HYDRAULIC REPORT

for

Massachusetts Highway Department

Bridge Replacement Project

for

Bridge No. W-30-002

Hix Bridge Road over the East Branch Westport River,

Westport, Massachusetts

Looking Downstream at Existing Bridge

Prepared by: Lamson Engineering Corporation
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Newton, Massachusetts 02160
Tel: (617) 558-0101

11/25/1997
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EXECUTIVE SUMMARY

1. **Purpose**

This hydraulic report is part of Lamson Engineering Corporation’s submittal to the Massachusetts Highway Department for the reconstruction of Bridge No. W-30-2. The purpose of the report is to perform hydrologic studies, hydraulic analyses and a scour evaluation of both the existing and the proposed bridge at the project site.

2. **Project Site**

Bridge No. W-30-2 is located on Hix Bridge Road over the East Branch Westport River in the Town of Westport, Bristol County, Massachusetts. The bridge is located approximately 6.4 km up the tidal estuary known as the East Branch Westport River (approximately halfway up the estuary). The East Branch Westport River estuary lies entirely within the town of Westport in Bristol County in the southwest corner of Massachusetts, adjacent to the state of Rhode Island. Horseneck Beach, consisting of dune sand and gravel, forms the southern boundary of this estuary. The upstream end of the East Branch is at an area known as the Head of Westport (at Old County Road). The East Branch Westport River is shown in its entirety on the US Geological Survey’s Westport, Mass.-R.I. quadrangle (Ref. _), at a scale of 1:24,000.

3. **Methodology**

The report and analyses are prepared in accordance with the Department’s “Guidance for Preparation of Hydrologic/Hydraulic Studies” for the Federal-Aid Non-National Highway System Bridge R&R Program. The report has been prepared in metric units.

4. **Existing Bridge**

The existing bridge carries one lane of traffic in each direction, and provides a route between State Route 88 to the west and South Westport to the east and beyond. The bridge consists of pavement on a concrete slab supported by 10 rows of columns (piers). Eight of the rows of columns have five parallel columns, the other two rows have twelve columns. Width of the columns vary from 0.6 to 1.2 meters (m). The total length of the bridge is 95.4 m from the left to right abutments. The width of the bridge in the direction of the tidal flow is 9.1 m. The bridge has concrete railings on both sides for its entire length as well as jersey barriers on its upstream end in order to protect fishermen and pedestrians. The bridge is at an approximate 90 degree angle in relation to the flow of the estuary.

The clear vertical clearance of the bridge above the water surface varies with the tide. Since the bridge deck varies from a low chord elevation of 1.65 m NGVD at its west end to 2.41 m NGVD on the east (right bank looking upstream), at mean high water (0.64 m NGVD), the vertical clearance ranges from 1.01 m at its west end to 1.77 m at its east end.

5. **Existing Condition Survey**

The bridge piers are in varying states of condition. The riprap skirting the west and east ends of the bridge shows no signs of erosion. A survey by the Massachusetts Division of Highways in
September of 1995 notes that the gravel bottom of the estuary upstream, under, and downstream of the bridge is eroding.

6. Hydrologic Analyses

Although it is recognized that both the normal and the highest (peak) elevations are tidally controlled, the flow from the freshwater drainage was estimated based upon its drainage area. The size of the crossing site catchment is 134 square kilometers (51.7 square miles according to Ref. ___) and the peak discharges for floods of various recurrence intervals have been established using methodology described in ???. The estimated peak flows are:

<table>
<thead>
<tr>
<th>Peak Discharge</th>
<th>(cu. meters/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-year</td>
<td>25-year</td>
</tr>
<tr>
<td>50-year</td>
<td>100-year</td>
</tr>
</tbody>
</table>

The East Branch Westport River is known to be tidally controlled at the Hix Road Bridge.
7. Hydraulic Analyses

8. Scour Evaluation

9. Summary and Recommendations
B. PROJECT DESCRIPTION

B.1 Background Description

As part of the Massachusetts Highway Department’s Bridge Replacement and Rehabilitation Program, Bridge No. W-30-2, located on Hix Bridge Road over the East Branch Westport River in the Town of Westport, Bristol County, Massachusetts, is to be replaced.

A Hydraulic Report, included in the Consultant’s Specific Scope of Work, is required to be prepared for this project due to the presence of the bridge over a waterway. This report was prepared to fulfill this requirement.

B.2 Purpose

The purpose of this report is to evaluate the existing hydraulic conditions of this bridge according to the Massachusetts Highway Department’s “Guidance for Preparation of Hydrologic/Hydraulic Studies for Federal-Aid Non-National Highway System Bridge R&R Program”. This report is prepared mainly in metric units.

The report includes data collection and engineering methods for hydrological, hydraulic, and scour analyses. Hydrologic analyses are performed to determine the peak tide elevations, then hydraulic analyses performed to determine the hydraulic characteristics at the bridge site, including estuary water velocities. A scour susceptibility evaluation is then conducted to assess the bridge undermining potential. Proposed countermeasures are presented if needs arise.

The results of these studies are then used to evaluate and determine the required size of the waterway opening at the bridge’s crossing, as well as any needed scour protection measures in the vicinity of the proposed bridge location. The data collected, the procedures of the analyses, and a discussion of scour are presented in the subsequent sections of this report.

B.3 Scope of Work

The scope of work includes the following:

- Perform site visits and field observations.
- Search and review the available data.
- Conduct hydrologic studies.
- Perform hydraulic analyses.
- Evaluate scour potential.

B.4 Project Location

Bridge No. W-30-2 is located on Hix Bridge Road over the East Branch Westport River in the Town of Westport, Massachusetts. The bridge is located 6.4 kilometers up (approximately halfway up) the tidal estuary known as the East Branch Westport River. The Westport River estuary (East and West Branches) in Bristol County is located in the southeast corner of Massachusetts, and lies entirely within the town of Westport, adjacent to the state of Rhode Island. Horseneck Beach, consisting of dune sand and gravel, forms the southern boundary of this estuary. The upstream end of the East Branch is at an area known as the Head of Westport (at Old County Road). The East Branch
Westport River is shown in its entirety on the US Geological Survey’s Westport, Mass.-R.I. metric topographic map, at a scale of 1:25,000.

C. DATA COLLECTION

C.1 General

As part of the effort to prepare this report, existing conditions and the history of the site must be investigated. This can be achieved by locating and reviewing available reports and data, and through site visits.

During the course of the site visits, field observations are made, physical dimensions are measured (in this case by the Mass. Highway Dept. and by Universal Engineering Corp.), and photos are taken. The contributing drainage basin is also visited to assess its nature.

C.2 Available Information

1. Flood Insurance Study

The Federal Emergency Management Agency (FEMA) produced a report entitled Flood Insurance Study (FIS), Town of Westport, MA, dated September 18, 1984. The FIS provides peak tidal elevations for both the downstream and upstream ends of the East Branch Westport River. Hix Bridge crosses the estuary approximately halfway between the two locations where elevations are determined.

2. Department’s Record

The Mass. Highway Department provided field notes documenting a site visit to the Hix Bridge Road bridge by G. Parker on September 20, 1995. Scour observations were made in the vicinity of the bridge. Depths from the low chord of the bridge to the bed of the estuary were measured.

3. Other Studies

Army Corps of Engineers Tidal Profiles for the New England Coastline dated September 1988 provided tidal information for various recurrence intervals at Westport (open ocean) as well as high watermarks for various hurricane events.

4. Maps

A soundings map published by the Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service Chart No. 13228, Westport River and Approaches, 1:20,000 scale, 10th Edition, May 11, 1996, was used to obtain below water topographic information. Above water cross-section information was obtained from the US Geological Survey, Westport, Mass.-R.I. 1:24,000 scale topographic map, 10-foot contour interval, 1977. Additional information on how these maps were used is provided in Section D.2.4 of this report.
C.3 Results of Field Observations and Field Survey

The results of field observations taken on the site visit are presented herein. Photographs taken during the site visit are presented in Appendix 6 of this report.

1. Hix Bridge Road

The existing two lane road provides a route between State Route 88 to the west and South Westport to the east.

2. Hix Bridge Road (bridge)

The existing Hix Bridge Road bridge over the East Branch Westport River, henceforth referred in this report as Hix Bridge, carries one lane of traffic in each direction. The bridge consists of pavement on a concrete slab supported by 10 rows of columns (piers). The number of columns in each row varies from five to twelve. Width of the columns vary from 0.6 to 1.2 meters (m). The length of the bridge is 95.1 m from the left to right abutments as measured by Mass. Highway personnel. The width of the bridge in the direction of the tidal flow is 9.1 m. The bridge has concrete railings on both sides for its entire length as well as jersey barriers, parallel to the railings, on its upstream end in order to provide a safe walkway for fishermen and pedestrians. This bridge was reportedly constructed in 1938 upon the washout of the previous bridge in that location during the 1938 hurricane.

The clear vertical clearance of the bridge above the water surface varies with the tide. The bridge deck varies from a low chord elevation of 1.65 m above the National Geodetic Vertical Datum (NGVD, formerly known as the mean sea level datum of 1929) at its west end to 2.41 m NGVD at its east end (right bank looking upstream). At mean high water (0.64 m NGVD), the vertical clearance ranges from 1.01 m at its west end to 1.77 m at its east end.

The bridge’s low chord elevation is at an average of 2.03 m above NGVD, while the top chord elevation, neglecting the concrete railing, is at an average of 3.69 m above NGVD.

3. Embankments

The embankments of this bridge are earthen fill. The embankments on both the east and west sides of the bridge approach encroach upon the floodplain of the East Branch Westport River.

4. Abutments and Wingwalls

The abutments are sloping with concrete stubs on top of exposed bents at the top. The slopes are protected by number 3 sized stone riprap. There are no wingwalls either on the upstream or downstream ends of the bridge.
D. ENGINEERING METHODS

D.1 HYDROLOGIC ANALYSES

D.1.1 Purpose

The purpose of these analyses is typically to establish the peak discharge corresponding to the selected recurrence intervals for the proposed bridge reconstruction project. However, because peak water surfaces at Hix Bridge are controlled by ocean tides, peak tidal water surface elevations are determined instead (of peak discharges). Peak discharges from freshwater sources are presented below for informational purposes only.

D.1.2 Drainage Basin

The size of the crossing site catchment at Hix Bridge is 134 square kilometers (51.7 square miles, Ref.11). Development along the East Branch Westport River and its tributaries is sparse with scattered farms and residences located along its shores. The larger tributary streams are Bread and Cheese Brook, Kirby Brook and Snell Creek which drain much of northern Westport. The drainage basin boundary, plotted on the US Geological Survey’s 1:250,000 scale Providence, R.I., Mass., Conn., NY 100-foot contour interval topographic map (revised 1969) is shown in Appendix 1.

D.1.3 Hydrologic Methodology

The Flood Insurance Study (FIS) for Westport notes that the highest (peak) water surfaces for the East Branch Westport River estuary, including at Hix Bridge, are tidally produced, and the freshwater drainage has minor impact in the range of frequencies we are examining. Freshwater flows are therefore provided for informational purposes only. Regression equations given for Eastern Massachusetts, including the Coastal River Basins, in U.S. Geological Survey Open File Report 80-676 (Ref. 15) were used to estimate the peak freshwater flows. The estimated peak flows are as follows:

**TABLE 1 - FRESHWATER RUNOFF PEAK DISCHARGES AT HIX BRIDGE FOR VARIOUS RECURRENCE INTERVALS**

<table>
<thead>
<tr>
<th>Peak Discharge (cu. meters/sec)</th>
<th>10-year</th>
<th>25-year</th>
<th>50-year</th>
<th>100-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-year</td>
<td>27.6</td>
<td>35.7</td>
<td>42.6</td>
<td>50.2</td>
</tr>
</tbody>
</table>

The freshwater runoff peak flows presented in Table 1 are only a few percent of the tidal flows (not elevations) determined by the hydraulic model (refer to Section D.2.4) for the range of floods studied. For example, the 100-year freshwater peak flow is only 5.2% of the tidal flow for the 100-year event) as determined by the hydraulic model. In addition, determining coincident frequencies of 100-year rainfall events and 100-year tidal elevations (or for other recurrence intervals) is beyond the scope of this job. Freshwater runoff is therefore ignored in the hydraulic model. Only tidal flows are examined.
The FIS provides peak water surface elevations for the open ocean and both the upper and lower ends of the East Branch Westport River estuary, with peak elevations caused by storm (hurricane) tides. The elevations at either end of the estuary are nearly identical for the recurrence intervals presented (peak water surface elevations are actually slightly higher at the upstream end of the estuary for the range of floods studied). As the FIS states, “coastal storm surges within the range studied were not significantly modified within Westport Harbor or the West Branch and East Branch Westport River estuaries The peak elevations at both the open ocean and the downstream end of the East Branch Westport River from the FIS are as follows:
TABLE 2 - PEAK TIDAL ELEVATION FOR VARIOUS RECURRENCE INTERVALS FOR WESTPORT (OPEN OCEAN AND AT THE DOWNSTREAM END OF THE EAST BRANCH WESTPORT RIVER) BASED ON FIS INFORMATION

<table>
<thead>
<tr>
<th>Recurrence Interval (years)</th>
<th>Peak Elevations (meters above NGVD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.41</td>
</tr>
<tr>
<td>25</td>
<td>NA</td>
</tr>
<tr>
<td>50</td>
<td>3.32</td>
</tr>
<tr>
<td>100</td>
<td>3.75</td>
</tr>
<tr>
<td>500</td>
<td>4.69</td>
</tr>
</tbody>
</table>

The U.S. Army Corps of Engineers tidal profiles (Ref. 1) also provide peak tide elevations for the open ocean portion of Westport (statute mile 152+00). These elevations are summarized as follows:

TABLE 3 - PEAK TIDAL ELEVATION FOR VARIOUS RECURRENCE INTERVALS FOR WESTPORT (OPEN OCEAN) BASED ON CORPS OF ENGINEERS INFORMATION

<table>
<thead>
<tr>
<th>Peak Elevation (meters above NGVD)</th>
<th>10-year</th>
<th>25-year</th>
<th>50-year</th>
<th>100-year</th>
<th>Std Proj Hurricane*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.95</td>
<td>NA</td>
<td>3.11</td>
<td>3.72</td>
<td>4.72</td>
<td></td>
</tr>
</tbody>
</table>

* the Standard Project Hurricane is assumed to be a 500-year event in this report

Note that there are differences between the Corps tidal elevations and those provided in the FIS, particularly at the 10- and 50-year events. Investigation into the cause of this discrepancy indicated that the elevations provided in FIS were based upon a shorter period of record (for the nearby New Bedford Harbor tide gage) than that used by the Corps in its 1988 tidal profiles report which updated January 1980 tidal profiles. The Corps information was based upon an additional 18 years of record, with the gage analysis period of record ending in 1978, versus 1960 used in the FIS. Because the Corps hydrology was based upon a longer period of record, the Corps data shown in Table 3 was adopted for use in the hydraulic model developed for the Hix Bridge.

D.1.3.4 Discussion of Findings

The maximum water levels at Hix Bridge occur due to high tidal surges, not freshwater runoff events. Tidal elevations presented in Table 3 (from Army Corps of Engineers Tidal Flood Profiles) are adopted for use in the hydraulic model of the East Branch Westport River estuary.

D.1.4 Design Criteria

The 10-year recurrence interval tidal flood has been selected as the design flood based upon the design storm guidelines presented in the Massachusetts Highway Department’s Hydraulic Design Criteria Appendix B.
D.1.5 **Summary**

The adopted peak tidal water surface elevations at the downstream end of the hydraulic model used in this study are as follows:

**TABLE 4 - ADOPTED PEAK TIDAL ELEVATION FOR VARIOUS RECURRENCE INTERVALS FOR THE DOWNSTREAM END (WESTPORT HARBOR) OF THE HYDRAULIC MODEL**

<table>
<thead>
<tr>
<th>Peak Elevation (meters above NGVD)</th>
<th>10-year</th>
<th>25-year</th>
<th>50-year</th>
<th>100-year</th>
<th>500-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.95</td>
<td>NA</td>
<td>3.11</td>
<td>3.72</td>
<td>4.72</td>
<td></td>
</tr>
</tbody>
</table>
D.2 HYDRAULIC ANALYSES

D.2.1 Purpose

The purpose of these analyses is to determine the hydraulic characteristics at the bridge site so that the required bridge opening and the scour potential can be determined.

D.2.2 Calculation Method

The Massachusetts Highway Department suggested that the DOS-based DYNLET computer model (version 2.01) be used to evaluate the hydraulic conditions at the Hix Bridge. The DYNLET model was developed by Amein and Associates of Raleigh, North Carolina under contract to the U.S. Army Corps of Engineers Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC). The model is capable of simulating one-dimensional (1-D) fluid flow from the ocean through a tidal inlet, into back bay regions, and up tributaries. An important feature of the model is the ability to represent an accurate flow distribution across any cross-section simulating the two-dimensional flow field. This yields the required water velocity information for scour analyses. The model is ideal for determining the impacts of changing pier and bridge deck scenarios to water surface elevations on either side of the bridge (based upon physical parameters). The model accounts for the bridge deck by increasing wetted perimeter, and it subtracts the submerged area of the bridge from the flow area. The DYNLET model has been tested by the US Federal Highway Administration.

The DYNLET model appears to be similar to the one-dimensional storm surge model used to determine the inland propagation of the coastal storm surge up the East Branch Westport River in the FIS for the Town of Westport.

D.2.3 Assumptions

1. Wave actions may be ignored, as they were in the Flood Insurance Study model. Inspection of the U.S. Geological Survey topographic map for Westport indicates that Hix Bridge is protected from receiving the brunt of wave forces and therefore is not in a V-zone, the area of the 100-year coastal flood with wave action. This is because the fetch length over which the wind can blow and waves be generated is quite short. (Note: this is not the case for Cadman Cove, lying 3500 feet southeast of the bridge, which may receive the full force of southerly winds).

2. Freshwater runoff does not have to be added to the peak tides.

3. Unobstructed flow at the bridge is assumed, i.e. no logs or other debris block the flow of water under the bridge.

4. The increase in flow through the bridge when the water surface is higher than the low beam may be neglected (the DYNLET model ignores pressure flow).

5. The impacts of the bridge’s guard rail and jersey barrier on water surface elevations can be neglected.

D.2.4 Analyses
As stated above, the DYNLET one-dimensional flow model was used to model hydraulics in the vicinity of Hix Bridge. Cross-sections for input into the DYNLET model for downstream and upstream of the bridge were generated by combining information from two sources: the National Ocean Service (NOS) hydrographic chart No. 13228 entitled “Westport River and Approaches”, scale 1:20,000 (Ref. 3) for the below water portions and the U.S. Geological Survey’s 1:24,000 scale Westport, Mass.-R.I. 10-foot contour interval topographic map (Ref. 12) for the above water portions. Adjustments to the NOS elevations were made since the NOS chart datum is soundings in feet at Mean Lower Low Water (in this area, it is only 0.03 m (0.1 foot) below Mean Low Water). All NOS soundings were converted to elevations above NGVD for input to the model. No conversion was needed for the data taken from the U.S. Geological Survey maps since it was already in NGVD datum.

The bridge cross-section was obtained by merging information from two sources. Channel bottom information was obtained from Mass. Division of Highways depth measurements (low chord of bridge to bottom of channel) of September 1995. An adjustment was made to account for the fact that the bridge is not perfectly level. Top of bridge information along the road centerline was obtained from Universal Engineering Corporation’s Hix Bridge Road Repair Project plans (Ref. 9). A plot of the existing bridge cross-section is shown in Fig. 1.

Cross-sections were located where there were significant changes in geometric properties (see Appendix 2 for cross-section locations). Cross-sections were located the full length of the East Branch Westport River and were oriented looking upstream, i.e. up the estuary, for input to the model. Roughness coefficients for each point of the cross-sections were estimated based upon inspection of the U.S. Geological Survey maps, with a minimum Manning’s roughness coefficient of 0.03 used.

The model was set up in English units rather than metric for a number of reasons. The hydraulic modeler was more comfortable with English units, and tide data, the bridge survey (by Mass. Highway Dept.), and the NOS and US Geological Survey maps used were in English units. Model results were converted to metric for presentation in this report.

High water mark information for calibration was unavailable except for that indicated on the Corps of Engineers tidal flood profiles for the September 21, 1938 hurricane, roughly a 100-year event on the open ocean. The 1938 high water marks at Hix Bridge were roughly 1.2 m lower than that of the open ocean. This appears to be low for a number of reasons: 1. winds were reportedly blowing directly north, pushing water up the estuary; 2. The 1938 hurricane was responsible for the complete washout and failure of Hix Bridge (see photo of bridge washout); 3. the FIS indicates that peak flood elevations up and down the estuary are all roughly the same. It appears possible that the benchmark used in surveying the high water marks was invalid. An attempt to obtain backup information on the 1938 high watermark data was unsuccessful. The 1938 data was therefore not used for model calibration.

Mr. Richard Earle, the Harbormaster for Westport Harbor, was unable to provide any additional high watermark data up the estuary. Mr. Earle does not believe that the bridge or the estuary constricts peak water surface elevations in any way, a belief supported by the field inspection findings. (Mr. Earle also noted that the Horseneck Beach Bridge, at the entrance to the East Branch Westport River and the only other bridge between the open ocean and Hix Bridge, does not constrict flows).
The only information available, therefore, for calibration purposes was that of the mean tide which occurs roughly twice per day (2 high tides and two low tides every 24 hours and 50 minutes in Westport), with an approximate delay of 1.5 hours up the estuary to Hix Bridge. NOS (Ref. 3) indicates that the mean high water (elevation 0.64 m NGVD) at Hix Bridge is less than 0.1 m lower in elevation than at Westport Harbor several kilometers downstream. Maximum velocities in the navigation channel under the bridge during normal tides were estimated by Mr. Earle at 1 to 1.5 knots (0.5 to 0.75 m/s).

Although DYNLET was found to be fairly insensitive to calibration attempts (i.e. varying the Manning’s roughness coefficients, the transition loss coefficients, the DYNLET weighing coefficient, and even the lengths between cross-sections made little difference in the model output at the mean tide event), the model produced results very close to that mimicking “known” information (maximum mean tide elevation and associated estimated maximum water velocity in the navigation channel). The model also produced expected reasonable and expected water surface elevations up the estuary. Model results are therefore believed sufficiently calibrated for purposes of this report.

The DYNLET model was run using the adopted peak water surfaces provided in Table 4 as input at cross-section 1, located in the lower East Branch Westport River estuary. The tide was routed up the estuary with sufficient time to observe the ebb of the hurricane tide and the ebb tide water velocities. The shape of the tide hydrograph (i.e. elevation versus time) for all recurrence intervals analyzed was that of the August 31, 1954 Hurricane Carol tide (Ref. 16). The “calibrated” model indicated only a slight attenuation in peak water levels up the estuary as was expected. It should be noted that the DYNLET model ignores pressure flow that begins to “kick in” when the water surface reaches the low chord of the bridge structure.

D.2.4 Model Results

Results of the physically-based hydraulic model indicate that for all recurrence intervals analyzed (10 to 500-year), there is minor difference in peak water surface elevations (and stage versus time) at cross-sections on either side of the bridge for the existing bridge. The existing bridge does not significantly impact water levels. Peak water surface elevations 1000 m upstream and 600m downstream of the bridge are presented in Table 5. Bridge elevations can be considered an average of the upstream and downstream elevations since the model sometimes reflected an elevation at the bridge that were slightly lower than the elevations upstream section.

<table>
<thead>
<tr>
<th>Location</th>
<th>MHW</th>
<th>10-year</th>
<th>25-year</th>
<th>50-year</th>
<th>100-year</th>
<th>500-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 m upstream of bridge</td>
<td>0.66</td>
<td>1.84</td>
<td>NA</td>
<td>2.97</td>
<td>3.58</td>
<td>4.68*</td>
</tr>
<tr>
<td>600 m downstream of bridge</td>
<td>0.66</td>
<td>1.91</td>
<td>NA</td>
<td>3.05</td>
<td>3.64</td>
<td>4.65*</td>
</tr>
</tbody>
</table>

* The hydraulic model was not able to complete the calculations for the 500-year water hurricane tide. This may be due to a computer program deficiency, perhaps when the bridge
is completely submerged. Elevations for the 500-year recurrence interval presented are based upon a model run with no bridge in place. Due to the bridge’s apparent very minor impact on peak water surface elevations at other recurrence intervals, this appears reasonable.

Results may be compared to a number of key bridge elevations. The bridge’s low deck elevation averages 2.03 m above NGVD, and the top chord elevation, neglecting the concrete railing, averages 3.69 m above NGVD (the bridge has a slight tilt). In actuality, the low chord is at elevation 1.65 m above NGVD on the bridge’s western end, sloping up to elevation 2.41 m NGVD at the bridge’s eastern end. The bridge’s western end has a top chord elevation of 3.32 m NGVD sloping up to 4.08 m NGVD at its eastern end. About 50 m west of the bridge’s western abutment, there is a 50 foot-long low spot of elevation 1.89 m above NGVD that would act as a relief valve to water higher than this elevation.

Note that the peak water surface elevation at the bridge (1.88 m NGVD) is below the average low chord elevation of the bridge at the 10-year recurrence interval, but touches the low chord on the western end of the bridge. The 50-year peak water surface elevation at the bridge (3.01 m NGVD) does not overtop the bridge, but is well over the low chord elevation and there is hydraulic relief over the western overbank. The 100-year peak water surface elevation at the bridge (3.61 m NGVD) would be just below the bridge’s average top chord elevation and would be well over the bridge’s western bank relief. The 500-year peak water surface elevation at the bridge (4.66 m NGVD) would completely submerge the top chord.

For informational purposes only, the percentage of the flow area blocked by the existing bridge’s piers and deck was determined by running the model with the bridge in place and then with the bridge “removed”. Results are as follows:

**TABLE 6 - PERCENTAGE OF FLOW AREA BLOCKED BY THE EXISTING HIX BRIDGE**

<table>
<thead>
<tr>
<th></th>
<th>Percentage blocked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean High Water</td>
<td>10-year</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>25-year</td>
<td>34</td>
</tr>
<tr>
<td>50-year</td>
<td>47</td>
</tr>
<tr>
<td>100-year</td>
<td></td>
</tr>
</tbody>
</table>

The maximum velocities through the bridge averaged (for the entire bridge cross-section) 0.53 m/s, 1.26 m/s, 1.84 m/s and 2.72 m/s for the mean tide, 10-year tide, 50-year tide, and 100-year tide, respectively. Velocities at various points of the bridge cross-section are presented in Section D.3.3.

D.2.5 Summary

The Hix Bridge is found to have very minor impact on peak water surface elevations.
D.3 SCOUR ANALYSES

D.3.1 Purpose

The scour investigation was undertaken to assess the vulnerability of the existing bridge due to floods and to determine if measures are necessary to counter the scour.

D.3.2 Calculation Method

Scour potential is evaluated using the method outlined in the Federal Highway Administration’s Hydraulic Engineering Circular No. 18 (HEC-18), entitled “Evaluating Scour at Bridges”.

D.3.3 Analyses

Peak velocities were determined at three locations under the existing bridge using the DYNLET computer program. The three locations where water velocities were determined were:

1. At bridge station 11 (172 m from the arbitrary cross-section starting point), located where the riprap is currently placed along the western abutment.

2. At bridge station 50 (236.5 m from the arbitrary cross-section starting point), located next to one of the piers along the current dredged navigation channel.

3. At bridge station 60, (254 m from the arbitrary cross-section starting point), located where the riprap is currently placed along the western abutment.

<table>
<thead>
<tr>
<th>Bridge Station</th>
<th>Mn High Water</th>
<th>10-year</th>
<th>Peak velocity</th>
<th>m/sec</th>
<th>25-year</th>
<th>50-year</th>
<th>100-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>0.28</td>
<td>0.84</td>
<td>NA</td>
<td>1.37</td>
<td>1.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.64</td>
<td>1.49</td>
<td>NA</td>
<td>2.14</td>
<td>2.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.05</td>
<td>0.16</td>
<td>NA</td>
<td>0.27</td>
<td>0.32</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Under the bridge is gravel with no. 2 size stone mixed in (per Mass. Div. Highways). The slopes (at bridge stations 11 and 50) are protected by no. 3 size riprap. The no. 3 stone size is evidently sufficient since there are no signs of stone washout.

No scour at the piers was noted. Scour was noted, however, in the channel at cross-sections upstream and downstream of the bridge.

D.3.4 Proposed bridge:
Lamson Engineering Corporation is proposing to make no change to the width of the existing bridge. It is proposed to be connected to the existing embankments, most likely supported by the existing abutments, and two rows of piers (versus the existing 10 rows of piers). Bridge superstructure elevation has not been determined yet, but will be at least as high as the existing bridge.

The new piers will caissons put into bedrock. Therefore pier scour is not of concern for the proposed bridge. Estuary water velocities at the piers is presented below for informational purposes only.

Peak velocities were determined at three locations under the proposed bridge using the DYNLET computer program. The three locations where water velocities were determined were:

1. At bridge station 11 (172 m from the arbitrary cross-section starting point), located where the riprap is currently placed along the western abutment.

2. At bridge station 31 (232 m from the arbitrary cross-section starting point), located next to one of the two proposed rows of piers, adjacent to the navigation channel.

3. At bridge station 37, (254 m from the arbitrary cross-section starting point), located where the riprap is currently placed along the western abutment.

**TABLE 8 - PEAK WATER VELOCITIES FOR THE PROPOSED BRIDGE AT VARIOUS BRIDGE LOCATIONS**

<table>
<thead>
<tr>
<th>Bridge Station</th>
<th>Mn High Water</th>
<th>10-year</th>
<th>Peak velocity</th>
<th>m/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>25-year</td>
<td>50-year</td>
</tr>
<tr>
<td>11</td>
<td>0.27</td>
<td>0.80</td>
<td>NA</td>
<td>1.30</td>
</tr>
<tr>
<td>31</td>
<td>0.64</td>
<td>1.49</td>
<td>NA</td>
<td>2.11</td>
</tr>
<tr>
<td>37</td>
<td>0.03</td>
<td>0.50</td>
<td>NA</td>
<td>0.98</td>
</tr>
</tbody>
</table>
E. Conclusions and Recommendations

E.1 Evaluation

Based on the results of our site visit, the hydrologic studies, the hydraulic analyses ….

E.2
Based upon the observations described above, we make the following recommendations:
F. REFERENCES


14. US Geological Survey, Providence, R.I., Mass., Conn., NY topographic map, 1:250,000 scale, 100-foot contour interval, revised 1969


19. **APPENDIX 1** - Crossing Site Catchment

(1:25000 USGS Quad)
APPENDIX 2 - Stream Cross-Section Layout Plan
APPENDIX 3 - Field Evaluation Forms
APPENDIX 4 - Hydrologic Computations
APPENDIX 5 - Hydraulic Computations

Files submitted on a diskette in support of this report are as follows.

For the existing bridge:

For the mean tide, the input files were inletmn.out, channlmn.dat, and velomean.dat.

For the 10-year tide, the input files were: inlet10.out, channl10.dat, and velo10yr.dat.

For the 50-year tide, the input files were: inlet50.out, channl50.dat, and velo50yr.dat.

For the 100-year tide, the input files were: inlet100.out, channl100.dat, and velo100.dat

For the 500-year tide, the input files were: inlet500.out, channl500.dat, and velo500.dat

For the proposed bridge:
APPENDIX 6 - Scour and/or Scour Counter Measure Computations
APPENDIX 7 - Photographs and Index