 1996; Denso 2000). These jackets and encasements have no structural significance and cannot be used to repair deteriorated wood piles.

Rockwater Manufacturing Corp. has developed a marine pile system for marine borer protection of wood piles that is similar to the other available systems in that it is reported to reduce the oxygen levels of the water inside the wrap. The company also provides fiberglass pile jackets that, when used with underwater grouts, can provide structural support (ADCI 1996; Rockwater 1999). The wraps and fiberglass pile jackets are nonstructural and cannot be used for wood pile restoration.

Osmose Marine, based in Griffin, Georgia, has developed a protection system for marine piles using a polyvinyl chloride (PVC) wrap with the trade name Pile-Gard, which has been described as producing an airtight seal. This product, which reportedly limits the oxygen supply to marine borers, was invented in the 1950s (U.S. Patent No. 3, 321, 924) and therefore has a long history of protecting piles (Liddell 1967; ADCI 1996; Osmose 2001). This method can only be used to protect undamaged wood piles or wood piles that have adequate structural capacity, since the method does not provide structural restoration.

Available Methods for Structural Restoration of Wood Piles

Hardcore Composites of New Castle, Delaware, has developed a method with the trade name Hardshell System, which is reported to protect as well as repair and restore timber piles. This system uses E-glass/vinyl ester composite shells fabricated by the vacuum-assisted resin transfer molding (VARTM) process. The shells are manufactured in two halves joined by using bonded H connectors. The H connector is a female-male type of connector in which one of the half shells has the female end and the other acts as the male. Adhesive is applied to the female portion of the seam, and straps are used to hold the two pieces together until the adhesive cures and the grout is pumped (Hardcore 1999, 2000). The fact that the bond area of the H connector is relatively small raises doubts about the ability of the system to provide structural continuity in the circumferential direction.

The second company with a system that rehabilitates wood piles is Fyfe Co. LLC, also known as the Fiberwrap Company, based in San Diego. This repair method uses a fabric reinforcement that is wrapped around the pile and then impregnated underwater with an epoxy resin providing a barrier against marine borers (Fyfe 1998). Since the fabric reinforcement impregnation is performed underwater, after the epoxy cures, the portion that is repaired is sealed from the surrounding environment. Impregnation of the fabric reinforcement underwater is difficult to execute

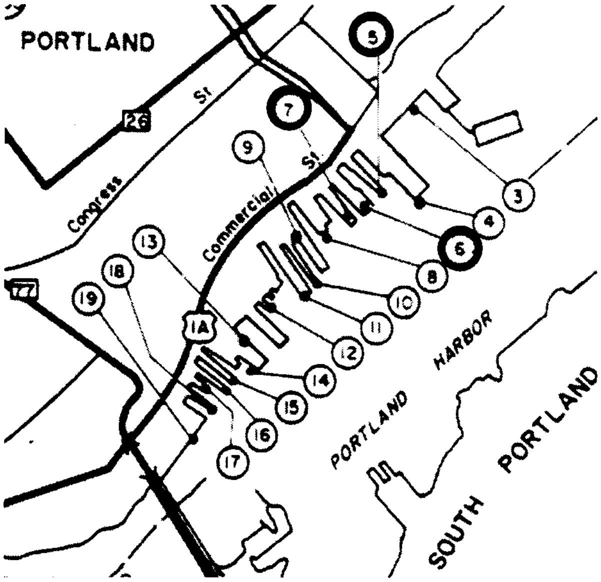

Fig. 1. Piers inspected in Portland Harbor, adapted from Maine DOT (1986)

and monitor. Even if the fibers are impregnated before they are introduced into the water, the resin may not cure properly.

Assessment of Existing Wood Pile Repair Methods in Portland Harbor, Maine

A harbor on the Northeast coast of the United States, a region where wood piles traditionally have been used, was selected to conduct a case study. The condition of structural wood piles repaired using various methods in Portland Harbor piers was determined by visual inspection in May 2000. The objective of the inspection was to assess methods currently used to repair damaged wood piles. Wood pile repair methods in three piers—Portland Pier (7), Custom House Wharf (6), and Maine Wharf (5)—were inspected during low tide, as depicted in Fig. 1. The Portland Pier had a timber-retaining wall with solid fill, wood piles, and a wood deck supporting a parking lot (Maine DOT 1986). The Custom House Wharf had an earth-filled pier structure with wooden timber and a steel crib bulkhead, wood piles, and an asphalt-paved wood deck; several marine-related businesses were operating on the pier (Maine DOT 1986). The Maine Wharf pier had wood piles with a concrete deck (Maine DOT 1986).

Inspection of Portland Pier

The wood pile repair method used in this pier consisted of a corrugated (profile wall) high-density polyethylene (HDPE) pipe encasing [Fig. 2(a)]. The corrugated HDPE pipe was split into two halves that were placed around the wood pile and held together with circumferential metal straps. The metal straps were spaced approximately 910 to 1,220 mm apart, and the space between the wood pile and the corrugated HDPE pipe was grouted with unreinforced concrete. Typical dimensions of the corrugated HDPE pipe used were 686 mm for the external diameter and 584 mm for the internal diameter. The thickness of the corrugated profile wall was 51 mm. Several problems with this repair method were observed in individual piles: (1) The steel straps were damaged and severed, and the corrugated HDPE pipe halves were

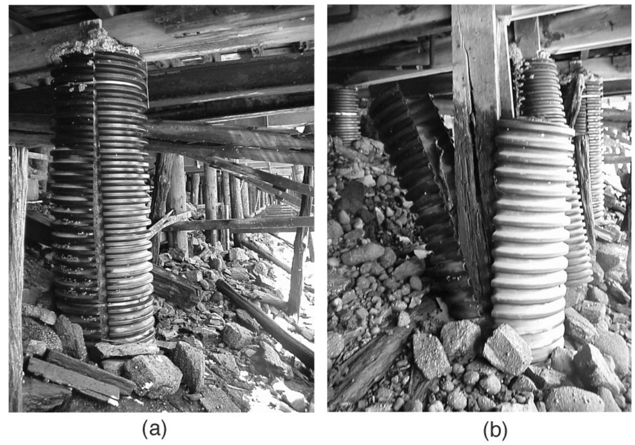

Fig. 2. Repair method using corrugated HDPE pipe encasing: (a) repaired wood pile; and (b) failure of HDPE pipe encasing

opened as shown in Fig. 2(b); (2) wood damage was observed at pile sections above the repaired area; (3) the concrete fill was deteriorated and disintegrated with relatively little effort; and (4) at the opened joint of the corrugated HDPE pipe, the concrete was spalling and exposing the interior wood pile.

Inspection of Custom House Wharf

Previous attempts to repair damaged wood piles were made on this pier as well, and the same repair method was used as at Portland Pier. However, some of the corrugated HDPE pipes were installed as a continuous section around the piles and not as two halves. This implied that the old pile was probably cut off and a new portion connected to the stub of the old pile. The corrugated HDPE pipe was then secured in place and grouted with concrete. The use of a continuous corrugated HDPE pipe eliminated the problem of concrete spalling observed at the joints. The wood piles at this structure were of smaller size and therefore a smaller size corrugated HDPE pipe was used (exterior diameter 533 mm, interior diameter 457 mm, and corrugated wall thickness 38 mm). According to one of the workers at a commercial facility on the pier, the wood pile repairs were performed 2 years earlier.

Another type of wood pile repair method observed was splicing. In this method the top portion of the old damaged pile was removed and a new wood pile portion was spliced using steel bolts, as shown in Fig. 3. For a wood pile with an approximate diameter of 254 mm, the steel bolts were spaced 203 mm apart. A

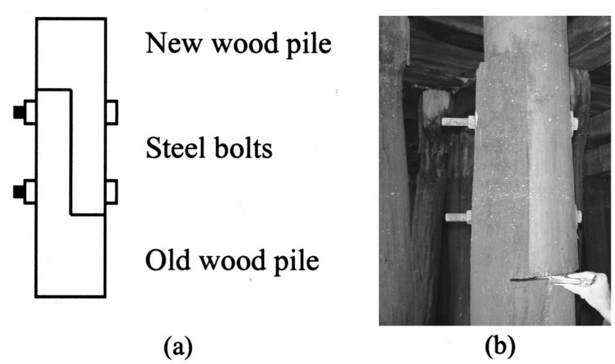

Fig. 3. Splicing of wood piles with steel bolts

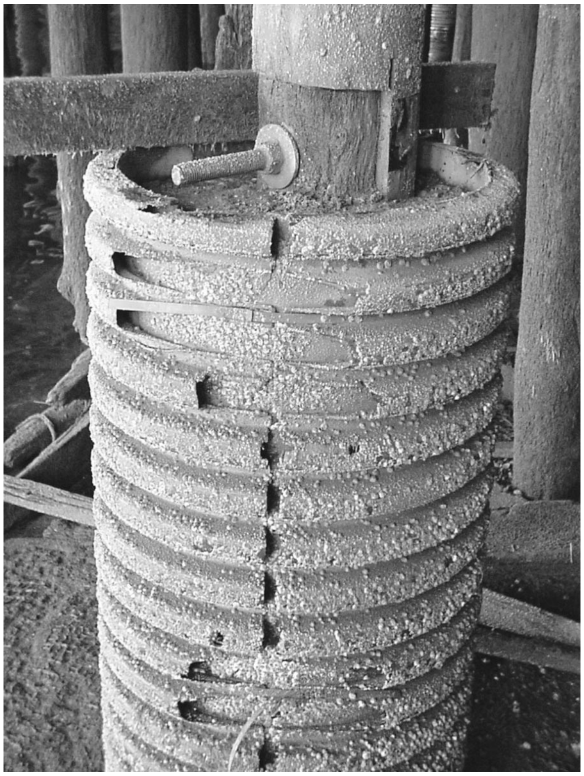

Fig. 4. Repair method using HDPE pipe encasing and splicing with steel bolts

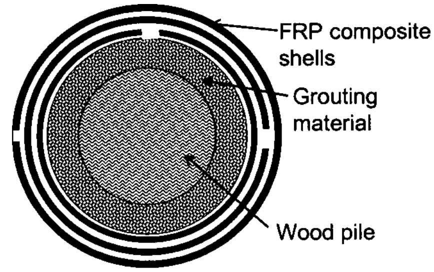

Fig. 5. Cross section of wood pile repaired with fiber-reinforced polymer composite shells

problem observed in the splices was a gap between the horizontal surfaces of the two wood pile portions, which does not allow for proper vertical load transfer by bearing. The splice also exposes the untreated center of the wood pile as pressure preservative treatments rarely extend all the way to the center of the impermeable heartwood region of a pile. In areas where gaps occurred in the splice, shipworm larvae could enter and attack the untreated wood.

Inspection of Maine Wharf

At the Maine Wharf, repair methods were also applied to several damaged wood piles. Several piles were repaired using splicing, as shown in Fig. 3(b). Corrugated HDPE pipes were also used at this facility. The pipes were placed around the pile in two halves and metal straps were used to hold them together. At the vertical joints metal plates were used to close the gap and contain the concrete. The concrete was in good condition. A combination of corrugated HDPE pipes and the splicing method with steel bolts was observed. Part of the splice length was buried in concrete and part was exposed, as shown in Fig. 4.

Proposed Repair Method Using Fiber-Reinforced Polymer Composite Shells

The available protection or restoration methods have limited applicability in most cases. Plastic wraps can protect against marine borers in some cases but cannot be used to restore structural capacity. Steel jackets can corrode, especially in the marine environment, and concrete encasement can develop problems with spalling. Fiber-reinforced composite jackets installed in halves with an H connector have bonded longitudinal joints, that may limit the ability of the pile encasement to deliver circumferential confinement. On the other hand, application of wet fabric reinforcement underwater can be difficult, and proper curing of the resin may not be achieved.

The wood pile repair method proposed in this paper utilizes an FRP composite encasement or shield that encapsulates and splices the deteriorated portion of the pile. The encasement was developed based on experience with appropriate technologies in the structural FRP composites field (Kshirsagar et al. 2000; Lopez-Anido and Karbhari 2000; Lopez-Anido et al. 2000; Lopez-Anido and Xu 2002) combined with the needs for wood pile protection and strengthening observed in the field inspection, survey, and literature review. The shield is made of bonded thin and flexible FRP composite prefabricated cylindrical shells that deliver the required strength to repair damaged wood piles. The shells are fabricated in a quality-controlled composites manufacturing facility. The cylindrical shells have a slit or opening along their length, which enables them to be opened and placed around the deteriorated wood pile. Since it is advantageous to encase the pile with a series of overlapping shells, the minimum number of FRP composite shells required is two; however, additional shells can be added, depending on the structural restoration needs. The slit in each cylindrical shell is staggered to avoid lines of weakness through the entire shield (Fig. 5).

In the proposed repair method, the space between the FRP composite shield and the wood pile is filled with a grouting material that does not provide a structural bond with the wood pile, but rather provides interlocking (friction) between the wood pile and the FRP composite shells. Since the grout is not expected to completely seal the wood core, seawater saturates the pile, creating a layer of stagnant water, potentially limiting the oxygen supply. Assuming a lack of oxygen, marine borers already inside the wood pile would be expected to die and new borers would be prevented from attacking the wood pile. A schematic of the proposed repair system is depicted in Fig. 6.

FRP composite shells need to be driven 0.3 to 0.6 m below the mud line to avoid secondary attack by marine borers; extending the FRP composite shells 0.6 m above the high-water level could prevent secondary attack by marine borers in the splash zone (Baileys 1995; Chellis 1961). However, caution should be exercised in extending the shell too far above the water line, as encapsulating the pile above the high-water line can trap fresh water in this zone. If the wood stays continually wet, the unprotected core and other poorly protected areas may then be subjected to more aggressive attack by decay fungi than would normally occur. The proposed structural restoration method utilizes the undamaged zone of the existing wood pile by encasing and splicing the damaged portion plus the required development length to en-

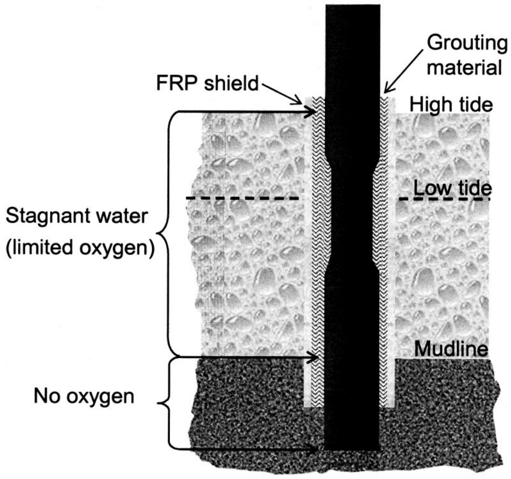

Fig. 6. Schematic of wood pile repair with fiber-reinforced polymer composite shells

sure reinforcement integrity (that is, partial length reinforcement of the pile).

Material Section—Prototype Development

Fiber-Reinforced Polymer Composite Shell

A unidirectional woven fabric (style VEW 260) (BTI 2000) with unit area weight of 880 g/m^2 was selected as the primary continuous reinforcement. The fabric reinforcement is provided by the manufacturer in rolls with a width of 1.22 m and an approximate weight of 105 kg. This type of fabric reinforcement was selected due to its adaptable directional properties (for example, continuous fiber reinforcement in selected orientations), ease of fabrication (for example, cutting and placement), and cost competitiveness. The number of fabric reinforcement layers in the longitudinal (axial) and hoop (circumferential) directions was selected based on the design loads and the extent of damage, and therefore the stresses imposed on the part. In addition, E-glass fiber chopped strand mat (CSM) with a unit area weight of 305 g/m^2 was used as secondary noncontinuous and randomly oriented reinforcement.

The proposed fiber architecture for the FRP composite shell consists of three layers of unidirectional continuous fabric reinforcement in the longitudinal direction (0°), one layer of unidirectional continuous fabric reinforcement in the hoop direction (90°), and two outer CSM layers (Fig. 7). The intent is to fabricate the final FRP composite shield from these shells in place on the pile using adhesive to bond the shells together. This is done because the individual shells have the required compliance to be opened wide enough along the seam to fit around the wood pile. The elastic nature of the shell would then allow it to return to its original fabrication dimensions. This design also allows the seams to be oriented so that overlapping of seams does not occur.

The fiber architecture design is based on maximizing fiber reinforcement in the axial direction with a minimum amount of fibers oriented in the hoop direction. Axial fiber reinforcement contributes to both the bending and axial stiffness and strength of the shell, which is required to splice the damaged portion of the wood pile. Hoop fiber reinforcement provides adequate integrity to the flexible shell, allowing the required shear strength and mechanical fastener support to be developed. One CSM layer is placed on each face of the shell laminate to provide improved bonding to the substrate and to develop a resin-rich area for environmental protection. The resulting laminate layup of the FRP composite shell is [CSM/0/90/0/0/CSM].

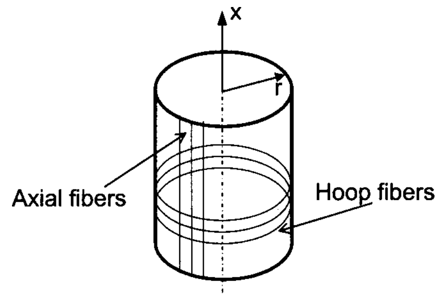

Fig. 7. Fiber reinforcement of fiber-reinforced polymer composite shell

A low-viscosity, epoxy-based vinyl ester resin, Derakane 411-C50, was selected as the matrix for the composite shells (Dow 1999). The epoxy-based vinyl ester resin was selected because of its high flexibility and impact resistance, its lower cost compared to other resin systems such as epoxies, and its good performance in harsh marine environments. This resin has a viscosity of 0.15 Pascal seconds (150 centipoise) and is well suited for resin infusion molding. The design outlined provides for high flexibility and impact resistance to allow the manufactured part to easily absorb impact loads from approaching vessels.

Grouting Systems

The criteria used to select the grouting system were (1) ability to be applied underwater, (2) pumping ability, (3) minimal shrinkage, (4) commercial availability, and (5) cost competitiveness. Research conducted on concrete columns suggested that the grout material used has fewer voids when pumped from the bottom rather than dropped from the top (Snow 1995). Two different types of grouting systems were selected and evaluated: (1) cement-based structural grout, and (2) expanding polyurethane chemical grout.

The cement-based grout can be pumped in place using conventional concrete pumps and cures underwater (Five Star 2001). This grout has minimal shrinkage and high compressive strength at early stages. The typical one-day compressive strength of this material at 23°C is 35 MPa, while at 28 days it reaches compressive strengths up to 52 MPa.

The expanding polyurethane chemical grout is a two-part material system: component A is the polyurethane, and component B is an accelerator (Sika 1998). This grout is a fluent material and can be easily pumped to place. The curing reaction is triggered when the grout comes in contact with moisture with less than 1 h curing time. The polyurethane grout system results in a flexible layer with high-energy absorption capabilities, but the polyurethane grout does not have any significant compression or bearing strength and therefore is nonstructural. The cost of polyurethane grout is relatively high compared to cement-based grout.

Shear Connectors

Shear connectors (steel-threaded rods) can be used to transfer shear forces between the FRP composite shield and the wood pile

(Lopez-Anido et al. 2004c). For example, four steel-threaded rods with a diameter of 19 mm were used at each end of the FRP composite shields as shear connectors to repair wood piles (Lopez-Anido et al. 2003). The steel-threaded rods were spaced along the pile axis at approximately 102 mm intervals and rotated approximately 30° in the circumferential direction. When a polyurethane chemical grout is used in wood pile strengthening, then shear connectors are required to develop the structural capacity of the FRP composite shield. For the cement-based grout, metal shear connectors are not required.

Underwater-Curing Adhesive

An underwater-curing adhesive is required to bond the FRP composite shells together and provide composite action. The selection criteria for the adhesive were (1) ability to cure underwater, (2) ability to be applied underwater, (3) ability to bond well to vinyl ester composites, and (4) durability in waterfront environments (Lopez-Anido et al. 2004b). The adhesive selected is an underwater-curing two-part epoxy adhesive. Part A is the epoxy resin and Part B is the hardener (Superior 2000). Part A, which is modified bisphenol-A polyglycidyl ether, is a viscous light amber liquid with mild odor that comes in various consistencies. Part B, which is a modified polyamine, is a viscous liquid with a fishy odor and comes in various colors and consistencies. Blue color was selected for the pile repair application because it is visible through the FRP composite shells and therefore would make it possible to visually inspect the adhesive spread area between shells. A paste consistency applied with a trowel is recommended for underwater applications. In the laboratory prototypes, the adhesive was applied around the circumference and along the length of the FRP composite cylindrical shells covering all the contact area between two shells.

Polymer Concrete Coating

A polymer concrete coating or overlay is required to develop friction between the FRP composite shell and the cement-based structural grout. The polymer concrete selected is a two-component, low-modulus polysulphide epoxy-based wearing course (TRANSPO 2000). Components A (resin) and B (hardener) are mixed in a 2:1 volume ratio. The selected polymer concrete is an impervious overlay typically used for restoring bridge decks and other pavements and applied with a thickness of 6 to 12 mm (TRANSPO 2000). In the wood pile repair application a polymer concrete layer with a thickness of 3 mm was applied on the interior surface of the innermost shell. First, the epoxy was applied using rollers, and then standard basalt sand was broadcast as the aggregate. The epoxy bonded well to the vinyl ester composite shell. The aggregate created a rough surface, which provided adequate interlocking with the cement-based grout. It was found that the shear strength at the interface between the cement-based grout and the innermost FRP composite shell was significantly increased due to the polymer concrete coating (Lopez-Anido et al. 2004a).

Fabrication of Fiber-Reinforced Polymer Composite Shells

The first manufacturing process used to fabricate the FRP composite cylindrical shells with the longitudinal slit was wet layup with vacuum bagging compaction. In this fabrication process the fabric reinforcement is impregnated with resin, placed on the mold, sealed using a plastic bag, and compacted by drawing a vacuum. The vacuum pressure also removes part of the excess resin from the part into the breeder/bleeder layers. One problem found with this fabrication method is the limited pot life of the resin used; that is, when long shells were manufactured, the resin gelled before all of the fabric reinforcement layers were impregnated. This fabrication process delivered a composite shell with relatively low-fiber volume content and a consolidated thickness of approximately 4.5 mm. The relatively high thickness of the consolidated part presents an obstacle to installation since the cylindrical shell lacks the required flexibility to let one worker open it around a wood pile.

Fig. 8. Dry fabrics and peel ply on PVC mold

To overcome the fabrication problems encountered, a variation of the VARTM process, the licensed Seemann Composites Resin Infusion Process (SCRIMP) (TPI 2001), was selected for fabricating the FRP composite cylindrical shells with the longitudinal slit. A PVC pipe rated for 900 kPa internal pressure was used as a mold or tool. The fabric reinforcement was placed on the cylindrical mold dry (Fig. 8), and then the fabric reinforcement was sealed with a tubular vacuum bag (Fig. 9). Vacuum pressure of −102 kPa was applied with a vacuum pump and resin was infused through a resin pot. The pressure differential between the atmosphere and the applied vacuum allowed infusion of the resin into the fabric reinforcement layup. Once the resin completely impregnated the fiber reinforcement, the vacuum pressure was reduced to −51 kPa until the resin gelled. The vacuum pressure debulked (compacted) the dry fiber reinforcement. After the resin gelled, vacuum pressure was removed and the part was allowed to cure. A cured, partially exposed cylindrical shell is shown in Fig. 10. The FRP composite shell was then removed by pulling open the longitudinal slit.

The VARTM/SCRIMP process produced FRP composite shells with a relatively high fiber volume content and a consolidated thickness of approximately 3.3 mm. The shells fabricated by the VARTM/SCRIMP process had adequate flexibility to be pulled open and placed around the wood pile prototypes.

The FRP composite shields are expected to be exposed to ultraviolet radiation (UV), where the weathering effects are expected to be more important in the piles located on the perimeter of the waterfront facility. Weathering and UV protection of the FRP composite shells can be efficiently attained with a surface layer containing a pigmented gel coat or by incorporating a UV

Fig. 9. Tube vacuum bag placed over system

Fig. 11. Application of fiber-reinforced polymer composite shells to predamaged wood pile

inhibitor as an additive to the polymer matrix (Haeberle et al. 2002).

Laboratory Prototypes—Fabrication

The feasibility of the repair method was demonstrated in the laboratory by fabricating FRP composite shells and restoring "damaged" wood pile prototypes (Fig. 11). Marine borer damage was simulated by reducing the cross-sectional area of the pile. The space between the wood core and the FRP composite shells was filled with a grouting system. Two different grouting materials were used: (1) portland cement-based (inorganic) structural grout (Fig. 12), and (2) polyurethane-based (organic) nonstructural grout with shear connectors that transfer loads from the wood pile to the FRP composite shells (Fig. 13). Laboratory prototypes were fabricated for two types of experiments: (1) pushout tests by compression loading to characterize the interface response (wood/grout/shear connector/FRP composite) (Lopez-Anido et al. 2004a); and (2) full-size bending tests to characterize the overall structural response (Lopez-Anido et al. 2003).

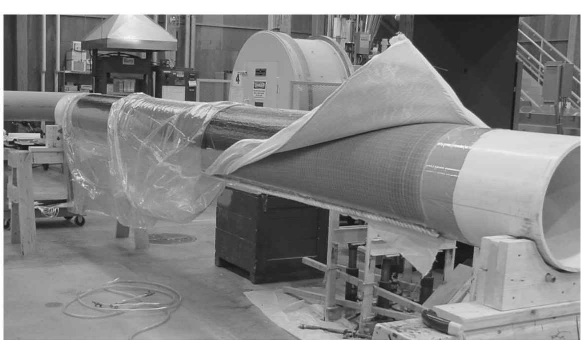

Fig. 10. Demolding of cured fiber-reinforced polymer composite shell

Installation Procedure

To implement the repair method in waterfront applications, a possible step-by-step installation procedure was developed and is presented.

Step 1: Clean Existing Wood Pile

Wood piles usually have marine fouling organisms growing on them. Even though achieving good bonding between the grout and the wood core is not expected, cleaning will be helpful. The marine organisms are primarily organic matter, and their presence creates voids in the grout, making it weaker and reducing the interlocking that is required for the repair system to work efficiently. Cleaning can be performed using a water jet without excessive pressure (USACE 2001). Excessive pressure can cause more damage to the already vulnerable wood pile. Cleaning can also be achieved by scraping off the marine organisms with a modified scraper that conforms to the shape of the wood pile (Hardcore 1999).

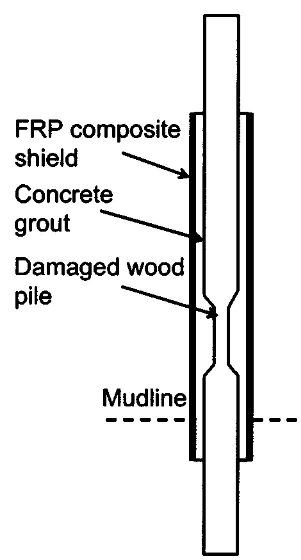

Fig. 12. Fiber-reinforced polymer composite repair system with cement-based grout

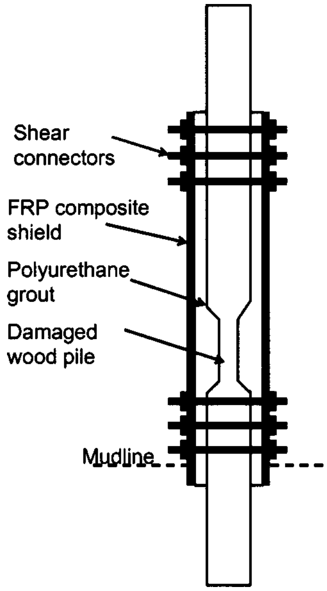

Fig. 13. Fiber-reinforced polymer composite repair system with shear connectors and polyurethane grout

Step 2: Place Shear Connectors at Wood-Grout Interface

If shear connectors, such as lag screws, are required at the wood-grout interface, they must be driven deep enough into the wood pile to be effective. The connectors need to extend as much as the thickness of the grout to serve as spacers.

Step 3: Position First Fiber-Reinforced Polymer Composite Shell Around Wood Pile

The longitudinal slit along the length of the FRP composite shell is opened and the shell is placed around the damaged wood pile.

Step 4: Apply Adhesive on First Shell

A coat of underwater epoxy adhesive is applied on the interior surface of the second shell and on the exterior surface of the first shell, if possible. The use of trowels is recommended to help spread the adhesive.

Step 5: Position Second Shell

The second shell is slid around the first one with the longitudinal slits or gaps staggered (preferably 180°) to avoid lines of weakness. This step is repeated for additional shells staggering the longitudinal slits.

Step 6: Strap Shells Together

It is necessary to use straps or other means to apply pressure on the FRP composite shells to hold them in place until the adhesive cures and also to force out any trapped water between them. Straps should be spaced at approximately 0.6 m intervals for satisfactory pressure to be applied to the adhesive contact area.

Step 7: Drive Fiber-Reinforced Polymer Composite Shield to Required Depth into Mud Line

After curing of the adhesive, the FRP composite shield can be driven into the mud line, which needs to be loosened. This can be achieved either by using a water jet that stirs and loosens the mud or by digging around the wood pile to the required depth and then backfilling the hole.

Table 1. Cost Items for FRP Composite Shells Fabricated in Laboratory

Item	Cost per fiber-reinforced polymer composite shell ($)
Fiber reinforcement	101
Resin	70
Catalyst	8
Fabrication supplies	114
Labor preparation	70
Labor application	15
Total	378

Note: Prices are for shells having a diameter of 394 mm and a length of 4.88 m.

Step 8: Drill Holes and Place Shear Connectors

If shear connectors are required for the transfer of loads from the wood pile to the FRP composite shield, then holes need to be drilled and the shear connectors placed before grouting. This will ensure that any possible voids are filled by the grout and no possible access points remain for marine borers to enter and damage the wood pile. If the holes are to be drilled underwater, then an air drill will be necessary. In the laboratory, regular steel threaded rods were used, but galvanized steel rods should be used in field applications to reduce corrosion.

Step 9: Prepare Grout and Pump it into Place

After the FRP composite shield is driven into the mud, then the grout material can be pumped. Grout should be pumped from the bottom to avoid segregation.

Cost Analysis

To assess the commercial feasibility of the wood pile repair method, a preliminary cost analysis was conducted. For this purpose, the cost of repairing full-size wood piles in the laboratory was calculated. The cost was divided among the following items: (1) materials, (2) fabrication supplies, and (3) labor for preparation and application. Material costs included the cost of the fiber reinforcement, resin, and catalyst. The fiber reinforcement cost for a typical composite shell, which has a diameter of 394 mm and a length of 4.88 m, was $101. The fiber reinforcement cost included the CSM mat cost, $17 per shell, and the woven unidirectional fabric cost, $84 per shell.

The resin cost for a typical composite shell was $70 and the catalyst cost was $8. The cost of fabrication supplies per shell included peel ply, $40; release film, $25; distribution media, $16; plastic tubing, $8.50; bagging film, $12; sealant tape, $7; and vacuum line, $5.50. The labor cost to prepare materials, supplies, and the mold for VARTM/SCRIMP fabrication of one shell was based on the time required, $3\frac{1}{2}$ h, for two student workers to complete the task at a wage rate of $10 per hour; therefore the total cost for labor application was $70 per shell. The labor application cost was based on the time required for one student worker to mix the resin and infuse the part. In the laboratory, $1\frac{1}{2}$ h were spent to complete the infusion process; therefore the total labor application cost was $15. The total cost for one shell was $378, where the cost items are summarized in Table 1.

The total cost for repairing a typical wood pile with a diameter of 335 mm using 4.88-m-long FRP composite shells can be determined by adding the cost of the underwater epoxy adhesive, $200, to that of the cement-based grout with a thickness of 50

Table 2. Cost items for wood pile repair with fiber-reinforced polymer composite shells

Item	Number of items	Cost per item ($)	Total cost ($)
FRP composite shell	2	378	756
Adhesive	4 gal	50	200
Grout	20 bags	11	220
Labor	10 hours	10	100
Equipment	—	—	200
Total			1,476

Note: Above prices are for wood piles with a diameter of 335 mm repaired with 4.88 m long FRP composite shells.

mm, or $220. The labor cost for the application of the adhesive and the grout, $100, was estimated assuming that $2\frac{1}{2}$ h are required for four student workers to complete these tasks. The cost of any equipment needed, such as concrete mixing trucks and pumps, is expected to exceed $200. The total cost for a typical wood pile repair is calculated to be $1,475 (approximately $1,500), where the cost items are summarized in Table 2. It is worth noting that additional cost items such as the shear connectors and polymer concrete coating are not included in this estimate. Some costs would be expected to decrease if multiple piles at the same site were reinforced. Actual worker rates will be higher than the student worker labor rates assumed in this study; however, it is expected that fabrication and installation time will be reduced with practice and expertise partially compensating changes in the overall labor cost.

In the cost analysis of the repair method, no cost item is needed for extraction of the existing damaged wood pile. This represents a cost saving compared to the alternative of pile removal since the cost of extracting and disposing of the old treated wood piles, including the disruption to the pier facility, is eliminated. The disturbance to the normal operation of the waterfront facility is expected to be minimal. Most of the repair work can take place beneath the pier facility; no heavy or large equipment is necessary to complete the task.

Conclusions and Recommendations

The study presented in this paper allows the following conclusions to be drawn:

1. Current methods of repairing marine piles were assessed and deemed problematic through literature review and field inspection.
2. The proposed repair of wood piles with prefabricated FRP composite has a dual function of marine borer protection and structural restoration. A method for fabrication of FRP composite shells based on the VARTM/SCRIMP processing technology was successfully implemented.
3. The proposed repair method is environmentally friendly since no new wood preservative chemicals are introduced to the surrounding marine environment. The encasement with the FRP composite shield is expected to attenuate further leaching of chemicals from treated wood piles.
4. The repair method has potential to be cost competitive compared to damaged pile extraction and new pile installation in cases where disruption to the waterfront facility (for example, pier or wharf) is of concern.

The following commentary and practical recommendations are proposed:

1. Modifications and improvements to the wood pile repair method are expected to take place when the technology is implemented in the field.
2. For extended protection of wood piles in service without marine borer damage, the use of the polymer grout with only two FRP composite shells may be advantageous.
3. For structural restoration of wood piles with damage (for example, necking with reduction in cross-sectional area), the use of the cement-based structural grout combined with polymer concrete overlay and the required number of FRP composite shells may provide the requisite load-bearing capacity (Lopez-Anido et al. 2004a).
4. It should be noted that the labor rate used for determination of labor cost is low ($10 per hour) since it is the rate for a student worker. In real applications the rate is expected to be approximately $40–$50 per hour. The total time for a typical repair to be performed by professionals is expected to be less, and therefore a portion of the cost will be balanced.

Acknowledgments

Partial funding for the study presented in this paper was provided by the National Oceanographic and Atmospheric Administration, U.S. Department of Commerce, through Sea Grant College Program Awards Nos. NA96RG0102 and NA16RG1034, and by the National Science Foundation through CAREER Grant No. CMS-0093678.

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APPENDIX G

Cost Estimates

CALCULATION COVER SHEET

Project Name: Mitchell River Bridge Repair/Rehabilitation Feasibility Study

Project No.: 10160874

Calculation Title: Repair/Rehabilitation Cost Estimates

Total Number of Pages (including cover sheet): ________

Prepared By: Swapnil Chogle **Date:** February 11, 2011

Checked By: George Patton **Date:** February 14, 2011

Description and Purpose:

Prepare Cost Estimate for two (2) alternatives:

1) Minimum Repair Work (to Address Items Requiring Immediate Corrective Action)
2) Rehabilitation (with Functional and Safety Improvements)

Design Basis / References / Assumptions:

Existing Bridge Design Plans Dated Jan 5, 1980.
Bridge Repair/Rehabilitation Feasibility Study

Remarks / Conclusions:

Estimated Construction Costs are as follows:

1) Minimum Repair Work	$ 9,363,000
2) Rehabilitation	$ 4,781,000

Approved By: George C. Patton, PE

Title: Project Engineer

Date: February 14, 2010

Distribution: ________________ ________________

________________ ________________

URS Corp.
260 Franklin Street
Boston, MA 02110

PROJECT Mitchell River Bridge Rehabilitation Feasibility Study
BRIDGE C-07-001 (437)
MADE BY SUC DATE 1/31/2011 JOB NO. 10160874
CHECKED BY GCP DATE 2/14/2011

Alternate: **Minimum Repair Scope of Work**

	W	L	H/T	No.	Quantity	Units
Deck	ft	ft	ft			
Timber Wearing Surface						
Spans 1,2,3,4,5,6,9,10,11,12	25.333	15.96	0.250	9	10916.6	FB
Bascule Spans	25.333	50.00	0.250	1	3800.0	FB
				Subtotal:	14716.6	FB
Timber Structural Deck						
Spans 1, 8 & 12	31.500	16.13	0.333	3	6097.9	FB
Spans 2 & 11	34.500	16.13	0.333	2	4452.4	FB
Spans 3,4,5,6,7,9 &10	37.500	16.13	0.333	7	16938.6	FB
				Subtotal:	27488.9	FB
Timber Sidewalk						
Included in "Timber Structural Deck"						
Timber Curb						
8" x 8" Nom	0.66666	193.58	0.66666	2	2064.8	FB
6" x 8" x 12" Nom	0.5	12	0.6666	66	3167.7	FB
				Subtotal:	5232.5	FB

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PROJECT Mitchell River Bridge Rehabilitation Feasibility Study
BRIDGE C-07-001 (437)
MADE BY SUC DATE 1/31/2011 JOB NO. 10160874
CHECKED BY GCP DATE 2/14/2011

Alternate: **Minimum Repair Scope of Work**

COUNTERWEIGHT	W	L	H/T	Number	Vol	
Ballast	31.50	3.50	1.56	1	84400	LB
				Subtotal:	84400	LB

URS Corp.
260 Franklin Street
Boston, MA 02110

PROJECT	Mitchell River Bridge Rehabilitation Feasibility Study				
BRIDGE	C-07-001 (437)				
MADE BY	SUC	DATE	1/31/2011	JOB NO.	10160874
CHECKED BY	GCP	DATE	2/14/2011		

Alternate: **Minimum Repair Scope of Work**

Substructure				
Timber Piles (FRP Jackets)				
West Abutment	8.00	4.00	32.0	FT
Bent No. 1	8.10	10.00	81.0	FT
Bent No. 2	10.92	10.00	109.2	FT
Bent No. 3	13.82	10.00	138.2	FT
Bent No. 4	16.80	10.00	168.0	FT
Bent No. 4A	17.25	6.00	103.5	FT
Bent No. 5	18.64	7.00	130.5	FT
Bent No. 6A	20.00	8.00	160.0	FT
Bent No. 6	20.00	10.00	200.0	FT
Bent No. 7A	20.00	7.00	140.0	FT
Bent No. 8	20.00	10.00	200.0	FT
Bent No. 9	18.60	16.00	297.6	FT
Bent No. 10	16.50	10.00	165.0	FT
Bent No. 11	12.50	11.00	137.5	FT
East Abutment	8.00	9.00	72.0	FT
		Subtotal:	2134.5	FT

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Alternate: **Minimum Repair Scope of Work**

Timber Bracing - Longitudinal Axis of Bent						
Bent No. 1	0.5	160.40	1	1	962.4	FB
Bent No. 2	0.5	164.00	1	1	984.0	FB
Bent No. 3	0.5	164.00	1	1	984.0	FB
Bent No. 4	0.5	164.00	1	1	984.0	FB
Bent No. 4A	0.5	14.80	1	1	88.8	FB
Bent No. 5	0.5	106.00	1	1	636.0	FB
Bent No. 6A	0.5	14.80	1	1	88.8	FB
Bent No. 6	0.5	164.00	1	1	984.0	FB
Bent No. 7A	0.5	40.50	1	1	243.0	FB
Bent No. 8	0.5	0.00	1	1	0.0	FB
Bent No. 9	0.5	27.60	1	1	165.6	FB
Bent No. 10	0.5	146.00	1	1	876.0	FB
Bent No. 11	0.5	165.64	1	1	993.8	FB
				Subtotal:	7990.4	FB
Timber Bracing - Lateral Axis of Bent						
Bent No. 2 to Bent No. 3	0.5	19.1	1	4	458.4	FB
Bent No. 5 to Bent No. 6A	0.5	19.1	1	4	458.4	FB
Bent No. 8 to Bent No. 9	0.5	19.1	1	4	458.4	FB
				Subtotal:	1375.2	FB
Concrete Abutments						
East Abut. Backwall	0.5	1	0.75	1	0.38	CF
East Abut. Breastwall	0.16667	4.5	0.4167	1	0.31	CF
				Subtotal:	0.7	CF

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Alternate: **Minimum Repair Scope of Work**

Channel & Channel Protection						
Timber Fender System						
Fender	0.5	7.6	1.000	66	3009.6	FB
6" x 12" x 41'-0"	0.5	41	1.000	4	984.0	FB
				Subtotal:	3993.6	FB
Traffic Safety						
Approach Guardrail/Transitions						
West Approach Sidewalk Rail		120		2	240.0	FT
East Approach Sidewalk Rail		120		2	240.0	FT
				Subtotal:	480.0	FT
Roadway (Milling and Resurfacing)	24		120	2	640.0	SY
Demolition						
Spans 1, 8 & 12	31.50	16.125		3	1523.8	SF
Spans 2 & 11	34.50	16.125		2	1112.6	SF
Spans 3, 4, 5, 6, 7, 9 & 10	37.50	16.125		7	4232.8	SF
				Subtotal:	6869.3	SF

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Alternate: **Minimum Repair Scope of Work**

SUMMARY

	UNIT PRICE	QUANTITY		COST
Treated Timber	$12,000.00	60.8	MB	$729,600
Steel Ballast For Counterweight	$1.00	84400	LB	$84,400
FRP Jackets	$2,500.00	2134	FT	$5,336,200
Roadway (Milling and Resurfacing)	$150.00	640	FT	$96,000
Approach Guardrail/Transitions	$105.00	480	FT	$50,400
Demolition	$30.00	6869	SF	$206,078
Operating Equipment	$700,000.00	1		$700,000
	Subtotal:			$7,202,677
Traffic Control (10% of Total)				$720,268
Mobilization (10% of Total Cost)				$720,268
Contingencies (10% of Total Cost)				$720,268
			Total Cost =	**$9,363,000**

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Alternative: **Rehabilitation**

ESTIMATED QUANTITIES

	W	L	H/T	No.	Quantity	Units
Deck	ft	ft	ft			
Timber Wearing Surface						
Spans 1,2,3,4,5,6,9,10,11,12	25.33	15.96	0.25	9	10916.6	FB
Bascule Spans	25.33	50.00	0.25	1	3800.0	FB
				Subtotal:	14716.6	FB
Timber Structural Deck						
Spans 1, 8 & 12	34.25	16.13	0.33	3	6630.2	FB
Spans 2 & 11	36.25	16.13	0.33	2	4678.3	FB
Spans 3, 4, 5, 6, 7, 9 & 10	38.25	16.13	0.33	7	17277.4	FB
				Subtotal:	28585.9	FB
Timber Sidewalk						
Included in "Timber Structural Deck"						
Timber Bridge Railing						
6" x 6" Top Rail	0.50	575.16	0.50	1	1725.5	FB
9 1/2" x 4 1/2" Mid Rail	0.38	575.16	0.79	1	2049.0	FB
4" x 6" Bottom Rail	0.33	575.16	0.50	1	1150.3	FB
6" x 8" x 24" Block	0.50	2.00	0.67	192	1536.0	FB
8" x 8" Post	0.67	5.17	0.67	96	2645.3	FB
				Subtotal:	9106.1	FB

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Alternative: **Rehabilitation**

ESTIMATED QUANTITIES

Superstructure					
Stringers 6" x 16" (Including Blocking)					
Span 1	0.50	15.96	1.33	26	3319.7 FB
Span 2	0.50	15.96	1.33	27	3447.4 FB
Span 3	0.50	15.96	1.33	29	3702.7 FB
Span 4	0.50	15.96	1.33	30	3830.4 FB
Span 5	0.50	15.96	1.33	29	3702.7 FB
Span 6	0.50	15.96	1.33	30	3830.4 FB
Span 7 (Counter Weight)	0.50	11.45	1.33	31	2839.6 FB
Span 8 (Bascule Span)	0.67	22.00	1.33	25	5869.6 FB
Span 9	0.50	16.55	1.33	30	3972.0 FB
Span 10	0.50	15.96	1.33	29	3702.7 FB
Span 11	0.50	15.96	1.33	27	3447.4 FB
Span 12	0.50	15.96	1.33	26	3319.7 FB
Diaphragm Blocks	0.79	1.00	1.00	327	3106.5 FB
				Subtotal:	48090.7 FB
Lifting Beam	0.67	35.50	1.00	1	285.4 FB
King Posts	1.17	29.25	1.17	2	955.4 FB

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Alternative: **Rehabilitation**

ESTIMATED QUANTITIES

COUNTERWEIGHT	W	L	H/T	Number	Vol	
Ballast	31.50	3.50	1.86	1	100600	LB
				Subtotal:	100600	LB
Substructure						
Timber Pile Replacement		60.00		128.00	7680.0	FT
Timber Pile Caps						
West Abutment Cap	0.67	31.08	0.67	1	165.8	FB
Bent No.1	1.33	31.50	1.17	1	588.0	FB
Bent Nos. 2,3,4,4A,5,6A,6,8,9 &10	1.33	37.50	1.17	11	7700.0	FB
Bent Nos. 7A	0.67	41.50	1.33	2	889.8	FB
Bent No. 11	1.33	31.35	1.17	1	585.3	FB
East Abutment Cap	1.00	31.42	0.67	1	251.3	FB
Wood Blocking	1.00	1.50	1.33	138	3312.0	FB
				Subtotal:	13492.1	FB

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Alternative: **Rehabilitation**

ESTIMATED QUANTITIES

Timber Bracing - Lateral						
Bent No. 1	0.50	160.40	1.00	1	962.4	FB
Bent No. 2	0.50	164.00	1.00	1	984.0	FB
Bent No. 3	0.50	164.00	1.00	1	984.0	FB
Bent No. 4	0.50	164.00	1.00	1	984.0	FB
Bent No. 4A	0.50	14.80	1.00	1	88.8	FB
Bent No. 5	0.50	106.00	1.00	1	636.0	FB
Bent No. 6A	0.50	14.80	1.00	1	88.8	FB
Bent No. 6	0.50	164.00	1.00	1	984.0	FB
Bent No. 7A	0.50	40.50	1.00	1	243.0	FB
Bent No. 8	0.50	0.00	1.00	1	0.0	FB
Bent No. 9	0.50	27.60	1.00	1	165.6	FB
Bent No. 10	0.50	146.00	1.00	1	876.0	FB
Bent No. 11	0.50	165.64	1.00	1	993.8	FB
				Subtotal:	7990.4	FB
Timber Bracing - Longitudinal						
Bent No. 2 to Bent No. 3	0.50	19.10	1.00	4	458.4	FB
Bent No. 5 to Bent No. 6A	0.50	19.10	1.00	4	458.4	FB
Bent No. 8 to Bent No. 9	0.50	19.10	1.00	4	458.4	FB
				Subtotal:	1375.2	FB
Concrete Abutments						
East Abut. Backwall	0.50	1.00	0.75	1	0.38	CF
East Abut. Breastwall	0.17	4.50	0.42	1	0.31	CF
				Subtotal:	0.69	CF

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Alternative: **Rehabilitation**

ESTIMATED QUANTITIES

Channel & Channel Protection						
Timber Fender System						
Fender	0.50	7.60	1.00	66	3009.6	FB
6" x 12" x 41'-0"	0.50	41.00	1.00	4	984.0	FB
				Subtotal:	3993.6	FB
Traffic Safety						
Approach Guardrail/Transitions						
Timber Traffic Rail						
Timber Post (10"x8" Nom)	0.667	4.250	0.833	87	2456.9	FB
Timber Block (4.5"x13.5")	0.396	1.167	1.125	87	542.4	FB
Top Rail (6.5"x6.5")	0.542	433.580	0.542	2	3053.1	FB
Bott.Rail (12"x6" Nom)	1.000	433.580	0.500	2	5203.0	FB
				Subtotal:	11255.4	FB
Roadway (Milling and Resurfacing)	24		120	2	640.0	SY
Concrete for Sidewalk (refer to hand sketch)						
A	4.625	0.5	120	4	41.1	CY
B	1.0	2.0	120	4	35.6	CY
				Subtotal:	76.7	CY
Curb & Gutter			120	4	480.0	FT
Demolition						
Spans 1, 8 & 12	31.50	16.13		3	1523.8	SF
Spans 2 & 11	34.50	16.13		2	1112.6	SF
Spans 3, 4, 5, 6, 7, 9 & 10	37.50	16.13		7	4232.8	SF
				Subtotal:	6869.3	SF

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Alternative: **Rehabilitation**

ESTIMATED QUANTITIES

SUMMARY

	UNIT PRICE	QUANTITY		COST
Treated Timber	$12,000.00	139.9	MB	$1,678,800
Steel Ballast For Counterweight	$1.50	100600	LB	$150,900
Concrete for Sidewalk	$875.00	76.7	CY	$67,083
Roadway (Milling and Resurfacing)	$150.00	640	SY	$96,000
Curb & Gutter	$22.50	480	FT	$10,800
Timber Pile Replacement	$100.00	7680	FT	$768,000
Demolition	$30.00	6869	SF	$206,078
Operating Equipment	$700,000.00	1	LS	$700,000
	Subtotal:			$3,677,661
Traffic Control (10% of Total)				$367,766
Mobilization (10% of Total Cost)				$367,766
Contingencies (10% of Total Cost)				$367,766
			Total Cost =	**$4,781,000**

APPENDIX H

Operating Equipment Evaluation

ECDriver

CALCULATION COVER SHEET

Project Name: URS Chatham Bridge, MA

Project No.: 10160874.00700

Calculation Title: Chatham Bridge Bascule Lifting Wire Rope Factors of Safety

Total Number of Pages (including cover sheet): 5

Prepared By: Michael Reponen **Date:** February 2011

Checked By: ______ **Date:** ______

Description and Purpose:

1) Determine the design loads for the non-code compliant existing lifting wire ropes
2) Determine the AASHTO required and provided factors of safety if the non-code compliant existing wire ropes are replaced with code compliant wire ropes
3) Determine the code required minimum deflector sheave diameter
4) Determine the provided factors of safety if the non-code compliant deflector sheaves and non-code compliant wire ropes are replaced with code compliant versions.

Design Basis / References / Assumptions:

AASHTO LRFD Moveable Highway Bridge Design Specifications 2nd Edition w/ 2008 Interims
This is a conceptual level calculation. Many calculation values have been assumed and greatly simplified

Remarks / Conclusions:

AASHTO requires that the wire rope design loads do not exceed the following: 30% of breaking strength for bending plus tension, and 16.7% of the breaking strength for pure tension. The existing wire ropes are not AASHTO code-compliant. The existing deflector sheaves are also not AASHTO code compliant. The existing wire ropes are specified as MIL-W-83420 "WIRE ROPE, FLEXIBLE, FOR AIRCRAFT CONTROL". If the existing wire ropes are replaced with AASHTO compliant Extra Improved Plow Steel wire ropes of a similar size, the existing design loads produce the following:

Direct Tension = 8% of breaking Tension + Bending = **57%** of breaking

If the wire ropes and the deflector sheaves are both replaced with code compliant versions:

Direct Tension = 8% of breaking Tension + Bending = 27% of breaking

Approved By: ______

Title: ______

Date: ______

Distribution: ______ ______

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EXISTING DRIVE MACHINERY SYSTEM

*Assuming equivalent AASHTO Approved Steel Cable

*Assume Wood δ = 45 PCF

Estimated Balance:

Bascule Deck Dimensions = 23.25 ft × 24 ft Roadway + 3'-9" Sidewalks

Framing: 6" × 16" Stringers @ 15½" oc = (0.5 ft)(1.3 ft)(12 in/15.5 in)(45 pcf) = 23.2 PSF

Structural Decking: 4" Thk Planking = (0.3 ft)(1 ft)(45 pcf) = 15 PSF

Wearing Surface: 3" Thk Planking = (0.25 ft)(1 ft)(45 pcf) = 11.3 PSF

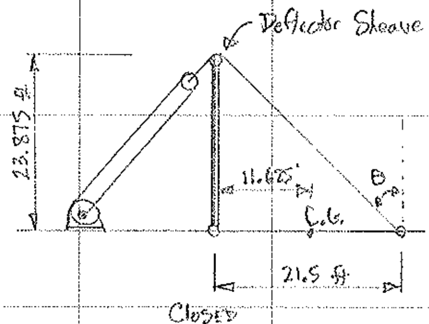
Pedestrian Railing: Assume 150 PLF

Traffic Curb: 8" × 8" × Cont. + 8" × 6" × 12" @ 6'-0" oc = 33 PLF

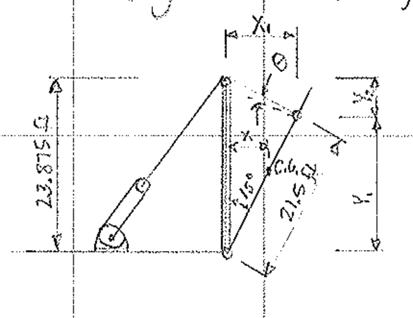
Forward Weight = (23.25 ft)(31.5 ft)(23.2 PSF + 15 PSF)
+ (23.25 ft)(24 ft)(11.3 PSF)
+ (150 PLF + 33 PLF)(2)(23.25 ft) = 42.79 K

Forward Moment = (42.79 K)(11.625 ft) = 497.4 K·ft

*Counterweight Balanced for 5 K tension in each lifting cable (Bridge is Tip Heavy)



CLOSED



FULL OPEN

$\cos 15° = y_1 / 21.5$ ft

$y_1 = 20.767$ ft

$\tan 15° = X_1 / 20.767$ ft

$X_1 = 5.565$ ft

(23.875 ft) − (20.767 ft) = 3.108 ft

$\tan \delta = 3.108 \text{ ft} / 5.565 \text{ ft}$

$\delta = 29.183°$

θ_{closed}: $\tan\theta = \frac{21.5 \text{ ft}}{23.875 \text{ ft}}$ $\theta = 42.0°$

$\theta_{open} = 29.183° - 15° = 14.18°$

$\cos 42° = \frac{\text{Vert Force}}{(2)(5\text{ K})}$ Vert Force = 7.43 K

Unbalanced Moment = (7.43 K)(21.5 ft) = 159.8 K·ft

Counterweight: (497.4 K·ft) − (159.8 K·ft) = 337.6 K·ft

Counterweight Moment Arm = 7 ft

Counterweight Estimated Weight = (337.6 K·ft)/(7 ft) = 48.2 K

Wire Rope: Assume ⅞" Ø Extra Improved Plow Steel 6×19 Class w/ 6×25 Filler Wire

P_{ult} = 70.8 K AASHTO Mov 6.8.3.3.6-1

Deflector Sheave Dia = 15 in

Allowable Stresses (6.6.5): 30.8 P_{ult} Tension + Bending; 16.78 P_{ult} Tension Only

Bending Stress (6.8.3.3.4): $\sigma_b = E_w \cdot \frac{d_w}{D}$ $d_w \approx D/16$ $E_w = 30 \times 10^6$ psi D = 15 in

$$\sigma_b = (30 \times 10^6 \text{ psi})\left(\frac{0.875 \text{ in}}{16}\right)\left(\frac{1}{15 \text{ in}}\right) = 109.38 \text{ ksi}$$

$A = 0.417 d^2 = 0.417(7/8 \text{ in})^2 = 0.319 \text{ in}^2$

$\sigma_u = (70.8 \text{ K}) / (0.319 \text{ in}^2) = 221.8$ ksi

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3 Load Cases AASHTO MOVEABLE 5.4.2 * Case 2 does not control by inspection

① Maximum Starting Torque
a) Static Friction
b) Unbalanced Conditions
c) 2.5 PSF Ice Load

② Max Const. Velocity Torque
a) Dynamic Friction
b) Unbalanced Conditions
c) Wind Load 2.5 PSF

③ Holding Open
a) Unbalanced Conditions
b) 20 PSF WIND on Vertical Projection

Case 1: Static Friction
*Assume 1" Ø Shaft

$W_{TOT} = (42.79\ K) + (48.2\ K) = 91.0\ K$

$F = \mu N = (0.30)(91.0\ K) = 27.3\ K$

$Torque_F = (27.3\ K)(0.5\ in) = 1.1\ K \cdot ft$

Unbalanced Conditions = 159.8 K·ft

Ice Load = (23.25 ft)(31.5 ft)(2.5 PSF)(11.625 ft) = 21.3 K·ft

Tot = 182.2 K·ft

Case 3: Unbalanced Conditions

Moment arm closed = 11.625 ft $\sin 15° = X / ((21.5\ ft)(0.5))$

Moment arm open = 2.78 ft

$\frac{(2.78\ ft)}{(11.625\ ft)} (159.8\ K \cdot ft) = 38.21\ K \cdot ft$

WIND Load (23.25 ft) cos 15° = 22.45 ft

(22.45 ft)(31.5 ft)(20 PSF)(11.225 ft) = 158.8 K·ft

Tot = 196.97 K·ft

Wire Rope Safety Factor: (6.6.5) (With Existing Sheave Size)

Required Safety Factors = 3.33 Tension + Bending (30% of P_{ult})
5.98 Tension Only (16.7% of P_{ult})

Provided Safety Factors

Case 1 Tension (182.2 K·ft / 21.5 ft) / cos 42° = 11.40 K $\sigma_t = (11.40\ K)/((2)(0.319\ in^2)) = 17.86$ ksi

Case 3 Tension (196.97 K·ft / 21.5 ft) / cos 14.18° = 9.45 K $\sigma_t = (9.45\ K)/((2)(0.319\ in^2)) = 14.81$ ksi

$SF_{① tens} = (221.8\ ksi) / (17.86\ ksi) = 12.4$ (OK)

$SF_{③ tens} = (221.8\ ksi) / (14.81\ ksi) = 14.9$ (OK)

$SF_{① tens+bend} = (221.8\ ksi) / (17.86\ ksi + 109.38\ ksi) = 1.74$ (NG) Start of Opening

$SF_{③ tens+bend} = (221.8\ ksi) / (14.81\ ksi + 109.38\ ksi) = 1.79$ (NG) OPEN POSITION

AASHTO Req'd Deflector Sheave Size: (6.8.3.1.3) 45·d_{wire}, 48·d_{wire} Preferred

45 (7/8 in) = 39.375 in   Use 40 in Ø

$\sigma_b = E_w \cdot \frac{d_w}{D} = (30 \times 10^6\ psi)\left(\frac{0.875\ in}{16}\right)\left(\frac{1}{40\ in}\right) = 41.0\ ksi$

Wire Rope Safety Factor: (With AASHTO approved Deflector Sheave)

$SF_{① tens} = 12.4$ (OK)

$SF_{③ tens} = 14.9$ (OK)

$SF_{① tens+bend} = (221.8\ ksi) / (17.86\ ksi + 41.0\ ksi) = 3.77$ (OK)

$SF_{③ tens+bend} = (221.8\ ksi) / (14.81\ ksi + 41.0\ ksi) = 3.97$ (OK)

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Try 3/4" ∅ Extra Improved Plow Steel Wire Rope: (w/ Code Req'd Sheave)

$P_{ult} = 52.4$ K

$A = 0.417(.75 \text{ in})^2 = 0.235 \text{ in}^2$

Req'd Deflec. Sheave = 45(0.75 in) = 33.75 in ∅

$\sigma_b = (30 \times 10^6 \text{ psi})\left(\frac{0.75 \text{ in}}{16}\right)\left(\frac{1}{33.75 \text{ in}}\right) = 41.7$ ksi

Breaking Stress = (52.4 K)/(0.235 in²) = 223.0 ksi

$SF_{①\ tens}$ = (11.40 K)/(2)(0.235 in²) = 24.3 ksi $\frac{223.0 \text{ ksi}}{24.3 \text{ ksi}} = 9.19$ (OK)

$SF_{②\ tens}$ = (9.45 K)/(2)(0.235 in²) = 20.0 ksi $\frac{223.0 \text{ ksi}}{20.0 \text{ ksi}} = 11.2$ (OK)

$SF_{①\ tens+bend}$ = (223.0 ksi)/(24.3 ksi + 41.7 ksi) = 3.37 < 3.33 (OK)

$SF_{②\ tens+bend}$ = (223.0 ksi)/(20.0 ksi + 41.7 ksi) = 3.61 < 3.33 (OK)

Check Safety Factor of Secondary Wire Rope:

* Assume ∅ Pulley = 15" ⇐ Approximated from photos
* Assume replace existing 5/8" ∅ rope with 5/8" Extra Improved Plow steel rope (5/8" ∅ is smaller than the AASHTO minimum size of 3/4")

$P_{ult} = 36.6$ K $A = 0.417(0.625 \text{ in})^2 = 0.1629 \text{ in}^2$ $\sigma_t = (36.6 \text{ K})/0.1629 \text{ in}^2 = 224.7$ ksi

$\sigma_b = (30 \times 10^6 \text{ psi})\left(\frac{0.625 \text{ in}}{16}\right)\left(\frac{1}{15 \text{ in}}\right) = 78.13$ ksi Mech. Advantage = 2

Direct Tension① = (11.40 K)/(2 ropes)(2)(0.1629 in²) = 17.50 ksi

Direct Tension② = (9.45 K)/(2 ropes)(2)(0.1629 in²) = 14.50 ksi

$SF_{①\ tens}$ = (224.7 ksi)/(17.5 ksi) = 12.8 (OK)

$SF_{②\ tens}$ = (224.7 ksi)/(14.5 ksi) = 15.5 (OK)

$SF_{①\ tens+bend}$ = (224.7 ksi)/(78.13 ksi + 17.50 ksi) = 2.35 (N.G.)

$SF_{②\ tens+bend}$ = (224.7 ksi)/(78.13 ksi + 14.50 ksi) = 2.43 (N.G.)

TABLE 21 MINIMUM BREAKING FORCE OF WIRE ROPE
6 x 19 Classification/Bright (Uncoated), Fiber Core

Nominal Diameter		Approximate Mass		Minimum Breaking Force*			
				Improved Plow Steel**		Extra Improved Plow**	
inches	mm	lb/ft	kg/m	tons	metric tonnes	tons	metric tonnes
1/4	6.4	0.11	0.16	2.74	2.49	3.02	2.74
5/16	7.9	0.16	0.24	4.26	3.86	4.69	4.25
3/8	9.5	0.24	0.35	6.10	5.53	6.72	6.10
7/16	11.1	0.32	0.48	8.27	7.50	9.10	8.26
1/2	12.7	0.42	0.63	10.7	9.71	11.8	10.7
9/16	14.3	0.53	0.79	13.5	12.2	14.9	13.5
5/8	15.9	0.66	0.98	16.7	15.1	18.3	16.6
3/4	19.1	0.95	1.41	23.8	21.6	26.2	23.8
7/8	22.2	1.29	1.92	32.2	29.2	35.4	32.1
1	25.4	1.68	2.50	41.8	37.9	46.0	41.7
1-1/8	28.6	2.13	3.17	52.6	47.7	57.8	52.4
1-1/4	31.8	2.63	3.91	64.6	58.6	71.1	64.5
1-3/8	34.9	3.18	4.73	77.7	70.5	85.5	77.6
1-1/2	38.1	3.78	5.63	92.0	83.5	101	91.6
1-5/8	41.3	4.44	6.61	107	97.1	118	107
1-3/4	44.5	5.15	7.66	124	112	137	124
1-7/8	47.6	5.91	8.80	141	128	156	142
2	50.8	6.72	10.0	160	145	176	160
2-1/8	54	7.59	11.3	179	162	197	179
2-1/4	57.2	8.51	12.7	200	181	220	200

* To convert to Kilonewtons (kN), multiply tons (minimum breaking force) by 8.896;
1 lb = 4.448 newtons (N).

** Minimum breaking forces listed above apply to ropes with bright or drawn galvanized wires. Minimum breaking forces are 10% lower for ropes with wires galvanized at finish size.

APPENDIX I

Correspondence

RECEIVED
JUL 13 2010
BY: FHWA

The Commonwealth of Massachusetts

William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

July 7, 2010

Lucy Garliauskas
Division Administrator
FHWA
55 Broadway 10th Floor
Cambridge, MA 02142

ATTN: Damaris Santiago

RE: Mitchell River Bridge, Bridge No. C-07-001, Chatham, MA; MHC# 46959

Dear Ms. Garliauskas:

The Massachusetts Historical Commission (MHC), office of the State Historic Preservation Officer (SHPO) has received your request for any additional comments regarding the determination of eligibility package to be sent to the Keeper of the National Register regarding the Mitchell River Bridge in Chatham, Massachusetts. After review of the submitted information and MHC files, MHC staff have the following comments.

The MHC reiterates its prior opinion that the Mitchell River Bridge in Chatham, Massachusetts is not eligible for listing in the National Register of Historic Places.

The purpose of this letter is to provide additional comments to supplement MHC's previous opinion letters dated 1/12/10 and 2/26/10 and MHC's National Register Eligibility Opinion dated 1/6/10 (copies enclosed). The Mitchell River Drawbridge is substantially a timber, single-leaf drawbridge dating to 1980-1982 that replaced an existing timber, single-leaf drawbridge at this location. The 1980-1982 bridge incorporated a majority of the wooden substructure pilings extant at that time and that dated to an earlier, 1925 reconstruction of the bridge at this location. The 1980-1982 bridge, like its predecessor, was a single-span, simple trunnion, cable lift bascule bridge. However, the 1980-1982 replacement bridge does not represent a historic reconstruction or replication of the design of the prior bridge. Nor can it be considered to represent routine, incremental, in-kind replacement and repair. The 1980-1982 bridge was the result of a new design that addressed new requirements for draw operation and transportation. These included a lengthening of the draw span, and most notably, the relocation of the draw hinge from the historic east end to the contemporary west end of the span. The decking of the bridge was also widened at this time. These features of the 1980-1982 bridge are noted and acknowledged in materials provided to the MHC by the Chatham Historical Commission.

Given that the design and potential significance of the engineering of the bridge lies in those features of the bridge related to its function as a timber drawbridge, MHC staff considers the surviving 1925 pilings as secondary to the features that relate directly to the functioning of the bridge as a lift bridge. As the design, engineering, materials, workmanship, and associations of the draw superstructure all relate to its construction in 1980-1982, MHC concludes that the bridge does not retain integrity of its historic character, and as a 1980-1982 construction does not meet the 50 year criterion for eligibility for listing in the National Register.

These comments are offered to assist in compliance with Section 106 of the National Historic Preservation Act of 1966 (36 CFR 800). Please do not hesitate to contact Michael Steinitz of my staff if you have any questions.

Sincerely,

Brona Simon

Brona Simon
State Historic Preservation Officer
Executive Director
Massachusetts Historical Commission

Enclosures

xc (w/encl): Carol Legard, ACHP (FHWA Liason)
Steve Roper, MassDOT

The Commonwealth of Massachusetts

William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

February 26, 2010

Norman & Carol Pacun
Friends of the Mitchell River Bridge
c/o 14 Sunset Lane
Chatham, MA 02633

RE: Mitchell River Bridge, Chatham, MA; MHC# 46959

Dear Mr. Pacun:

Thank you for your submission regarding the above referenced project, received January 28, 2010. The staff of the Massachusetts Historical Commission (MHC) has reviewed the information submitted and has the following comments.

MHC in its previous correspondence of January 12, 2010 wrote that in the opinion of MHC staff, the Mitchell River Drawbridge is substantially a modern structure dating to 1980-81 that incorporates some elements – timber piles – from the prior bridge at this site, and therefore does not meet the criteria for listing on the National Register of Historic Places, as it is less than 50 years of age.

It is the opinion of the MHC staff that the Mitchell River Drawbridge is also not eligible for listing on the National Register of Historic Places under Criteria Consideration G relating to properties that have achieved significance within the past fifty years. To achieve eligibility under Criteria Consideration G, properties must demonstrate exceptional importance.

MHC acknowledges that the Mitchell River Drawbridge appears to be the only extant single-leaf wooden drawbridge in Massachusetts. Further substantiation beyond correspondence from the Coast Guard would be necessary to show conclusively that the bridge is indeed "the last remaining single-leaf wooden drawbridge in the entire United States." It must however be recognized that a resource does not achieve exceptional importance only by being the only one of its kind, or the last of its kind within a local, state or national context. The resource must also demonstrate exceptional qualities or associations. In particular, the Mitchell River Drawbridge does not appear to be an example of particularly significant or outstanding engineering or design.

220 Morrissey Boulevard, Boston, Massachusetts 02125
(617) 727-8470 • Fax: (617) 727-5128
www.sec.state.ma.us/mhc

Moreover, as a wooden structure, the Mitchell River Drawbridge may be expected to experience a material lifespan of less than 50 years, but this does not lead to a conclusion that the bridge embodies exceptionally important characteristics that are so fragile that any survivor, of any age, becomes significant. The Mitchell River Drawbridge appears to represent a modern, 1980-81 construction of a typical single leaf, cable lift, trunnion bascule form.

The case for exceptional importance for properties less than fifty years of age may be bolstered when there is a substantial amount of professional, documented materials on the resource and the resource type demonstrating a widespread scholarly or professional recognition of its value. Although materials provided in your earlier submission to MHC include correspondence from historic bridge scholar James Cooper, Dr. Cooper's comments do not in themselves establish such an evaluative literature framework. .

These comments are offered to assist in compliance with Section 106 of the National Historic Preservation Act of 1966 (36 CFR 800), M.G.L. Chapter 9, Section 26-27C, (950 CMR 71.00) and MEPA. Please do not hesitate to contact Michael Steinitz of my staff if you have any questions.

Sincerely,

Brona Simon

Brona Simon
State Historic Preservation Officer
Executive Director
Massachusetts Historical Commission

xc: Steve Roper, MHD

The Commonwealth of Massachusetts

William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

January 12, 2010

Norman & Carol Pacun
Friends of the Mitchell River Bridge
c/o 14 Sunset Lane
Chatham, MA 02633

RE: Mitchell River Bridge, Chatham, MA; MHC# 46959

Dear Mr. Pacun:

Thank you for your submission regarding the above referenced project, received December 17, 2009. The staff of the Massachusetts Historical Commission (MHC) has reviewed the information submitted and has the following comments.

It is the opinion of the MHC staff that the Mitchell River Drawbridge does not meet the criteria for the National Register of Historic Places, as it is less than 50 years of age.

The Mitchell River Drawbridge is a timber, single-span, single trunnion, cable-life bascule bridge with timber pile bent approaches. The first bridge on the site was constructed in 1858 and is reportedly to have been of a similar design. After numerous repairs the bridge was rebuilt completely in 1925, again reportedly in the same style as the original bridge; it was widened in 1949 using many of the piles from the 1925 bridge. In 1980-82, the superstructure of the bridge was replaced, although many of the piles from the earlier structure were reportedly reused.

The fact that the present structure may incorporate fragments of an earlier structure on the site, however, does not mitigate against the overriding presence of the 1989-1982 superstructure, the character-defining feature of the bridge. As a structure erected in 1980-1982, the bridge does not meet the criteria for the National Register of Historic Places, as it is less than 50 years of age.

These comments are offered to assist in compliance with Section 106 of the National Historic Preservation Act of 1966 (36 CFR 800), M.G.L. Chapter 9, Section 26-27C, (950 CMR 71.00) and MEPA. Please do not hesitate to contact Michael Steinitz of my staff if you have any questions.

Sincerely,

Brona Simon

Brona Simon
State Historic Preservation Officer
Executive Director
Massachusetts Historical Commission

xc: Steve Roper, MHD

220 Morrissey Boulevard, Boston, Massachusetts 02125
(617) 727-8470 • Fax: (617) 727-5128
www.sec.state.ma us/mhc

Original yellow form: Eligibility file
Copies: Inventory form
Town file(w/corresp.) ✓
Macris
NR director ____

Community: Chatham

MHC OPINION: ELIGIBILITY FOR NATIONAL REGISTER

Date Received: 17 Dec. 2009 Date Due: Date Reviewed: 01/06/2010

Type: _X_ Individual _District (Attach map indicating boundaries)

Name: Mitchell River Drawbridge Inventory Form: **CHA.914;** DPW No. C-07-001

Address: Bridge Street, Chatham

Requested by: "Friends of the Mitchell River Wooden Drawbridge"

Action: __Honor __ITC __Grant _X_R & C __Other:

Agency: Staff in charge of Review: Brandee Loughlin

INDIVIDUAL PROPERTIES

__ Eligible
__ Eligible, also in district
__ Eligible <u>only</u> in district
_X_Ineligible
__ More information needed

DISTRICTS

__ Eligible
__ Ineligible
__ More information needed

CRITERIA: __A __B __C __D

LEVEL: __Local __State __National

STATEMENT OF SIGNIFICANCE by Peter Stott

It is the opinion of MHC Staff that the Mitchell River Drawbridge, dating to 1980-82, does not meet the criteria for the National Register of Historic Places, as it is less than 50 years of age.

The Mitchell River Drawbridge is a timber, single-span, single-trunnion, cable-lift bascule bridge with timber pile bent approaches. The first bridge on the site was constructed in 1858 and is reportedly to have been of a similar design. After numerous repairs the bridge was rebuilt completely in 1925 again reportedly in the same style as the original bridge; it was widened in 1949 using many of the piles from the 1925 bridge. In 1980-82, the superstructure of the bridge was replaced, although many of the piles from the earlier structure were reportedly reused.

The fact that the present structure may incorporate fragments of an earlier structure on the site, however, does not mitigate against the overriding presence of the 1980-82 superstructure, the character-defining feature of the bridge. As a structure erected in 1980-82, the bridge does not meet the criteria for the National Register of Historic Places, as it is less than 50 years of age.

United States Department of the Interior

NATIONAL PARK SERVICE
1849 C Street, N.W.
Washington, D.C. 20240

IN REPLY REFER TO:

DETERMINATION OF ELIGIBILITY NOTIFICATION

National Register of Historic Places
National Park Service

Name of Property: Mitchell River Bridge
Location: Barnstable County **State:** MA

Request submitted by: Lucy Garliauskas, Division Administrator, US Department of Transportation Federal Highway Administration.

Date received: 9/07/2010 **Additional information received** 9/09/2010

Opinion of the State Historic Preservation Officer:

__**Eligible** X **Not Eligible** _**No Response** _**Need More Information**

Comments:

The Secretary of the Interior has determined that this property is:

X **Eligible** A and C ___**Not Eligible**
Applicable criteria:

Comment:

See attached for detailed comment

Carol D. Shull
Keeper of the National Register

Date: 10-1-2010

WASO-28

United States Department of the Interior

NATIONAL PARK SERVICE
1849 C Street, N.W.
Washington, D.C. 20240

IN REPLY REFER TO:

DETERMINATION OF ELIGIBILITY NOTIFICATION

NATIONAL REGISTER OF HISTORIC PLACES
NATIONAL PARK SERVICE

Name of Property: Mitchell River Bridge
Location: Chatham, Barnstable County, Massachusetts

The Mitchell River Bridge, in Chatham, Massachusetts, is eligible for the National Register of Historic Places under Criterion A for its association with local transportation history and under Criterion C as a rare surviving example of a structure embodying the distinctive characteristics of a once-common method of construction. The Mitchell River Bridge, constructed in 1980 atop the pilings of an earlier bridge, is one of a continuous line of wooden drawbridges that have spanned this river crossing for over 150 years. It is the last remaining single-leaf wooden drawbridge in Massachusetts (and perhaps in the entire United States), and as such, is of exceptional significance.

The importance of a wooden drawbridge over the Mitchell River has long been recognized by the residents of Chatham, Massachusetts. The records show that over the years, residents have insisted that when authorities proposed alterations to the Mitchell River Bridge that priority was to be given to in kind replacement of its materials, and retention of its simple design, form and function as a wooden drawbridge. The three successive wooden drawbridges over the Mitchell River (1858, 1925, and 1980) have been depicted through the decades in drawings, paintings, postcards and photographs. The Chatham Historical Commission, the Friends of the Mitchell River Wooden Drawbridge and others have repeatedly affirmed that they consider the bridge to be historically significant, and that the simple, yet distinctive, configuration of the bridge and its presence on the landscape form an exceptionally important part of the community's historic identity.

Carol D. Shull

Carol D. Shull
Interim Keeper
National Register of Historic Places
October 1, 2010

Deval L. Patrick, Governor
Timothy P. Murray, Lt. Governor
Jeffrey B. Mullan, Secretary & CEO
Luisa Paiewonsky, Administrator

massDOT
Massachusetts Department of Transportation
Highway Division

February 8, 2011

Leonard M. Sussman, Chairman
Chatham Board of Selectmen
549 Main Street
Chatham, MA 02633

Dear Mr. Sussman:

I am responding to your letter of January 12, 2011, regarding the status of the Mitchell River Bridge in Chatham. I wish to reiterate to you that this project remains programmed for funding under our Accelerated Bridge Program. As you know, the ABP is an eight-year program with funding available through June 2016. Therefore, all ABP projects must be permitted, designed, and fully constructed during that time frame. The determination by the Keeper of National Register of Historic Places that the Mitchell River Bridge is eligible for the National Register does not have any bearing on the availability of funds for this project.

On October 29, 2010, my staff met with several members of the Board of Selectmen to provide a project update, assure the Town that MassDOT and Federal Highway Administration is fully committed to this project, and to completing a full review under Section 106 of the National Historic Preservation Act of 1966, as amended. As part of our continuing compliance with Section 106, MassDOT is investigating whether or not the existing wooden bridge can be repaired or rehabilitated. We anticipate that a rehabilitation feasibility report will be completed by the end of February and the results made available to all stakeholders.

In the event that we determine that the bridge cannot be rehabilitated, MassDOT is confident that we can mitigate the adverse effect of removing the bridge by working with the Town and the consulting parties to come up with a design that will honor the historic character of the existing bridge. However, MassDOT continues to have very serious reservations regarding the proposed use of wood piles in the water. We are confident that as the evaluations are completed, we can confirm our position regarding use of wood in water. As referenced in your letter regarding my remarks to the Boston Globe, we take the determination by the Keeper seriously. However, the Keeper's determination does not obligate the Commonwealth to fund or replace the existing structure with a full wooden structure, but only to show that we have fully avoided, minimized or mitigated the removal of the structure.

In addition, at the request of the Town and other interested parties that have attended the public information meetings to date, MassDOT is evaluating several superstructure options, including cladding over steel and concrete and the use of wood for the railings, sidewalks and the riding surface. Once these evaluations are complete and acceptable to both MassDOT and the Federal Highway Administration, MassDOT will meet with the consulting parties to present the results and make the results available to the Town.

I hope this adequately answers your questions and I thank you for your continued support for this project. If you have any further questions, please contact Joseph A. Pavao, Jr., Project Manager, at (617) 973-8178.

Sincerely,

Luisa Paiewonsky
Highway Administrator

cc: Frank A. Tramontozzi, P.E., Chief Engineer
Shoukry Elanhal, P.E., Deputy Chief of Bridges and Tunnels
Thomas Donald, P.E., Director Project Development
Joseph A. Pavao, Jr. P.E., Project Manager