HYDROLOGY REPORT

Jock Stream Bridge – Cobbosseecontee Rd, Monmouth, BR #2412

General Information and Scope

This study is prepared to furnish hydrologic information from water regulating agencies; on the waterway crossing over Jock Stream at the Jock Stream Bridge in Monmouth, Maine. The most reliable information will be used in the hydraulic evaluation of the existing and proposed bridge openings. The Jock Stream Bridge carries Cobbosseecontee Road over the Cobbosseecontee Lake and Jock Stream Junction, and it is located 0.83 miles northerly of the Litchfield town line. The existing natural waterway opening is approximately 43 ft wide along the centerline of the bridge. The flow direction is northerly from Jock Stream to Cobbosseecontee Lake. The current channel has limited clearance during high flow periods.

The scope of this study is to determine the flood flows and the expected corresponding stages, which are used to perform a detailed hydraulic analysis and or modeling of the waterway underneath the bridge. The hydrologic information and data presented herewith are obtained from three different sources:

1- Flood Emergency Management Agency (FEMA)

2- United States Geological Survey (USGS)

3- The Maine DOT Hydrology Department.

Flood Emergency Management Agency (FEMA)

FEMA has conducted flood studies on the Cobbosseecontee Lake for flood insurance purposes. It has issued flood maps for the 100 year flood event, with peak stage elevation of 170 ft (NGVD). The 500 year flood zone was also shown on the maps, but had minimal effect on the overall stage. Since the bridge opening links two water bodies, and no dams, weirs, spillways, and man made obstructions exist, the water stages in the vicinity of the bridge are expected to be the same as that of the upstream lake. FEMA has also conducted flood insurance study for the Cobbosseecontee Lake and determined the following stages:

Type of flow	Stage(ft) (NGVD)
Ordinary High Water (Q10)	168.7
Design Discharge (Q50)	169.7

Check Discharge (Q100)	170.2
Scour Discharge (Q 500)	171.4

The (NGVD) 1929 elevations shown are converted to (NAVD) 1988 elevations By using the following formula:

Elevation (NAVD) = Elevation (NGVD) – datum shift

The datum shift is obtained from the following website:

http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl

The datum shift for the bridge location is 0.669 ft

The converted (NAVD) stage elevations are as follows:

Type of flow	Stage(ft) (NAVD)
Ordinary High Water (Q10)	168.0
Design Discharge (Q50)	169.0
Check Discharge (Q100)	169.5
Scour Discharge (Q 500)	170.7

United States Geological Survey

The USGS maintains gaging station # 01049500 at the Cobbosseecontee River, which is a tributary to the Cobbosseecontee Lake, and located nearly two miles to the northeast of Jock Stream. Thus the flow at Jock Stream is considered ungaged. The gaging station has measured peak flows for a 20 year period considering a 217 sq. miles drainage area as follows:

	Q_{10} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)	Q_{500} (cfs)
USGS Real time gaging Period (1976-1996)	3566	4449	4767	5438

According to the USGS 1999 Report, the flows at the non-gaged station can be estimated
using a weighting average formula:

$Qu = Qw\ (Au/Ag)^b$ where:

Qu = Final weighted average peak flow of ungaged site for a given recurrence interval.

Qw = Weighted average peak flow for the gaged site for a given recurrence interval.
Au = Drainage- basin area of the ungaged site = 17 sq. miles
Ag = Drainage - basin area of the gaged site = 217 sq. miles
b = Coefficient of the regression equation for a given recurrence interval

	Q_{10}	Q_{50}	Q_{100}	Q_{500}
Coefficient b	0.783	0.757	0.748	0.729

Based on the above, the flows at the gaged site at the Cobbosseecontee River can be transposed to the following flows at the ungaged site at Jock Stream:

	Q_{10} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)	Q_{500} (cfs)
Flows at Jock Stream Bridge	485.5	647.2	709.5	849.5

<u>Maine DOT</u>

Maine DOT hydrologists determined their flows for the ungaged site based on the 1999 USGS full regression equation. According to the MDOT Bridge Design Guide (BDG), the full regression equations can be used for this rural watershed. The flood flows for Jock Stream Bridge were based on a smaller drainage basin of 17 sq. miles, and provided as follows:

	Q10 (cfs)	Q50(cfs)	Q100 (cfs)	Q500 (cfs)
Maine DOT Results (1999 USGS Full Regression Equation)	990.4	1485.7	1718.9	2295.6

<u>Data Comparison</u>

A preliminary hydraulic check of the existing channel will be conducted to determine the adequacy of the channel for both the USGS transposed flows and that of the Maine DOT. The results of the check should give a clear idea and indication of which flows to be used in a detailed hydraulic analysis for the proposed bridge. The results could also influence future design decisions related to required span length, geometry, alignment, and configuration of the new bridge.

Selected Design Flows

The results of the preliminary analysis by HEC-RAS indicate that the transposed USGS flow data result in a maximum stage elevation at the Q100 interval of 159.8 ft, while the corresponding stage for Maine DOT flows is 170.1 ft. The historically observed high water level at the bridge is nearly 169 ft. Therefore, the Maine DOT flood stage is in proximity to observed elevation in the existing channel. Also, photographs taken at different times in the year further reinforce that fact. As a result, the Maine DOT flows will be adopted for detailed hydraulic analysis of the new bridge and channel as follows:

Q_{10} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)	Q_{500} (cfs)
990.4	1485.7	1718.9	2295.6

Flood Plain Information

The information on flood plains and the possibility of flooding is available from the National Flood Insurance Program. Its Flood map produced for the Cobbosseecontee Lake area shows the 100 and 500 year flood limits. The 100 and 500 yr flood limits show that overflow of the Maple Ridge Island upstream of the bridge is highly probable and should be considered to be located within the flood plain region. Also susceptible to overflow are the two islands upstream of the bridge at Jock Stream. The maps however show slight overflow of the Cobbosseecontee Lake banks at the 100 and 500 year occurrence intervals.

Bridge users and maintenance information

Further information on the hydraulic conditions of the bridge and the approach roadway were based on bridge users and bridge maintenance manager observations over a period of nearly 40 years. None of them reported that there was ever any water on the bridge or on the approaches. However they noted that during periods of high flow, the water stage was nearly to the bottom of the superstructure slab. Photos taken over the years of water stage during high spring flows reinforce these observations. The water line on the abutments and pier is quite visible to be nearly less than a foot from the bottom of the superstructure.

It was also reported by the maintenance manager that during periods of combined high flows and winds, the wave surge from the Cobbosseecontee Lake struck the superstructure slab fascia. As a result, there is strong evidence of water splash action damage on the existing superstructure fascia and pier.

Conclusion

Based on the above studies and observations, the existing channel under the bridge may or may not be satisfactory in containing and directing flood flows. This conclusion must be substantiated by detailed hydraulic analysis using discharges for both the 50 year design flow, and the 100 year check flood flow events. If the existing channel is not capable of safely passing these flows, the proposed bridge opening may have to be increased or the clearance increased by raising the vertical alignment. It seems as though that the existing bridge is just hydraulically satisfactory for the present time. The results of the hydraulic analysis of the existing bridge and channel should help to better understand the hydraulic conditions, and to determine whether a change in either alignment or flow area is warranted.

Reported by:
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Date: October, 2009

HYDRAULIC REPORT

Jock Stream Bridge – Cobbosseecontee Rd, Monmouth, Br #2412

The hydraulic analysis for the project was conducted by using the design flows obtained in the Hydrology section in two stages; the first stage was for existing bridge channel opening, and the second for the proposed bridge opening.

Based on the analysis results, the ability of the existing and proposed channels to accommodate and safely pass flood flows is determined. To achieve this, a computer program developed by the Hydrologic Engineering Center of the US Army Corps of Engineers; HEC-RAS was utilized. The program develops a hydraulic model for the river or channel, and applies the flood flows to it.

The analysis results in corresponding water stage elevations, and flow velocity for each flow condition. Based on the stage elevations obtained, the adequacy of the channel can be determined. If the channel is deemed inadequate, a recommendation to modify the existing opening for the new bridge can be proposed. Any decision to modify an existing channel or embankment must be approved by the regulating environmental agency. This is largely due to impact on wetlands, ecology, and possibly fish passage.

I- Existing bridge analysis and results

The analysis of the existing bridge opening was conducted for the channel using two cross sections at the bridge, three cross sections upstream, and three down stream. The cross sections were extracted from the current topography and survey plans using In-Roads program, and applied to the HEC-RAS model. The results of the analysis for the existing bridge opening were obtained and tabulated as follows:

Type	Flow (cfs)	Headwater Elev (ft)	Velocity(ft/s)
Q_{10}	990.4	166.98	2.10
Q_{50}	1485.7	167.96	2.90
Q_{100}	1718.9	169.48	2.97
Q_{500}	2295.6	170.69	3.33

Freeboard @ Q_{50} = 0.17 ft
Existing Opening = 445.4 sq. ft

From the above results, it can be concluded that both the Q10, and Q50 flows can barely pass through the existing channel, and the requirement of at least 2 feet of freeboard at Q50 is not met. In addition, the Q100 flow will inundate the superstructure, and the Q500 flow will overtop the bridge and approaches along the causeway. This suggests that in the 40 years observations by residents around the bridge, the Q100 and Q500 flows has probably never occurred, and if this is to happen today the bridge will be overtopped; knowing that the top of pavement elevation at the centerline of the bridge is 170 ± ft. It can thus be concluded that the new bridge has to have more flow area. This can be achieved by increasing the bridge span and removing the existing abutments, or by raising the vertical alignment at the bridge to increase freeboard. These adjustments could become almost unavoidable if a combination of pier removal and span increase is considered, as that requires much deeper superstructure and may warrant a raise of the vertical alignment.

1-Scour Analysis

A comprehensive scour analysis was conducted for the existing bridge and channel using HEC-RAS software; and hand computations to study the effects of scour on the existing substructure. Since the flow is considered a river type flow, but also flowing into the Cobbosseecontee Lake with considerable storage volume downstream of the bridge, scour was evaluated for the 500 yr flood flows. River bed contraction scours, local pier scour, and abutments scour depth were computed and recorded as follows:

a- Total scour within channel

Local Scour (Pier shaft and footing) = 2.83 ft
Live Bed Contraction scour = 14.18 ft

Total scour Depth within channel = 17.01 ft

Average stream bed elevation before scour = 154.94 ft
Stream Bed elevation after scour has occurred = 137.93 ft

b- Total scour at left abutment

Local Scour (Abutment scour) = 21.75 ft
Contraction = 14.18 ft

Total scour Depth within channel = 35.93 ft

Average stream bed elevation before scour = 156.91 ft
Stream Bed elevation after scour has occurred = 120.98 ft

c- Total scour at Right abutment

Local Scour (Abutment scour) = 16.63 ft
Contraction = 14.18 ft

d- Total scour Depth within channel = 30.81 ft

Average stream bed elevation before scour: 156.50 ft
Stream Bed elevation after scour has occurred = 125.69 ft

2- Conclusion and comments

From the above results and considering that the top of the piles supporting the abutments are at the bottom elevation of the abutments foundations, the existing wooden piles will be exposed and unsupported for nearly 35 feet. Specifications for wood piles from that era show that the maximum length of a 15 ton friction wood pile was 70'. Therefore, if the 500 year flood is to occur today, it will result in a loss of nearly half of the piles capacity, and a sure structural instability of the bridge. Likewise, with 17' of exposed piles for the center pier, a 25% loss of piles load carrying capacity is expected and significant structural instability at the pier will result. Therefore, and based on the above facts, the existing bridge can be labeled as Scour Critical. In the new bridge proposal, significant scour counter measures will be required to mitigate the scour problem, which can be largely attributed to the silt substrata that underlay the stream bed. Silt is very susceptible to erosion and stream bed degradation. Historical information reveals that in 1997, a significant scour countermeasure action was carried out to armor the stream bed with Dry Pack Grout.

II- Proposed bridge analysis and results

The proposed opening considered is based on increasing the channel width by 12', removing the central pier, and elevating the bridge by an average of 2 ft to accommodate recreational boat passage, and increase free board at normal water levels. The advantage of such action can be seen in the following hydraulic analysis results:

Type	Flow (cfs)	Headwater Elev (ft)	Velocity(ft/s)
Q_{10}	990.4	166.00	1.84
Q_{50}	1485.7	166.94	2.52
Q_{100}	1718.9	168.48	2.57
Q_{500}	2295.6	169.66	3.11

Freeboard @ Q_{50} = 2.82 ft
Proposed Opening = 628 sq. ft

The proposed opening results in an increase of nearly 2.65 ft in freeboard results in an average drop of 1' in flood stage elevations. This is considered an important improvement to the hydraulic conditions of the proposed channel. It however comes at the expense of increasing the superstructure length and cost, as well as, the required superstructure depth; especially with the pier removed. On the other hand, it sees savings from not having to place a pier, and significant elimination of debris and ice blockage problems. It must be noted that the hydraulic advantage of further increase in channel width and bridge span is outweighed by additional cost, and reduced freeboard as the superstructure depth proportionally increases. Additionally, it does not seem that further increase in channel width will improve the scour situation all that much, as scour is largely dependent on other hydraulic factors. This will be discussed in the scour analysis topic.

1- Scour Analysis

A detailed scour analysis was conducted for the proposed bridge channel using HEC-RAS software; to determine the effects of scour on the proposed substructure and channel bed. Scour computations were conducted for the 500 year flood flow. River bed contraction scours, local scours of abutments, and total scours were computed and reported as follows:

a- Total scour within channel

Contraction = 9.62 ft +/-

Total scour depth within channel = 9.62 ft +/-

Average stream bed elevation before scour = 154.94 ft
Stream Bed elevation after scour has occurred = 145.32 ft

b- Total scour at left abutment

Local Scour (Abutment scour) = 15.65 ft
Contraction = 9.62 ft

Total scour depth within channel = 25.28 ft +/-

Average stream bed elevation before scour = 156.91 ft
Stream Bed elevation after scour has occurred = 121.62 ft

c- Total scour at Right abutment

Local Scour (Abutment scour) = 11.91 ft
Contraction = 9.62 ft +/-

d- Total scour depth within channel = 21.53 ft +/-

Average stream bed elevation before scour: 156.50 ft
Stream Bed elevation after scour has occurred = 134.97 ft

2- Comment about scour analysis

The calculated overall depth of scour using HEC-RAS software and numerical equations tend to overestimate the amount of scour; as compared to the measured scour. The measured scour at the site was estimated at 6'-2" prior to abutment and pier repair in 1997; while the calculated scour is in excess of 25'. The large difference in scour values reinforces this fact.

2- Comparison between scour results of existing and proposed bridge

Based on above analysis, the scour depth of the proposed bridge is reduced by 30% as compared with the existing. This is largely due to the removal of the central pier and opening up the channel. Specifically, the removal of the pier reduced contraction scour, and the enlargement of the bridge opening reduced flow velocity, thereby reducing sediment transport and degradation of stream bed. However, all of these improvements are not enough to totally eliminate scour effects. As previously stated, the soil composition which is largely silt is the major contributor to the scour problem. Therefore, still significant counter-measures shall be employed to protect the proposed substructure from exposure to scour. These will be in the form of a heavy rip rap apron, and or erosion control blankets to protect the embankments in the vicinity of the bridge substructure.

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