Contraction Scour Calculation

Based on HEC-18 (FHWA, 2012), Chapter 6

Bankline abutments, i.e. no abutments in floodplain (no flow in the floodplain under bridge)

Inputs	Variable	Value
Average depth of flow upstream	y1	4.30 ft
Average depth in contracted section before scour	y0	4.30 ft
Particle size for which 50% are smaller	D50	0.17 ft
Flow in the upstream channel	Q1	1131
Flow in the contracted section	Q2	1131
Width of upstream channel	W1	42.0
Width in contracted, less pier width	W2	35.0
Average velocity in upstream channel	V1	8.80 ft/s
Average velocity in contracted section	V2	9.00 ft/s
Slope of energy grade line of main channel	S1	0.013 ft/ft
Fall velocity of D50 (chart)	T	2.00 ft/s
Calculations		
Critical velocity	Vc	7.9
Average V > Vc?	Yes	Live bed scour
Shear velocity	V*	1.34 ft/s
V* / T		0.67
Exponent in live bed equation	k1	0.64
Live bed contraction section flow depth	y2	4.83
Live bed scour depth	**ys = y2-y0**	**0.53 ft**
Clear water contraction section flow depth	y2	3.80
Clear water scour depth	**ys = y2-y0**	**-0.50 ft**

Abutment Scour Calculation using Froehlich Equation

Based on HEC-18 (FHWA, 2012), Chapter 8

Bankline abutments, i.e. no abutments in floodplain (no flow in the floodplain under bridge)

Inputs	Variable	Value	
Bridge span		35	ft
Water surface width in upstream approach		42	ft
Upstream flow depth	y1 or y0	4.3	ft
Length of embankment	L	4.4	ft
Length of active flow obstructed by abutment	L'	3	ft
Flow area of cross-section obstructed by abutment	Ae	6.2	ft2
Total flow	Q	1131	cfs
Flow obstructed by abutment	Qe	55	cfs
Coefficient for abutment shape (Fig. 8.6)	K1	0.82	
Coefficient for angle of approach flow (Fig. 8.5)	K2	1	
Water surface elevation upstream of bridge		5967.6	ft
Bottom of channel elevation at abutment		5963.3	ft

Method 1: Froehlich Equation			
Average depth of flow in abutment area	ya	1.41	ft
Average velocity in obstructed flow area	Ve	8.87	ft/s
Froude number of approach flow upstream of abutment	Fr	1.32	
Scour depth	ys	5.3	ft
Elevation of bottom of scour		5960.9	ft
Depth of scour below bottom of main channel		2.4	ft

Method 2: NCHRP Live-Bed Scour			
Bridge unit discharge	q2c	32.3	cfs/ft
Upstream channel unit discharge	q1	26.9	cfs/ft
Unit discharge ratio	q2c / q1	1.20	
Contraction scour	yc	5.03	ft
Amplification factor (Fig. 8.10)	alpha-a	1.7	
Max depth at scour	ymax	8.5	ft
Scour depth	ys	4.2	ft

Conclusions:

Given evidence from existing 35-ft bridge (same span & configuration), little scour has occurred even though no appreciable riprap. Place foundation depth 2.5 feet below main channel, and use riprap to depth of 2.5 feet with gradation according to USCE procedure.

Riprap Design Worksheet

Based on Corps of Engineers EM-1110-2-1601

Input:

Parameter Name	Symbol	Value	Units	Data source / remarks
Average channgel velocity	Vavg	9.0	ft/s	HEC-RAS calculated, maximum during 100-year Q
Centerline radius of bend	R	800	ft	From CAD, alignment is nearly straight
Water surface width in channel	W	42	ft	HEC-RAS
Stability coefficient	Cs	0.3		0.3 for angular rock, 0.375 for rounded rock
Vertical velocity distribution coefficient	Cv	1.12		Varies 1.0 to 1.25, see page 3-6 of EM
Thickness coefficient	Ct	1		Use 1.0 for riprap thickness 1xD100
Local depth of flow at location of Vss	d	4.3	ft	HEC-RAS
Bank side slope, angle with horizontal	Theta	34	degrees	1.5:1 = 34 degres, 2:1 = 27 degrees, 3:1 = 18 degrees
Unit weight of stone	Gamma-s	165	lb/ft3	
Safety factor	Sf	1.2		Range 1.1 to 1.3 based on judgment

Calculated:

R / W		19.05		
Vss / Vavg		1.07		
Characteristic velocity	Vss	9.7	ft/s	
Side slope factor	K1	0.70		
D30 (min)	D30	0.89	feet =	11 inches

Choose gradation from Table 3-1 based on D30 (min)

Rip-rap Gradation Curve

Based on EM 1110-2-1601 Table 3-1

D30(min) from Riprap Design Worksheet: 0.89 feet

	W% (lb)		D% (inches)	
% finer	Max	Min	Max	Min
0	26	11	8	6
15	78	32	12	9
30	118	61	13	11
50	158	105	15	13
90	343	186	19	15.5
100	529	213	22	16.2

<-------- Manually enter D0 values for range of absolute minimum stone size