Appendix B – Amended Local Abutment Scour Equations for Connecticut

The HEC-18 recommends the use of either Froehlich's or the HIRE abutment scour equations. The HIRE equation was developed from ACOE data relative to scour at the end of spur dikes on the Mississippi River. It is only valid when the ratio of projected abutment length (L') to flow depth (Y_a) is greater than 25. The vast majority of watercourses in Connecticut do not meet this criteria, and therefore require the use of Froehlich's equation.

Froehlich developed equations for both live bed and clear water contraction scour, however, HEC-18 recommends the use of the live bed scour equations for all evaluations. The formula is as follows:

$$Y_S / Y_a = 2.27 K_1 K_2 \left(\frac{L'}{Y_a} \right)^{0.43} Fr^{0.61} + 1$$

where:

K_1 = coefficient for abutment shape (See Table 6, Section 4.3.6 in HEC-18 Third Ed., dated Nov. 95)

K_2 = coefficient for angle of embankment to flow (Refer to Section 4.3.6, Figure 16 in HEC-18, Third Ed., dated Nov. 95)

L' = the length of abutment projected normal to flow, m (ft)

Y_a = average depth of flow in the floodplain = A_e / a', m (ft)

A_e = the flow area of the approach cross section obstructed by the embankment, m^2 (ft^2)

Fr = the Froude Number = $V_e / (g\ y_a)^{0.5}$

V_e = Q_e / A_e, m/s (ft/s)

Q_e = the flow obstructed by the abutment and approach embankments, m^3/s (ft^3/s)

Y_s = scour depth, m (ft)

One of the chief contributors to the conservative nature of the abutment scour prediction is the L' / Y_a parameter. Another contributor, however, is the +1 figure on the right side of the equation. This value, intended as a factor of safety (F.S.), was not in Froehlich's original paper, and essentially increases the predicted scour depth by the depth of the overbank flow. This is based upon the fact that, when F.S. =1 is used, 98% of the laboratory scour holes would be less than those predicted. Therefore the Froehlich equation, as presented in the HEC-18 document, defines the upper limit of predicted scour depths. Given the conservative nature of the laboratory data in comparison to field conditions, the use of the +1 value on the right side of the abutment scour equation appears to create an unwarranted compounding of safety factors (particularly in pile supported structures where additional factors of safety are incorporated in the stability

analysis). Therefore, with due consideration given to the application of engineering judgement in the determination of predicted scour depths, the +1 factor of safety will not be applied in the computation of local scour depths. Rather, a factor of 0.05 will be used and the predicted scour depth will be termed the *amended scour depth.* This will place the predicted scour values at the 50th percentile based upon the results of laboratory scour studies. **The amended local abutment scour equation is, then**:

$$Y_s / Y_a = 2.27 K_1 K_2 \left(\frac{L'}{Y_a} \right)^{0.43} Fr^{0.61} + 0.05$$

The amended scour depths as computed by this equation, together with all other relevant factors, shall be considered.

GUIDELINES FOR APPLYING ENGINEERING JUDGEMENT WITH REGARD TO PREDICTED SCOUR AT ABUTMENTS FOR EXISTING BRIDGES.

Upon establishing the total scour depth, the following guidelines shall be applied to address the conservative nature of the abutment scour equations as related to the recommended NBIS Item 113 rating for the bridge in question:

Abutments on Spread Footings

- Should the total abutment scour depths as modified through the application of engineering judgement for the bridge indicate that the footings for the structure will be undermined for any of the flood events studied and the field documentation supports the presence, history or high potential for scour at the abutment(s), then a scour critical rating should be recommended.
- Should the total amended scour depths for the bridge be less than the actual embedment depths to the tops of the footings at the structure, and field documentation indicates that the bridge is not scour susceptible, then the structure should be rated low risk and assigned an NBIS Item 113 rating of 8.
- If countermeasures have apparently been installed in accordance with HEC-18 guidelines, and the countermeasures have survived at least one major flood event without showing signs of deterioration, then the bridge should be assigned an NBIS Item 113 rating of 7. (Refer to Chapter 6, Appendix E for Historical Floods of Record).
- Should the predicted scour depths indicate that the bridge will be unstable for any of the events studied and the field documentation does not support a scour critical rating, then engineering judgement should be applied to resolve the discrepancy between the predicted scour and the field evidence. This judgement shall consider, but shall not be limited to the following factors: armoring potential of the streambed, vegetated cover of the overbank areas, evidence of scour at the structure (or lack thereof), angle of inclination, hydraulic adequacy of the structure, flow distribution in the approach section and the age of the structure with respect to floods of record. Engineering judgement for this scenario are as follows:

Spread footings with less than 1.2m (4 ft.) of embedment

Should the field documentation show that the bridge does not appear to be scour critical, then the structure may be rated as scour susceptible and assigned an NBIS Item 113 rating of 5.

Spread footings with more than 1.2m (4 ft.) of embedment

Should the field documentation show that the bridge does not appear to be scour critical, then the structure may be designated as scour susceptible or low risk based on engineering judgement.

Abutments on Pile Foundations

- Should the total amended scour depths determined for the bridge indicate that the piles will be unstable for the flood events studied and the field documentation supports the presence, history or high potential for scour at the abutment(s), then the bridge should be rated scour critical and the NBIS Item 113 rating of 3.
- Should the foundation for the bridge be determined to be stable at the modified scour depths for the structure, and the field documentation indicates that the bridge is not scour susceptible, then the structure should be rated low risk.
- If countermeasures have apparently been installed in accordance with HEC-18 guidelines, and the countermeasures have survived at least one major flood event without showing signs of deterioration, then the bridge should be assigned an NBIS Item 113 rating of 7. (Refer to Chapter 6, Appendix E for Historical Floods of Record).
- Should the amended scour depths indicate that the bridge will be unstable for the flood events studied, and the field documentation does not support a scour critical rating, then engineering judgement should be applied to resolve the discrepancy between the predicted scour and the field evidence. This judgement shall consider, but shall not be limited to the following factors: armoring potential of the streambed, vegetated cover of the overbank areas, evidence of scour at the structure (or lack thereof), angle of inclination, hydraulic adequacy of the structure, flow distribution in the approach section and age of the structure relative to floods of record. Should the field documentation show that the bridge does not appear to be scour critical, then the bridge may be designated as scour susceptible or low risk based on engineering judgement.