OK RJ

SCOUR ANALYSIS AND REPORTING FORM

Bridge Structure No. 52435310 Date 4/15/11 Initials CW Region (A B C D)

Site _____ Location SD 238/St. Patrick St over Rapid Creek

Q_{100} = 4830 by: drainage area ratio ✓ flood freq. anal. ____ regional regression eq. ____

Bridge discharge (Q_2) = 4830 (should be Q_{100} unless there is a relief bridge, road overflow, or bridge overtopping)

Analytical Procedure for Estimating Hydraulic Variables Needed to Apply Method

PGRM: "RegionA", "RegionB", "RegionC", or "RegionD"

Bridge Width = 110 ft. Flow angle at bridge = 15 ° Abut. Skew = 0 ° Effective Skew = 15 °

Width (W_2) iteration = 110 100 107 ____

Avg. flow depth at bridge, y_2 iteration = 5.8 6.1 6.1 ____

Corrected channel width at bridge Section = W_2 times cos of flow angle = ~~106.25~~ 98.52 ft* $q_2 = Q_2/W_2$ = ~~45.5~~ 49.0 ft^2/s

Bridge Vel, V_2 = 8.1 ft/s Final $y_2 = q_2/V_2$ = 6.1 ft Δh = 1.3 ft

Average main channel depth at approach section, $y_1 = \Delta h + y_2$ = 7.4 ft

** NOTE: repeat above calculations until y_2 changes by less than 0.2* *Effective pier width = L sin(q) + a cos(q)*

If y_2 is above LS, then account for Road Overflow using PRGM: RDOVREGA, RDOVREGB, RDOVREGC, or RDOVREGD,

Water Surface Elev. = ____ ft

Low Steel Elev. = 10.5 ft

n (Channel) = ~~0.035~~ 0.040

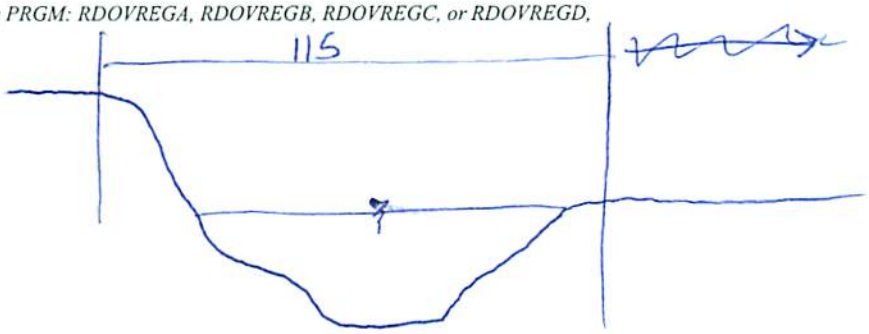
n (LOB) = 0.033

n (ROB) = 0.033

Pier Width = ~~1.03~~ 1.0 ft

Pier Length = 63 ft

Piers for 100 yr = 2 ft



CONTRACTION SCOUR

PGRM: Contract

Width of main channel at approach section W_1 = 115 ft

Width of left overbank flow at approach, W_{lob} = 0 ft Average left overbank flow depth, y_{lob} = 0 ft

Width of right overbank flow at approach, W_{rob} = 0 ft Average right overbank flow depth, y_{rob} = 0 ft

Live Bed Contraction Scour (use if bed material is small cobbles or finer)

x = _____ From Figure 9 W_2 (effective) = _____ ft y_{cs} = _____ ft

PGRM: CWCSNEW

Clear Water Contraction Scour (use if bed material is larger than small cobbles)

Estimated bed material D_{50} = 0.20 ft Average approach velocity, $V_1 = Q_{100}/(y_1W_1)$ = 5.68 ft/s ~~2 = 3.322~~

Critical approach velocity, $Vc = 11.52 y_1^{1/6} D_{50}^{1/3}$ = 9.12 ft/s

If $V_1 < V_c$ and $D_{50} >= 0.2$ ft, use clear water equation below, otherwise use live bed scour equation above.

$D_{c50} = 0.0006(q_2/y_1^{7/6})^3$ = 0.0640 ft If $D_{50} >= D_{c50}$, $\chi = 0.0$

Otherwise, $\chi = 0.122 y_1 [q_2/(D_{50}^{1/3} y_1^{7/6})]^{6/7} - y_1$ = ____ From Figure 10, y_{cs} = 0.0 ft

PGRM: Pier

PIER SCOUR CALCULATIONS

L/a ratio = 63 Correction factor for flow angle of attack (from Table 1), K2 = 2.5

Froude # at bridge = 0.54 Using pier width a on Figure 11, ξ = 4.9 Pier scour y_{ps} = 11.2 ft

PGRM: Abutment

ABUTMENT SCOUR CALCULATIONS

Average flow depth blocked by: left abutment, y_{aLT} = 0 ft right abutment, y_{aRT} = 0 ft

Shape coefficient K_1= 1.00 for vertical-wall, 0.82 for vertical-wall with wingwalls, 0.55 for spill-through

Using values for y_{aLT} and y_{aRT} on figure 12, ψ_{LT} = 0 and ψ_{RT} = 0

Left abutment scour, $y_{as} = \psi_{LT}(K_1/0.55)$ = 0 ft Right abutment scour $y_{as} = \psi_{RT}(K_1/0.55)$ = 0 ft

SCOUR ANALYSIS AND REPORTING FORM

Bridge Structure No. 52435310 Date 4/15/11 Initials CLr Region (A B C D)

Site _____ Location SD 238/St. Patrick St. over Rapid Creek

Q_{500} = 18200 by: drainage area ratio ✓ flood freq. anal. ____ regional regression eq. ____

Bridge discharge (Q_2) = 14165 (should be Q_{500} unless there is a relief bridge, road overflow, or bridge overtopping)

Analytical Procedure for Estimating Hydraulic Variables Needed to Apply Method

PGRM: "RegionA", "RegionB", "RegionC", or "RegionD"

Bridge Width = 110 ft. Flow angle at bridge = 15 ° Abut. Skew = 0 ° Effective Skew = 15 °

Width (W_2) iteration = 110

Avg. flow depth at bridge, y_2 iteration = 12 > 10.5 → RD Overflow 110 cos 15 = 106.25

Corrected channel width at bridge Section = W_2 times cos of flow angle = 106.25 ft* $q_2 = Q_2/W_2$ = ~~133.26~~ ft^2/s 133.3

Bridge Vel, V_2 = 12.7 ft/s Final $y_2 = q_2/V_2$ = 10.5 ft Δh = 3.3 ft

Average main channel depth at approach section, $y_1 = \Delta h + y_2$ = 13.8 ft

** NOTE: repeat above calculations until y_2 changes by less than 0.2* *Effective pier width = L sin(q) + a cos(q)*

If y_2 is above LS, then account for Road Overflow using PRGM: RDOVREGA, RDOVREGB, RDOVREGC, or RDOVREGD,

Water Surface Elev. = ____ ft

Low Steel Elev. = 10.5 ft

n (Channel) = 0.040

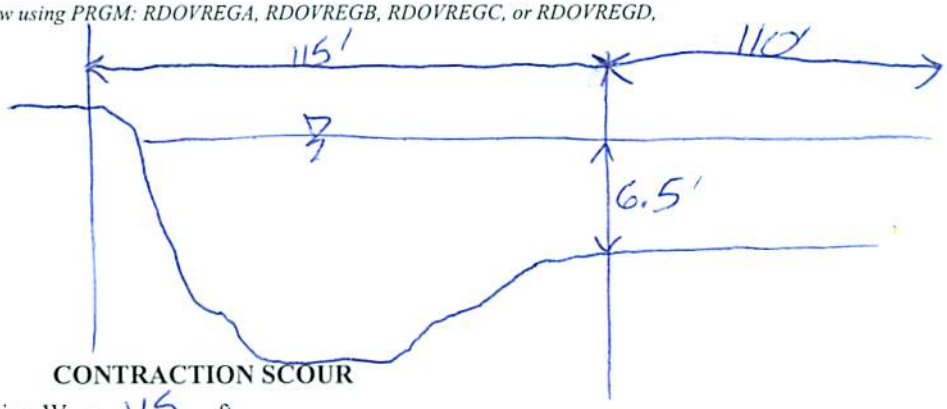
n (LOB) = 0.033

n (ROB) = 0.033

Pier Width = 1.0 ft

Pier Length = 63 ft

Piers for 500 yr = 2 ft



CONTRACTION SCOUR

PGRM: Contract

Width of main channel at approach section W_1 = 115 ft

Width of left overbank flow at approach, W_{lob} = 0 ft Average left overbank flow depth, y_{lob} = 0 ft

Width of right overbank flow at approach, W_{rob} = 110 ft Average right overbank flow depth, y_{rob} = 6.5 ft

Live Bed Contraction Scour (use if bed material is small cobbles or finer)

x = _____ From Figure 9 W_2 (effective) = _____ ft y_{cs} = _____ ft

PGRM: CWCSNEW

Clear Water Contraction Scour (use if bed material is larger than small cobbles)

Estimated bed material D_{50} = 0.20 ft Average approach velocity, $V_1 = Q_{500}/(y_1 W_1)$ = ~~3.93~~ 4.56 ft/s Z = ~~3.392~~ 0

Critical approach velocity, $Vc = 11.52 y_1^{1/6} D_{50}^{1/3}$ = 10.12 ft/s

If $V_1 < V_c$ and $D_{50} >= 0.2$ ft, use clear water equation below, otherwise use live bed scour equation above.

$D_{c50} = 0.0006(q_2/y_1^{7/6})^3$ = 0.1456 ft If $D_{50} >= D_{c50}$, $\chi = 0.0$

Otherwise, $\chi = 0.122 y_1 [q_2/(D_{50}^{1/3} y_1^{7/6})]^{6/7} - y_1$ = ✓ From Figure 10, y_{cs} = 0.0 ft

PIER SCOUR CALCULATIONS

PGRM: Pier

L/a ratio = 63 Correction factor for flow angle of attack (from Table 1), K2 = 2.5

Froude # at bridge = 0.169 Using pier width a on Figure 11, ξ = 4.9 Pier scour y_{ps} = 11.5 ft

ABUTMENT SCOUR CALCULATIONS

PGRM: Abutment

Average flow depth blocked by: left abutment, y_{aLT} = 0 ft right abutment, y_{aRT} = 6.5 ft

Shape coefficient K_1= 1.00 for vertical-wall, 0.82 for vertical-wall with wingwalls, 0.55 for spill-through

Using values for y_{aLT} and y_{aRT} on figure 12, ψ_{LT} = 0 and ψ_{RT} = 17.7

Left abutment scour, $y_{as} = \psi_{LT}(K_1/0.55)$ = 0 ft Right abutment scour $y_{as} = \psi_{RT}(K_1/0.55)$ = 17.7 ft

SD HWY 238/

Route St. Patrick Stream Rapid Creek MRM _____ Date 4/15/11 Initials GL

Bridge Structure No. 52435310 Location SD238/St Patrick St over Rapid Creek

GPS coordinates: N 44°04'03.3" W103°10'49.9" taken from: USL abutment X centerline of ⇑ MRM end _____

Datum of coordinates: WGS84 X NAD27 _____

Drainage area = 423.38 sq. mi. 15.7

The average bottom of the main channel was ~~14.0~~ ft below top of guardrail at a point ~~89~~ 80 ft from left abutment.

Method used to determine flood flows: ____Freq. Anal. ✓ drainage area ratio ____regional regression equations.

MISCELLANEOUS CONSIDERATIONS

Flows	Q_{100} = 4830			Q_{500} = 18200		
Estimated flow passing through bridge	4830			14165		
Estimated road overflow & overtopping	—			4035		
Consideration	Yes	No	Possibly	Yes	No	Possibly
Chance of overtopping		X		X		
Chance of Pressure flow		X		X		
Armored appearance to channel		X			X	
Lateral instability of channel		X			X	

Riprap at abutments? X Yes ____No ____Marginal

Evidence of past Scour? X Yes ____No ____Don't know Upstream

Debris Potential? X High ____Med ____Low

Does scour countermeasure(s) appear to have been designed?

Riprap	X Yes	____No	____Don't know	____NA
Spur Dike	____Yes	____No	____Don't know	X NA
Other _____	____Yes	____No	____Don't know	X NA

Bed Material Classification Based on Median Particle Size (D_{50})

Material	Silt/Clay____	Sand____	Gravel X	Cobbles____	Boulders____
Size range, in mm	<0.062	0.062-2.00	2.00-64	64-250	>250

Comments, Diagrams & orientation of digital photos

Photos

1557 - ID
88 - US
89 - US RB
90 - US LB
91 - US R. Abut.
92 - US R. Abut
93 - US L. Abut
94 - US L. Abut
95 - US face of bridge
96 - App XS RB
97 - App XS
98 - App XS LB

Summary of Results

	Q100	Q500
Bridge flow evaluated	4830	14165
Flow depth at left abutment (yaLT), in feet	0.0	0.0
Flow depth at right abutment (yaRT), in feet	0.0	6.5
Contraction scour depth (ycs), in feet	0.0	0.0
Pier scour depth (yps), in feet	11.2	11.5
Left abutment scour depth (yas), in feet	0.0	0.0
Right abutment scour depth (yas), in feet	0.0	17.9
1Flow angle of attack	15°	15°

See Comments/Diagram for justification where required