Scour Guidance Packet

This package provides information to help establish a framework for performing a scour analysis.

- Scour evaluation summary sheets and computation summary worksheets were developed in conjunction with information contained in the National Highway Institute (NHI), Hydraulic Engineering Circular No. 18 (HEC-18), Fifth Edition, Dated April 2013

Items included with this packet are:

- Scour evaluation summary sheets which can be used to help provide a synopsis of the structure and analysis.
- Computation worksheets that can be used to help document methods & parameters used in the scour analysis. They are also a useful tool to help the person doing or checking the analysis outline their work.

- **<u>Two Sample Sites</u>**

  - A sample based on using the worksheets to help document how the analysis was prepared along with the outcome for one frequency. Exhibits and calculations are included which support the study.
    - A pre-worksheet & summary sheet version of the same location showing how results and supporting calculations were effectively presented. This was prepared independently from the worksheet version. The results between the two studies are very similar.

  - A sample that was prepared prior to the development of the worksheets. This example shows an alternative presentation of how calculations and judgement were applied to the relevant scour equations at the project site. Augmented with the summary sheets this study would be more easily reviewed.

Scour Summary

Existing or Proposed Structure (circle one)

Structure Number:

Attach a brief narrative/summary of noting key findings such as the following:

Design Scour Event (such as 10-yr, 50-yr or 100-yr):

- Attach Total Scour Plot
- Superimpose scour check onto total scour plot

  Scour check event (typically 200-yr event) :

- On plot identify elevation of bed before scour
- Add any other relevant notes
- Does the use of open abutments allow total scour to be used for design to be reduced: Yes or No*

  Note: *If Yes, then the total scour does not need to include abutment scour.

  If Yes, does the total scour plot reflect and note this adjustment: Yes or No

- Include a summary table of the computed scour depths

Note: Design Scour Event and Extreme Event II are discussed in the November 7, 2014 All Bridge Designers (ABD) memorandum 14.2

Identify critical scour depths below: (identify total scour and components such as contraction, pier…)

Scour Summary

Existing or Proposed Structure (circle one)

Structure Number:

Structure Type

☐ **Bridge:** Number of Spans: (note span length; ex 1 @ 60’ or 3 @ 60’-90’-60’)

Number of Piers*:

Type and width of each pier (feet):

Note: * If number of piers is not zero then attach pier scour calculations and summary data

Abutment Type: Open*, Closed, Closed with Wing Walls (Circle one)

Note: *If structure has open abutments, then the total scour does not need to include abutment scour.

☐ **Bottomless Culvert** (Three Sided): Width (feet):

Height (feet):

Wing Walls: Yes or No (circle one)

Describe source of Median Bed Size (D_{50}) estimate used in Phase I scour evaluation:

Median Bed Size used in scour evaluation (Identify Units): D_{50} =

Blank Summary Sheets and Work Sheets

Summary Sheets

The Scour Summary Sheet consists of two pages. A brief narrative noting any items such as assumptions or discrepancies that had to be accounted for should accompany it. The Hydraulic Report will also include discussion of the scour evaluation in more detail.

Work Sheets

Work sheets were developed to help summarize parameters used in the application of different equations for abutment and contraction scour. It should be noted that the NCHRP 24-20 method includes contraction scour within the method. A worksheet for pier scour was not developed. Pier scour evaluation can vary depending on different pier arrangements and other circumstances, so a single worksheet to represent all situations seemed cumbersome.

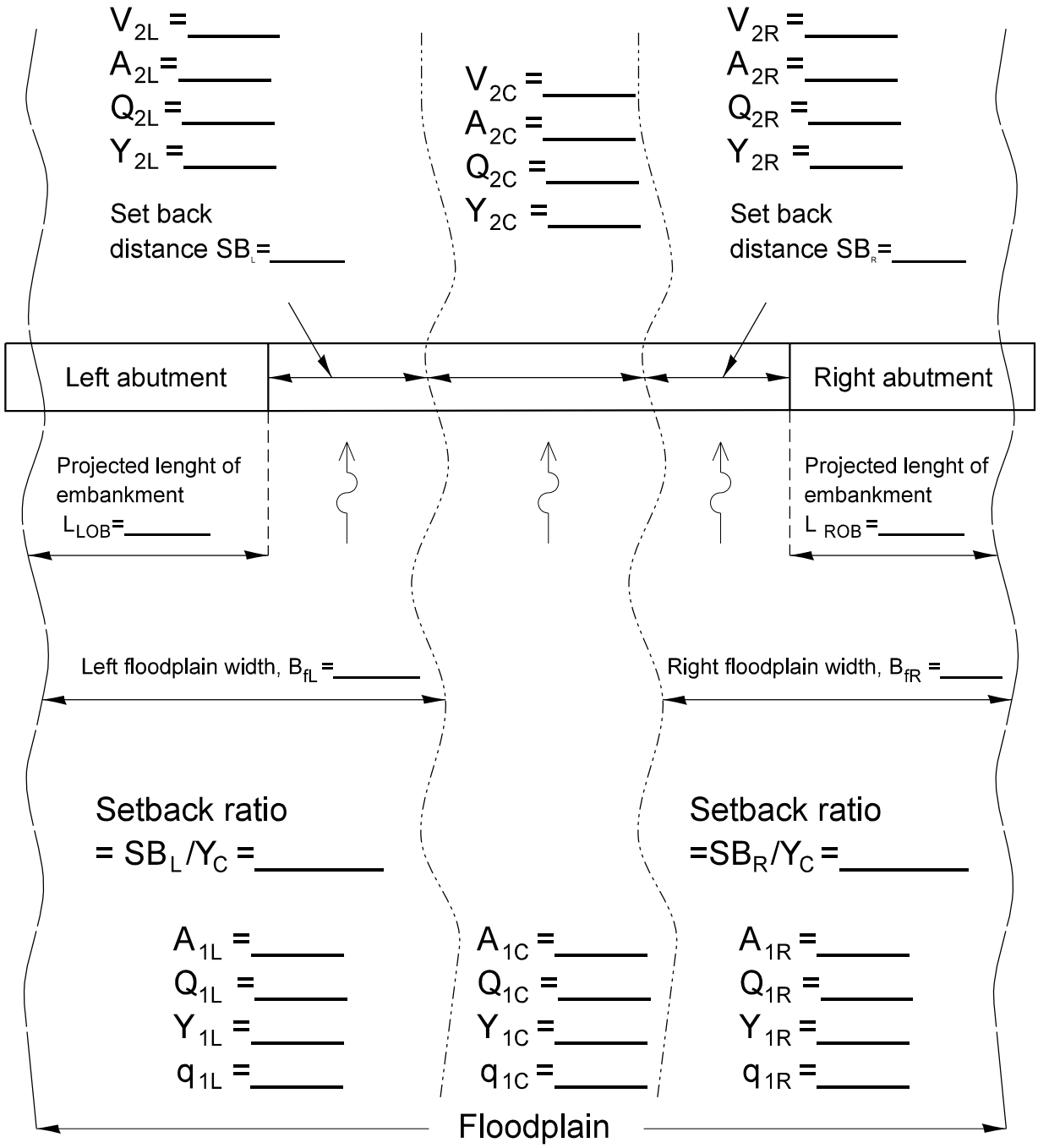
Three worksheets were developed: 1) Abutment Scour (HIRE & Froelich Equations), 2) Contraction Scour and 3) NCHRP 24-20 method.

☐ Existing ☐ Proposed Flood Event: _____ (years)

Structure Type:

☐ Bridge: # of Spans / Piers _____/_____

☐ Bottomless Culvert / 3-Sided: Span _____ft



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

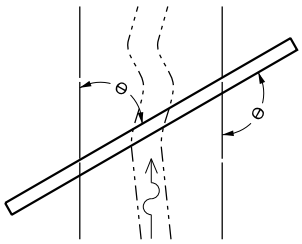
STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	NCHRP 24–20 Abutment Scour Approach, Total Scour at an Abutment	ROUTE:
		WATERWAY:
		COUNTY:
		STRUCTURE NUMBER:

☐ Existing ☐ Proposed Flood Event: _____ (years)

Check method being used for abutment scour:

☐ HIRE Equation* ☐ Froelich's Equation

If item does not apply, write "N/A"
Not to be used for NCHRP 24-20 Approach
*If $L/y_1 < 25$ HIRE Equation does not apply



Θ = _____° Left abutment Direction:_____

Θ = _____° Right abutment Direction:_____

Direction: Upstream , Downstream or Perpendicular
Θ < 90° if embankment points downstream
Θ > 90° if embankment points upstream
Θ = 90° if embankment is perpendicular to floodplain

L_L= _____
V_{1L}= _____
y_{1L}= _____
L/y_{1L}= _____

Y_{MAX} = _____
V_{MAX} = _____

L_R = _____
V_{1R} = _____
y_{1R}= _____
L/y_{1R} = _____

Left abutment		Right abutment

Q_{eL} = _____
A_{eL}= _____
V_{eL}= _____
L = _____
y_{aL} = _____

L=_____(ft)
L'=_____(ft)

Q_{eR}= _____
A_{eR} = _____
V_{eR} = _____
L = _____
y_{aR}= _____

L=_____(ft)
L'=_____(ft)

Left Overbank Channel Right Overbank

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

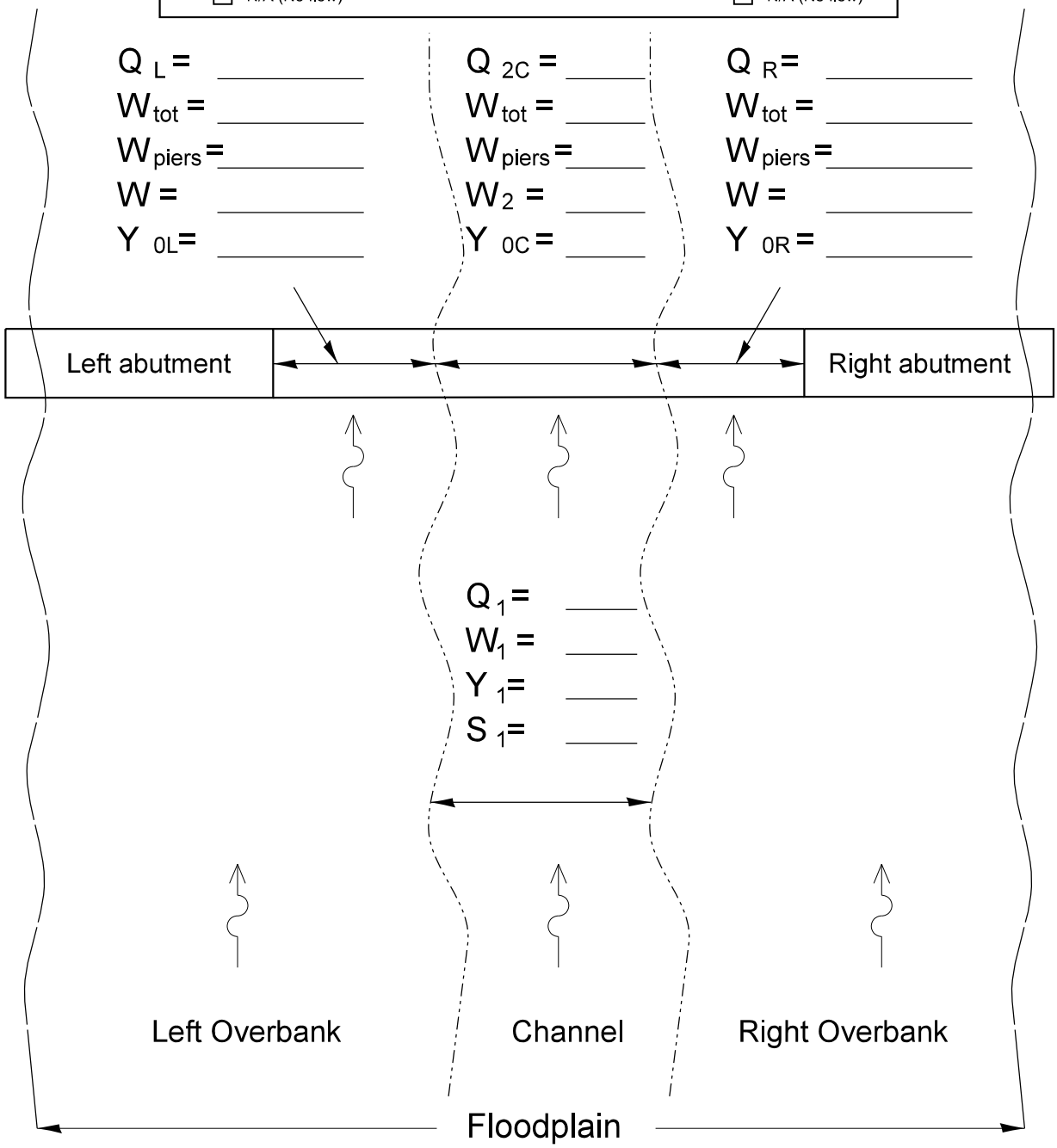
STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Local Scour Data Sheet For Froelich's or HIRE Equations	ROUTE:
		WATERWAY:
		COUNTY:
		STRUCTURE NUMBER:

D1 PDPDF5 (02/03/17)

☐ Existing ☐ Proposed Flood Event: _____ (years)

Check bed condition for contraction scour:

Left overbank	Channel	Right overbank
☐ Live bed	☐ Live bed	☐ Live bed
☐ Clear water	☐ Clear water	☐ Clear water
☐ N/A (No flow)		☐ N/A (No flow)



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Contraction Scour Data Sheet	ROUTE:
		WATERWAY:
		COUNTY:
		STRUCTURE NUMBER:

Scour Summary

Existing or Proposed Structure (circle one)

Structure Number: 045-2105 (Prop.)

Structure Type

☑ **Bridge:** Number of Spans: 3@ 50' ea. (note span length; ex 1 @ 60' or 3 @ 60'-90'-60')

Number of Piers*: 2

Type and width of each pier (feet): 3' (Round Nose)

Note: * If number of piers is not zero then attach pier scour calculations and summary data

Abutment Type: Open*, Closed, Closed with Wing Walls (Circle one)

Note: *If structure has open abutments, then the total scour does not need to include abutment scour. -7 Abut Scour NOT Calculated for Prop. Structure

☐ **Bottomless Culvert** (Three Sided): Width (feet):

Height (feet):

Wing Walls: Yes or No (circle one)

Describe source of Median Bed Size (D_{50}) estimate used in Phase I scour evaluation:

Boring Logs in Ex. Struct. MicroFilm Show Silty-Sand Soil

Median Bed Size used in scour evaluation (Identify Units): D_{50} =

0.3mm

≅ 0.000984252 FT

Scour Summary

Existing or Proposed Structure (circle one)

Structure Number: 045-2105 (Prop.)

Attach a brief narrative/summary of noting key findings such as the following:

Design Scour Event (such as 10-yr, 50-yr or 100-yr): 100-yr Design

- ✓ Attach Total Scour Plot
- ✓ Superimpose scour check onto total scour plot

  Scour check event (typically 200-yr event): 200-yr check

- ✓ On plot identify elevation of bed before scour
- ✓ Add any other relevant notes
- Does the use of open abutments allow total scour to be used for design to be reduced: Yes or No*

  Note: *If Yes, then the total scour does not need to include abutment scour.

  If Yes, does the total scour plot reflect and note this adjustment: Yes or No

Total Scour Plots DO NOT include Abut. Scour.

- ✓ Include a summary table of the computed scour depths

Note: Design Scour Event and Extreme Event II are discussed in the November 7, 2014 All Bridge Designers (ABD) memorandum 14.2

Identify critical scour depths below and in narrative: (identify total scour and components such as contraction, pier...)

Summary: (100yr Design / 200 yr check)

Contraction: 2.09' / 2.90'

Pier = 4.61' / 4.87' => Contraction + Pier = (6.7' / 7.77')

NCHRP: (L) 6.98' / 8.34'

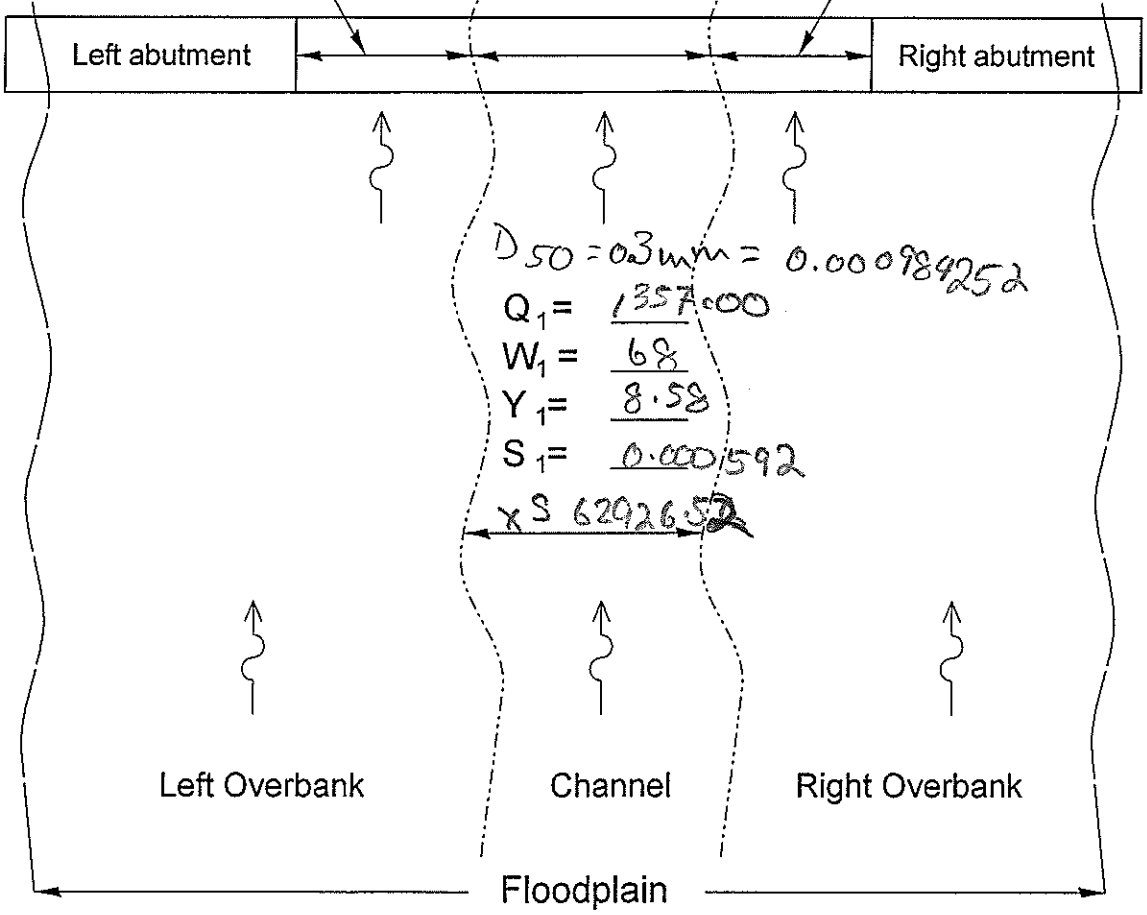
(R) 2.42' / 6.17'

☐ Existing ☑ Proposed Flood Event: 100 (years)

Check bed condition for contraction scour:

Left overbank	Channel	Right overbank
☐ Live bed	☐ Live bed	☐ Live bed
☐ Clear water	☐ Clear water	☐ Clear water
☐ N/A (No flow)		☐ N/A (No flow)

Q_L = N/A	Q_{2C} = 2808	Q_R = N/A
W_{tot} =	W_{tot} = 139.39	W_{tot} =
W_{piers} =	W_{piers} = 2@3'@9	W_{piers} =
W =	W_2 = 133.39'	W =
Y_{0L} =	Y_{0C} = 7.96	Y_{0R} =



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Contraction Scour Data Sheet	ROUTE: US 30
		WATERWAY: Blackberry
		COUNTY: Kane
		STRUCTURE NUMBER: 045-0105

☐ Existing ☑ Proposed Flood Event: 100 (years)

Check method being used for abutment scour:

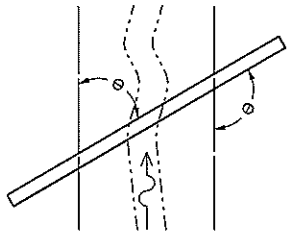
☐ HIRE Equation* ☐ Froelich's Equation

*N/A - No Abut Scour Becase of open Abut Config

If item does not apply, write "N/A"

Not to be used for NCHRP 24-20 Approach

*If L/y < 25 HIRE Equation does not apply



θ = 6 ° Left abutment Direction: N/A

θ = 0 ° Right abutment Direction: N/A

Direction: Upstream , Downstream or Perpendicular
θ < 90° if embankment points downstream
θ > 90° if embankment points upstream
θ = 90° if embankment is perpendicular to floodplain

L_L = N/A
V_{1L} =
y_{1L} =
L/y_{1L} =

Y_{MAX} = 9.47
V_{MAX} = 2.97

L_R = N/A
V_{1R} =
y_{1R} =
L/y_{1R} =

Left abutment		Right abutment
Q_{eL} = N/A		Q_{eR} = N/A
A_{eL} =		A_{eR} =
V_{eL} =		V_{eR} =
L =		L =
y_{aL} =		y_{aR} =
L= (ft)		L= (ft)
L'= (ft)		L'= (ft)

Left Overbank | Channel | Right Overbank

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Local Scour Data Sheet For Froelich's or HIRE Equations	ROUTE: US 30
		WATERWAY: Blackberry
		COUNTY: Kane
		STRUCTURE NUMBER: 045-2105

☐ Existing ☑ Proposed Flood Event: 100 (years)

Structure Type:

☑ Bridge: # of Spans / Piers 3, 2

☐ Bottomless Culvert / 3-Sided: Span ____ ft

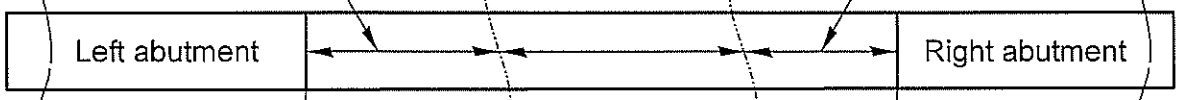
V_{2L} = 2.63
A_{2L} = 1069.29
Q_{2L} = 2808
Y_{2L} = 2.43
q_{2fL} = ____

V_{2C} = N/A
A_{2C} = 1069.29
Q_{2C} = 2808
Y_{2C} = 7.96
W_{2C} = 138.37
q_{2C} = 20.14

V_{2R} = N/A
A_{2R} = ____
Q_{2R} = ____
Y_{2R} = ____
q_{2fR} = ____

Set back distance SB_L = 0'

Set back distance SB_R = ____



Projected lenght of embankment L_L = 60.45

Projected lenght of embankment L_R = 361.47

Left floodplain width, B_{fL} = 110.57

Right floodplain width, B_{fR} = 411.67

L_L/B_{fL} = 0.55 { ☐ Live bed ☑ Clear water

L_R/B_{fR} = 0.88 { ☑ Live bed ☐ Clear water

V_{1L} = N/A
A_{1L} = 437.01
Q_{1L} = 386.98
Y_{1L} = 4.20
W_{1L} = 104.16
q_{1fL} = 3.72

V_{1C} = N/A
A_{1C} = N/A
Q_{1C} = 1357
Y_{1C} = 3.58
W_{1C} = 68
q_{1C} = 19.96

V_{1R} = N/A
A_{1R} = ____
Q_{1R} = ____
Y_{1R} = ____
W_{1R} = ____
q_{1fR} = ____

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	NCHRP 24-20 Abutment Scour Approach, Total Scour at an Abutment	ROUTE: US 30 WATERWAY: Blackberry COUNTY: Kane STRUCTURE NUMBER: 045-2105

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US30
LIMITS @ Blackberry Ck
DESCRIPTION Scour Calcs.

SHEET NO. 1
TOTAL NO. 4

Contraction Scour

$V_c = 11.17\, y^{1/6} D_{50}^{1/3}$

$= 11.17\,(8.58)^{1/6}\,(0.000984252)^{1/3}$

$= 1.59$ FPS

$V = 2.33 > V_c \Rightarrow$ Live Bed

$V^* = \sqrt{g y S} = \sqrt{(32.2)(8.58)(0.000592)}$

$V^* = 0.404$

$\omega = 0.04$ m/s $\times 3.28$ ft/m/s $= 0.1312$

$V^*/\omega = 3.08 \Rightarrow K_1 = 0.69$ (Fig 6.10)

$y_2 = y_1 \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{\omega_1}{\omega_2}\right)^{K_1} = (8.58)\left(\frac{2209}{1357}\right)^{6/7}\left(\frac{62}{133.39}\right)^{0.69}$

$y_2 = 10.05$ FT

$y_s = y_{d2} - y_{d0} = 10.05 - 7.96 = \boxed{2.09 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US 30
LIMITS @ Blackberry Ck.
DESCRIPTION Scour Sample Calc.

SHEET NO. 2
TOTAL NO. 4

Pier Scour

$y_s/a = 2.0\ K_1 K_2 K_3 \left(y_1/a\right)^{0.35} Fr^{0.43}$; $K_1 = 1.0$, $K_2 = 1.0$, $K_3 = 1.1$

$Fr = V_1/\sqrt{g y_1} = 2.97/\sqrt{(32.2)(9.47)} = 0.170$

$y_s/a = (2)(1)(1)(1.1)\left(9.47/3\right)^{0.35}(0.170)^{0.43}$

$y_s/a = 1.535$ FT

$\boxed{y_s = 4.61 \text{ FT}} < 2.4a$ ✓ (Eq. 7.2 check)

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US30
LIMITS @ Blackberry Cr.
DESCRIPTION sample Scour Calcs

SHEET NO. 3
TOTAL NO. 4

For WCHRT:

(4) Abutment

$L = 60.45$ $BS = 110.57$

$L/BS = 0.55$

$\therefore$ Clear Water

SER (4) = 0 $\therefore$ CASE (A) Applies (Fig 8.14)

q_{2F} = use entire opening

$Q_{TOT} = 2807$ cfs $A_{TOT} = 1069.29$ SF $V = Q/A = 2.63$ FPS

$q_{2F} = V \cdot y_2 = (2.63)(2.43) = 6.39$ cfs/FT

$y_c = \left[q_{2F} / (11.17)(D_{50})^{1/3} \right]^{6/7} = \left[6.39 / (11.17)(0.00098425)^{1/3} \right]^{6/7}$

$y_c = 4.48$ FT

$q_{1F} = Q_{1L} / W_{1L} = 386.98 / 104.16 = 3.72$ cfs/FT
(Flow (4) FIP)

$q_{1F} / q_{2F} = 6.39 / 3.72 = 1.72 \Rightarrow \alpha_B = 2.1$ (Fig. 8.11)

$y_{max} = \alpha_B y_c = (2.10)(4.48) = 9.41$ FT

$y_s = y_{max} - y_{o2} = 9.41 - 2.43 = \boxed{6.98 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US 30
LIMITS 01 Blackberry Ck
DESCRIPTION sample scour calcs.

SHEET NO. 4
TOTAL NO. 4

NCHRP Method Cont:

For (R) Abut:

$L = 361.47$ $B_s = 911.67$

$L/B_s = 0.878$

$\boxed{\therefore \text{ Live Bed}}$

$Q_{2c} = 2808$ cfs $w_{2c} = 139.39 \Rightarrow q_{2c} = 20.14$ cfs/ft

$Q_1 = 1357$ cfs $w_1 = 68' \Rightarrow q_1 = 19.96$ cfs/ft

$y_c = y_1 \left(q_{2c}/q_1\right)^{6/7} = 8.58 \left(20.14/19.96\right)^{6/7}$

$y_c = 8.65$ ft

$y_{max} = \alpha_A y_c$; $q_{2c}/q_1 = 1.01 \Rightarrow \alpha_A = 1.20$ (Min Val of Fig. 8-9)

$y_{max} = (1.2)(8.65) = 10.38'$

$y_s = y_{max} - y_0 = 10.38' - 7.96' = \boxed{2.42'}$

Summary:

Cont: 2.09 ft

Pier = 4.61 $\Rightarrow$ Cont + Pier = 6.7 ft

NCHRP (L) = 6.98 ft

(R) = 2.42 ft

* Note: (L) & (R) local Abut scour NOT Included Rec. of open Abut Config.

Plan: PR Blackberry Creek Main before A RS: 62926.52 Profile: Q100

E.G. Elev (ft)	659.66	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.	0.106	0.064	0.106
W.S. Elev (ft)	659.62	Reach Len. (ft)	32.92	32.92	32.92
Crit W.S. (ft)		Flow Area (sq ft)	437.01	583.39	1383.73
E.G. Slope (ft/ft)	0.000592	Area (sq ft)	437.01	583.39	1659.72
Q Total (cfs)	2808.00	Flow (cfs)	386.98	1357.00	1064.03
Top Width (ft)	580.16	Top Width (ft)	104.16	68.00	407.99
Vel Total (ft/s)	1.17	Avg. Vel. (ft/s)	0.89	2.33	0.77
Max Chl Dpth (ft)	9.68	Hydr. Depth (ft)	4.20	8.58	3.39
Conv. Total (cfs)	115409.7	Conv. (cfs)	15904.8	55773.0	43731.8
Length Wtd. (ft)	32.92	Wetted Per. (ft)	104.46	69.82	408.75
Min Ch El (ft)	649.94	Shear (lb/sq ft)	0.15	0.31	0.13
Alpha	2.16	Stream Power (lb/ft s)	646.00	0.00	0.00
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	32.78	29.70	52.67
C & E Loss (ft)	0.01	Cum SA (acres)	7.77	4.14	15.84

Errors Warnings and Notes

Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.

Plan: PR Blackberry Creek Main before A RS: 62823.34 Profile: Q100

E.G. US. (ft)	659.62	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	659.43	E.G. Elev (ft)	659.58	659.47
Q Total (cfs)	2808.00	W.S. Elev (ft)	659.47	659.36
Q Bridge (cfs)	2808.00	Crit W.S. (ft)	653.13	653.13
Q Weir (cfs)		Max Chl Dpth (ft)	9.47	9.36
Weir Sta Lft (ft)		Vel Total (ft/s)	2.63	2.66
Weir Sta Rgt (ft)		Flow Area (sq ft)	1069.29	1054.01
Weir Submerg		Froude # Chl	0.16	0.17
Weir Max Depth (ft)		Specif Force (cu ft)	4932.07	4814.97
Min El Weir Flow (ft)	666.97	Hydr Depth (ft)	7.96	7.87
Min El Prs (ft)	661.63	W.P. Total (ft)	157.79	157.03
Delta EG (ft)	0.20	Conv. Total (cfs)	96891.8	94879.2
Delta WS (ft)	0.28	Top Width (ft)	139.39	138.92
BR Open Area (sq ft)	1314.78	Frctn Loss (ft)	0.11	0.00
BR Open Vel (ft/s)	2.66	C & E Loss (ft)	0.00	0.05
Coef of Q		Shear Total (lb/sq ft)	0.36	0.37
Br Sel Method	Energy only	Power Total (lb/ft s)	-267.16	-277.85

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Warning:	For the final momentum answer at the bridge, the upstream energy was computed lower than the downstream energy.
	This is not physically possible, the momentum answer has been disregarded.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: PR Blackberry Creek Main before A RS: 62823.34BR U Profile: Q100

E.G. Elev (ft)	659.58	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.11	Wt. n-Val.		0.059	
W.S. Elev (ft)	659.47	Reach Len. (ft)	127.17	127.17	127.17
Crit W.S. (ft)	653.13	Flow Area (sq ft)		1069.29	
E.G. Slope (ft/ft)	0.000840	Area (sq ft)		1116.78	
Q Total (cfs)	2808.00	Flow (cfs)		2808.00	
Top Width (ft)	139.39	Top Width (ft)		139.39	
Vel Total (ft/s)	2.63	Avg. Vel. (ft/s)		2.63	
Max Chl Dpth (ft)	9.47	Hydr. Depth (ft)		7.96	
Conv. Total (cfs)	96891.8	Conv. (cfs)		96891.8	
Length Wtd. (ft)	127.17	Wetted Per. (ft)		157.79	
Min Ch El (ft)	650.00	Shear (lb/sq ft)		0.36	
Alpha	1.00	Stream Power (lb/ft s)	499.23	0.00	0.00
Frctn Loss (ft)	0.11	Cum Volume (acre-ft)	32.57	29.08	51.60
C & E Loss (ft)	0.00	Cum SA (acres)	7.70	4.04	15.57

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Warning:	For the final momentum answer at the bridge, the upstream energy was computed lower than the downstream energy.
	This is not physically possible, the momentum answer has been disregarded.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

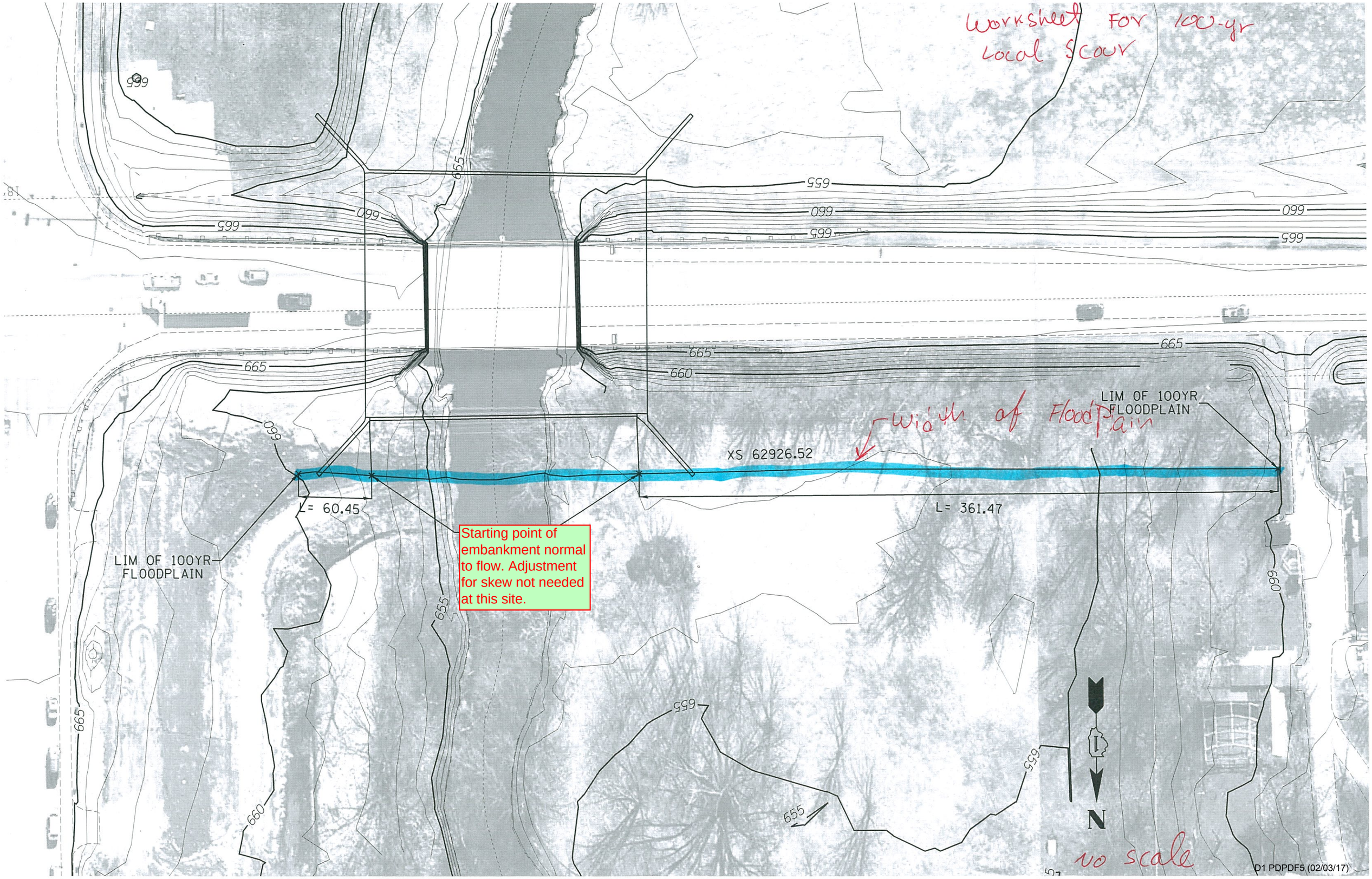
Plan: PR Blackberry Creek Main before A RS: 62823.34BR U Profile: Q100

	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(ft)	(ft)	(cfs)	(sq ft)	(ft)	Conv	Depth(ft)	(ft/s)	(lb/sq ft)	(lb/ft s)
1	Chan	-64.58	-52.52	26.46	23.70	10.89	0.94	2.43	1.12	0.11	0.13
2	Chan	-52.52	-40.47	227.73	92.98	13.14	8.11	7.71	2.45	0.37	0.91
3	Chan	-40.47	-28.41	230.80	114.19	21.53	8.22	9.47	2.02	0.28	0.56
4	Chan	-28.41	-25.41	0.00	26.77	12.30	0.00	9.47	0.00	Pier 0.11	0.00
5	Chan	-25.41	-12.41	366.31	123.13	13.00	13.05	9.47	2.97	0.50	1.48
6	Chan	-12.41	0.59	366.31	123.13	13.00	13.05	9.47	2.97	0.50	1.48
7	Chan	0.59	13.59	366.31	123.13	13.00	13.05	9.47	2.97	0.50	1.48
8	Chan	13.59	26.59	366.31	123.13	13.00	13.05	9.47	2.97	0.50	1.48
9	Chan	26.59	39.59	254.32	123.13	22.47	9.06	9.47	2.07	0.29	0.59
10	Chan	39.59	42.59	0.00	20.72	11.66	0.00	9.47	0.00	Pier 0.09	0.00
11	Chan	42.59	57.17	355.75	129.10	15.29	12.67	8.85	2.76	0.44	1.22
12	Chan	57.17	65.17	191.18	51.77	8.00	6.81	6.47	3.69	0.34	1.25
13	Chan	65.17	78.75	56.53	41.88	14.47	2.01	3.24	1.35	0.15	0.20

Max Pier

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Warning:	For the final momentum answer at the bridge, the upstream energy was computed lower than the downstream energy.
	This is not physically possible, the momentum answer has been disregarded.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.


Worksheet for 100-yr
Local Scour
665
655
660
665
660
665
655
660
665
665
660
665
665
660
Width of Floodplain
LIM OF 100YR
FLOODPLAIN
XS 62926.52
L= 60.45
L= 361.47
Starting point of embankment normal to flow. Adjustment for skew not needed at this site.
LIM OF 100YR
FLOODPLAIN
655
660
655
655
655
660
665
N
no scale
D1 PDPDF5 (02/03/17)

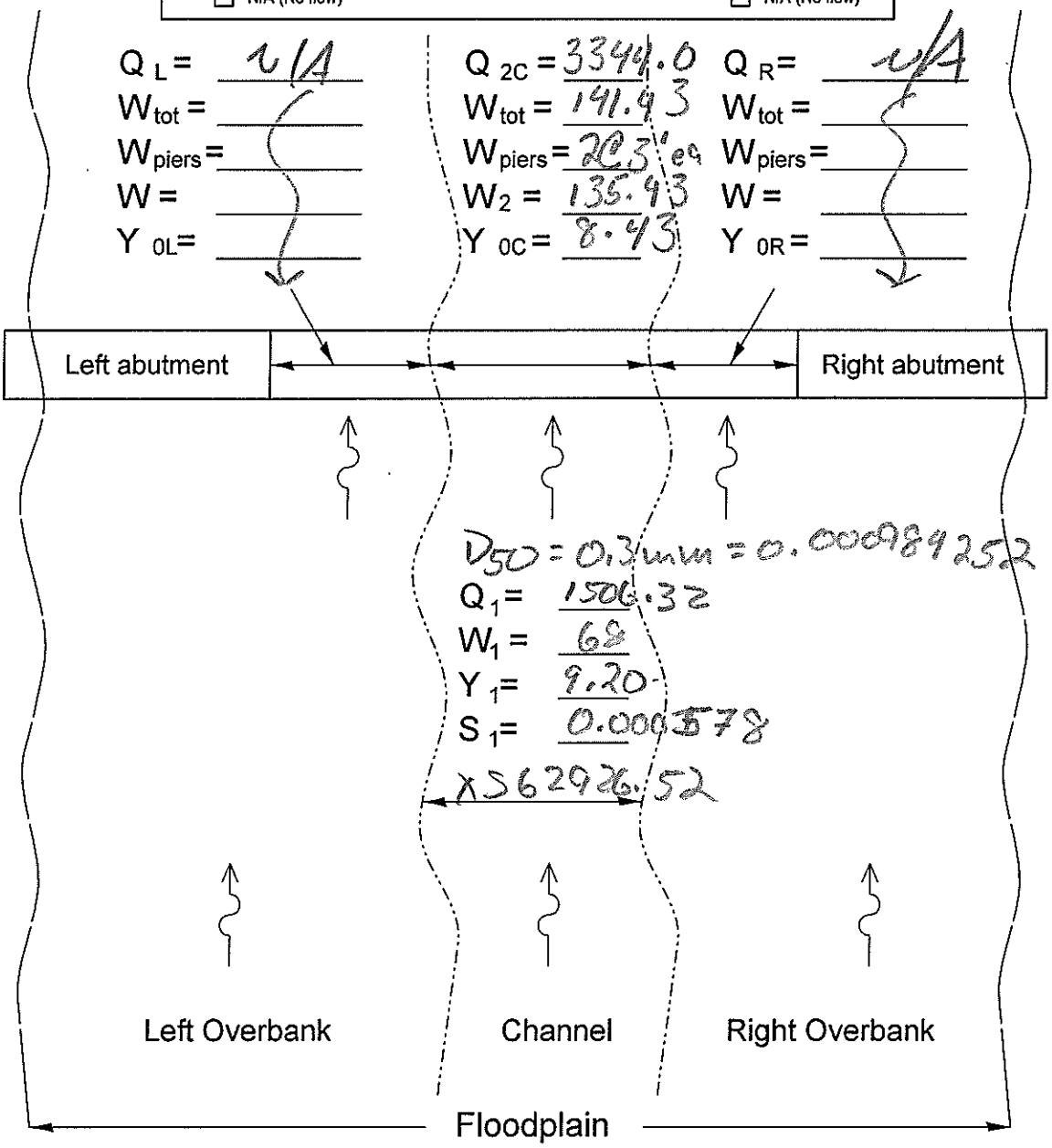
☐ Existing ☑ Proposed Flood Event: 200 (years)

Check bed condition for contraction scour:

Left overbank	Channel	Right overbank
☐ Live bed	☑ Live bed	☐ Live bed
☐ Clear water	☐ Clear water	☑ Clear water
☐ N/A (No flow)		☐ N/A (No flow)

N/A N/A

Q_L = N/A	Q_{2C} = 3344.0	Q_R = N/A
W_{tot} =	W_{tot} = 141.43	W_{tot} =
W_{piers} =	W_{piers} = 20.3 eq	W_{piers} =
W =	W_2 = 135.43	W =
Y_{0L} =	Y_{0C} = 8.43	Y_{0R} =



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Contraction Scour Data Sheet	ROUTE: US 30 WATERWAY: Rio Salado COUNTY: Kane STRUCTURE NUMBER: 045-2105

☐ Existing ☑ Proposed Flood Event: 200 (years)

Check method being used for abutment scour:

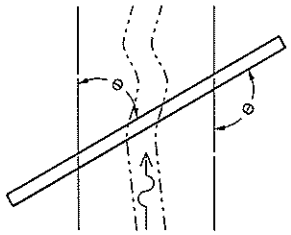
☐ HIRE Equation* ☐ Froelich's Equation

N/A - No Abut Scour Bc. of open Abut Con Fig.

If item does not apply, write "N/A"

Not to be used for NCHRP 24-20 Approach

*If L/y < 25 HIRE Equation does not apply



θ = 0 ° Left abutment Direction: N/A

θ = 0 ° Right abutment Direction: N/A

Direction: Upstream , Downstream or Perpendicular

θ < 90° if embankment points downstream

θ > 90° if embankment points upstream

θ = 90° if embankment is perpendicular to floodplain

L_L= N/A

V_{1L}=

y_{1L}=

L/y_{1L}=

Y_{MAX} = 10.06

V_{MAX} = 3.31

L_R = N/A

V_{1R} =

y_{1R}=

L/y_{1R}=

Left abutment		Right abutment

Q_{eL}= N/A

A_{eL}=

V_{eL}=

L =

y_{aL}=

L= (ft)

L'= (ft)

Q_{eR}= N/A

A_{eR} =

V_{eR} =

L =

y_{aR}=

L= (ft)

L'= (ft)

Left Overbank | Channel | Right Overbank

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Local Scour Data Sheet For Froelich's or HIRE Equations	ROUTE: US 30 WATERWAY: Mississippi COUNTY: Kane STRUCTURE NUMBER: 047-0108

☐ Existing ☑ Proposed Flood Event: 200 (years)

Structure Type:

☐ Bridge: # of Spans / Piers ____/____

☐ Bottomless Culvert / 3-Sided: Span ____ft

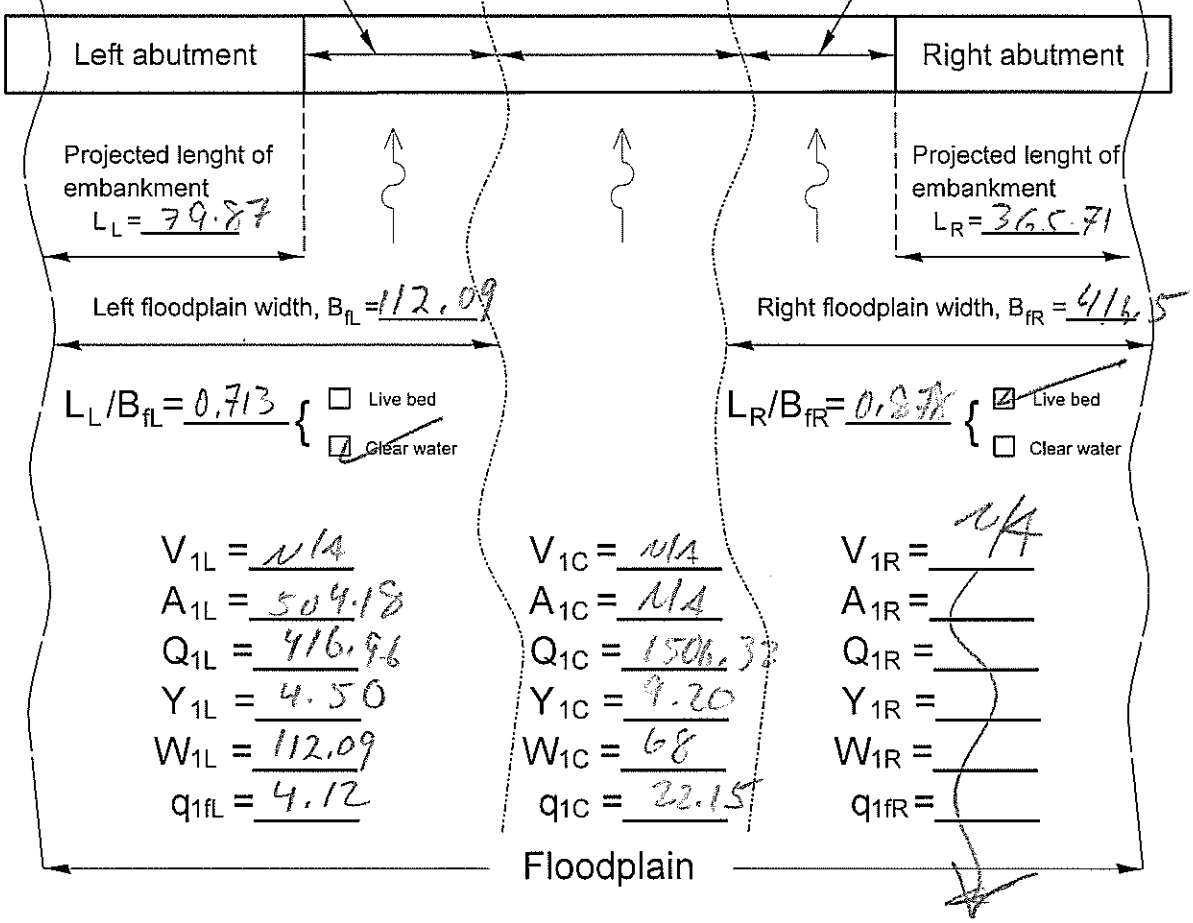
V_{2L} = 2.91
A_{2L} = 1149.46
Q_{2L} = 3344
Y_{2L} = 2.73
q_{2fL} = 6.39

V_{2C} = N/A
A_{2C} = 1149.46
Q_{2C} = 3344
Y_{2C} = 8.44
W_{2C} = 141.21
q_{2C} = 23.68

V_{2R} = N/A
A_{2R} = ____
Q_{2R} = ____
Y_{2R} = ____
q_{2fR} = ____

Set back distance SB_L = 0'

Set back distance SB_R = ____



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	NCHRP 24–20 Abutment Scour Approach, Total Scour at an Abutment	ROUTE: US 30
		WATERWAY: Blackberry
		COUNTY: Kane
		STRUCTURE NUMBER: 047-2105

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/10/15
CHECKED		

ROUTE US 30
LIMITS @ Blackberry CK
DESCRIPTION Sampled Scour Calcs

SHEET NO. 1
TOTAL NO. 4

Contraction Scour

$V_c = 11.17\, y^{1/6}\, D_{50}^{1/3}$

$= 11.17\,(9.20)^{1/6}\,(0.000984252)^{1/3}$

$= 1.61$ FPS

$V = 2.41$ FPS $> V_c$ ∴ Live Bed Conditions

$V^* = (ygS)^{1/2} = [(32.2)(9.20)(0.000578)]^{1/2}$

$V^* = 0.4138$ FPS

$\omega = 0.04\,m/s * (3.28) = 0.1312$ FPS

$V^*/\omega = 3.154 \Rightarrow K_1 = 0.69$ (Pg. 6.10)

$y_2 = y_1\left(\frac{Q_2}{Q_1}\right)^{6/7}\left(\frac{\omega_1}{\omega_2}\right)^{K_1} = 9.20\left(\frac{3344}{1506.32}\right)^{6/7}\left(\frac{68}{135.43}\right)^{0.69}$

$y_2 = 11.329$ FT

$y_s = y_2 - y_0 = 11.329 - 8.43 = \boxed{2.90 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED	JS	12/16/15
CHECKED		

ROUTE US 30
LIMITS 01 Blackberry CK
DESCRIPTION Scour sample calcs

SHEET NO. 2
TOTAL NO. 4

Pier Scour

$y_s/a = 2.0\ K_1 K_2 K_3 (y_1/a)^{0.35} Fr^{0.43}$; $K_1 = 1.0$, $K_2 = 1.0$ ($\theta = 0°$), $K_3 = 1.1$

$Fr = V_1/\sqrt{g y_1} = 3.31/\sqrt{32.2 \times 10.06} = 0.1839$

$y_s/a = (2)(1)(1)(1.1)\left(\frac{10.06}{3}\right)^{0.35}(0.1839)^{0.43}$

$y_s/a = 1.62$ FT

$y_s = (3)(1.62) = \boxed{4.87 \text{ FT}} < 2.4a$ ✓ (eq. 7.2 check)

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/10/15
CHECKED		

ROUTE US RTE 30
LIMITS o/ Blackberry Cr.
DESCRIPTION Sample Scour calcs

SHEET NO. 3
TOTAL NO. 4

FOR NCHRP
(c) Abutment

$L = 79.87$ $B_f = 112.09$

$L/B_f = 0.713$

$\boxed{\therefore \text{ clear water}}$

SBR (c) = 0 ∴ case A applies (Fig. 8.14)

q_{2F} use entire bridge opening

$Q_{TOT} = 3344$ $A_{TOT} = 1149.46 \Rightarrow v = Q/A = 3344/1149.46 = 2.91$

$q_{2F} = v \cdot y_2 = 2.91 \times 2.73 = 7.944$

$y_c = \left(q_{2F}/(11.17)(D_{50})^{1/3}\right)^{6/7} = \left[7.944/(11.17)(0.000984252)^{1/3}\right]^{6/7}$

$y_c = 5.398$

$q_{1F} = 4.12 \Rightarrow q_{2F}/q_1 = 1.928 \Rightarrow \alpha_B \cong 2.05$ (Fig 8.11)

$y_{max} = \alpha_B y_c = 11.07'$

$y_s = y_{max} - y_{o2} = 11.07 - 2.73 = \boxed{8.34 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED		
CHECKED		

ROUTE US 30
LIMITS 01 Blackberry Ck.
DESCRIPTION

SHEET NO. 4
TOTAL NO. 4

NCHRP Method Cont.

(C) Abutment

$L = 365.71$ $B_f = 416.5$

$L/B_f = 0.878$ —

$\boxed{\text{Live Bed}}$

$Q_{2c} = 3344$ $w_{2c} = 141.21 \Rightarrow q_{2c} = 23.68$ cfs/ft

$Q_1 = 1506.32$ $w_1 = 68' \Rightarrow q_1 = 22.15$ cfs/ft

$y_c = y_1 \left(q_{2c}/q_1 \right)^{6/7} = (8.20)\left(23.68/22.15 \right)^{6/7} = 9.74$ ft

$q_{2c}/q_1 = 1.07 \Rightarrow K_1 \approx 1.50$ (Fig. 8.9)

$y_{max} = K_1 y_c = (1.5)(9.74) = 14.61$

$y_s = y_{max} - y_o = 14.61 - 8.44 = \boxed{6.17'}$

Summary:

Const = 2.90

Pier = 4.87 $\Rightarrow$ Const + Pier = 7.77 ft

NCHRP (C) = 8.34 ft

(B) = 6.17 ft

★ Note: (C) & (B) Local Abut Scour

Not Calc because of open Abut Conf.

Plan: PR Blackberry Creek Main before A RS: 62926.52 Profile: Q200

E.G. Elev (ft)	660.29	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.	0.106	0.064	0.106
W.S. Elev (ft)	660.24	Reach Len. (ft)	32.92	32.92	32.92
Crit W.S. (ft)		Flow Area (sq ft)	504.18	625.69	1639.53
E.G. Slope (ft/ft)	0.000578	Area (sq ft)	504.18	625.69	1915.52
Q Total (cfs)	3344.00	Flow (cfs)	461.96	1506.32	1375.72
Top Width (ft)	596.45	Top Width (ft)	112.09	68.00	416.36
Vel Total (ft/s)	1.21	Avg. Vel. (ft/s)	0.92	2.41	0.84
Max Chl Dpth (ft)	10.30	Hydr. Depth (ft)	4.50	9.20	3.94
Conv. Total (cfs)	139133.3	Conv. (cfs)	19220.7	62673.2	57239.3
Length Wtd. (ft)	32.92	Wetted Per. (ft)	112.42	69.82	417.15
Min Ch El (ft)	649.94	Shear (lb/sq ft)	0.16	0.32	0.14
Alpha	2.07	Stream Power (lb/ft s)	646.00	0.00	0.00
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	37.48	32.15	62.13
C & E Loss (ft)	0.02	Cum SA (acres)	7.93	4.15	16.33

Errors Warnings and Notes

Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.

Plan: PR Blackberry Creek Main before A RS: 62823.34 Profile: Q200

E.G. US. (ft)	660.24	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	660.02	E.G. Elev (ft)	660.20	660.07
Q Total (cfs)	3344.00	W.S. Elev (ft)	660.06	659.93
Q Bridge (cfs)	3344.00	Crit W.S. (ft)	653.49	653.48
Q Weir (cfs)		Max Chl Dpth (ft)	10.06	9.93
Weir Sta Lft (ft)		Vel Total (ft/s)	2.91	2.96
Weir Sta Rgt (ft)		Flow Area (sq ft)	1149.52	1131.59
Weir Submerg		Froude # Chl	0.16	0.18
Weir Max Depth (ft)		Specif Force (cu ft)	5661.87	5517.25
Min El Weir Flow (ft)	666.97	Hydr Depth (ft)	8.43	8.31
Min El Prs (ft)	661.63	W.P. Total (ft)	161.45	160.73
Delta EG (ft)	0.22	Conv. Total (cfs)	107822.8	105318.6
Delta WS (ft)	0.31	Top Width (ft)	141.43	141.20
BR Open Area (sq ft)	1314.78	Frctn Loss (ft)	0.13	0.00
BR Open Vel (ft/s)	2.96	C & E Loss (ft)	0.00	0.05
Coef of Q		Shear Total (lb/sq ft)	0.43	0.44
Br Sel Method	Energy only	Power Total (lb/ft s)	-267.16	-277.85

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Warning:	For the final momentum answer at the bridge, the upstream energy was computed lower than the downstream energy.
	This is not physically possible, the momentum answer has been disregarded.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: PR Blackberry Creek Main before A RS: 62823.34BR U Profile: Q200

E.G. Elev (ft)	660.20	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.13	Wt. n-Val.		0.059	0.106
W.S. Elev (ft)	660.06	Reach Len. (ft)	127.17	127.17	127.17
Crit W.S. (ft)	653.49	Flow Area (sq ft)		1149.46	0.05
E.G. Slope (ft/ft)	0.000962	Area (sq ft)		1199.92	0.05
Q Total (cfs)	3344.00	Flow (cfs)		3344.00	0.01
Top Width (ft)	141.43	Top Width (ft)		141.21	0.22
Vel Total (ft/s)	2.91	Avg. Vel. (ft/s)		2.91	0.10
Max Chl Dpth (ft)	10.06	Hydr. Depth (ft)		8.44	0.23
Conv. Total (cfs)	107822.8	Conv. (cfs)		107822.6	0.2
Length Wtd. (ft)	127.17	Wetted Per. (ft)		161.01	0.44
Min Ch El (ft)	650.00	Shear (lb/sq ft)		0.43	0.01
Alpha	1.00	Stream Power (lb/ft s)	499.23	0.00	0.00
Frctn Loss (ft)	0.13	Cum Volume (acre-ft)	37.22	31.47	60.88
C & E Loss (ft)	0.00	Cum SA (acres)	7.85	4.05	16.05

neglect.
Make part of
Main channel

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Warning:	For the final momentum answer at the bridge, the upstream energy was computed lower than the downstream energy.
	This is not physically possible, the momentum answer has been disregarded.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

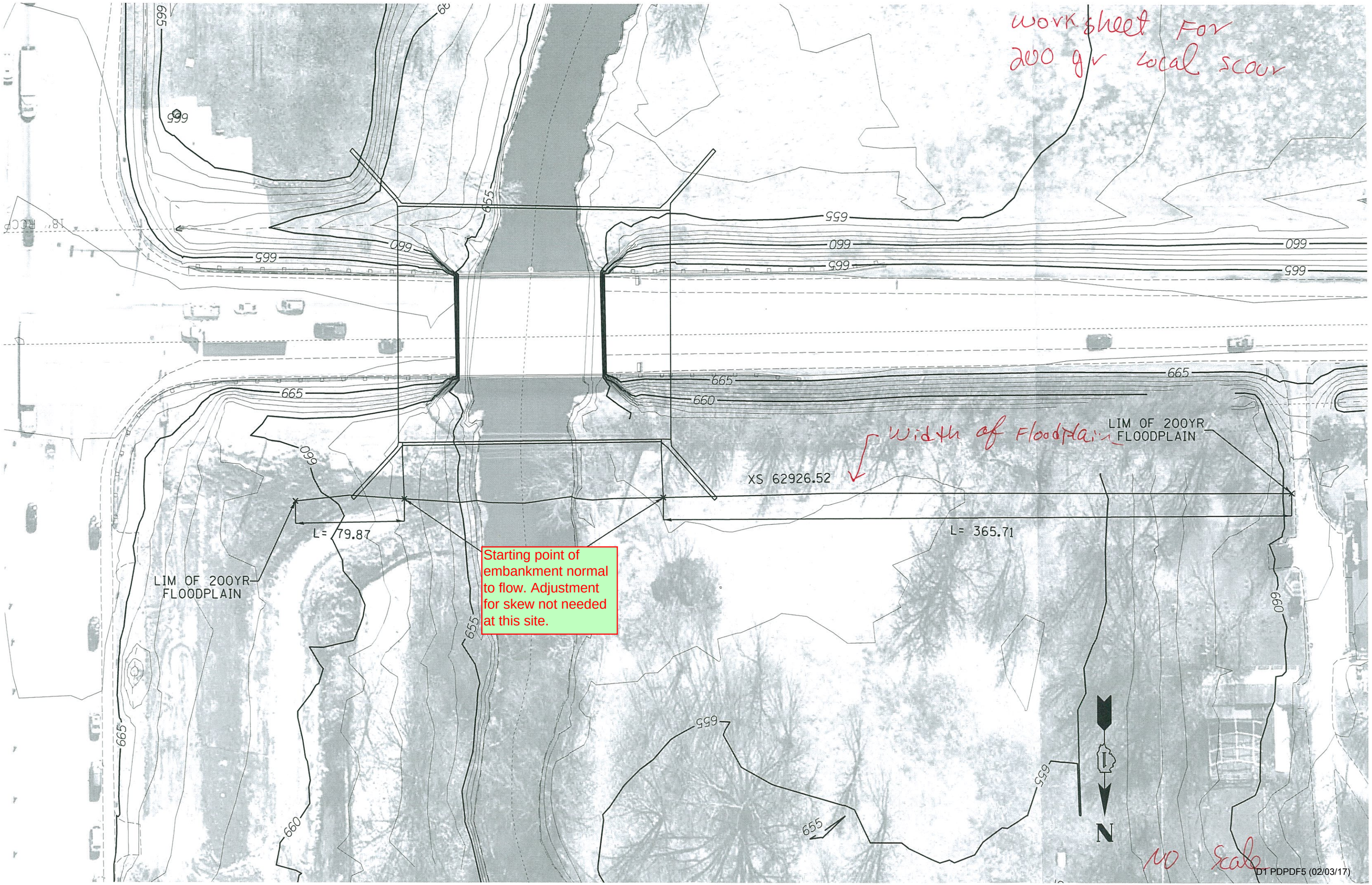
Plan: PR Blackberry Creek Main before A RS: 62823.34BR U Profile: Q200

	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(ft)	(ft)	(cfs)	(sq ft)	(ft)	Conv	Depth(ft)	(ft/s)	(lb/sq ft)	(lb/ft s)
1	Chan	-64.58	-52.52	38.36	29.82	12.21	1.15	2.73	1.29	0.15	0.19
2	Chan	-52.52	-40.47	275.00	100.12	13.14	8.22	8.30	2.75	0.46	1.26
3	Chan	-40.47	-28.41	267.70	121.32	22.12	8.01	10.06	2.21	0.33	0.73
4	Chan	-28.41	-25.41	0.00	28.44	12.89	0.00	10.06	0.00	0.13	0.00
5	Chan	-25.41	-12.41	432.63	130.83	13.00	12.94	10.06	3.31	0.60	2.00
6	Chan	-12.41	0.59	432.63	130.83	13.00	12.94	10.06	3.31	0.60	2.00
7	Chan	0.59	13.59	432.63	130.83	13.00	12.94	10.06	3.31	0.60	2.00
8	Chan	13.59	26.59	432.63	130.83	13.00	12.94	10.06	3.31	0.60	2.00
9	Chan	26.59	39.59	295.21	130.83	23.06	8.83	10.06	2.26	0.34	0.77
10	Chan	39.59	42.59	0.00	22.01	12.25	0.00	10.06	0.00	0.11	0.00
11	Chan	42.59	57.17	423.04	137.73	15.29	12.65	9.45	3.07	0.54	1.66
12	Chan	57.17	65.17	236.14	56.51	8.00	7.06	7.06	4.18	0.42	1.77
13	Chan	65.17	78.75	78.05	49.82	15.18	2.33	3.67	1.57	0.20	0.31
14	ROB	78.75	79.01	0.01	0.05	0.44	0.00	0.20	0.11	0.01	0.00

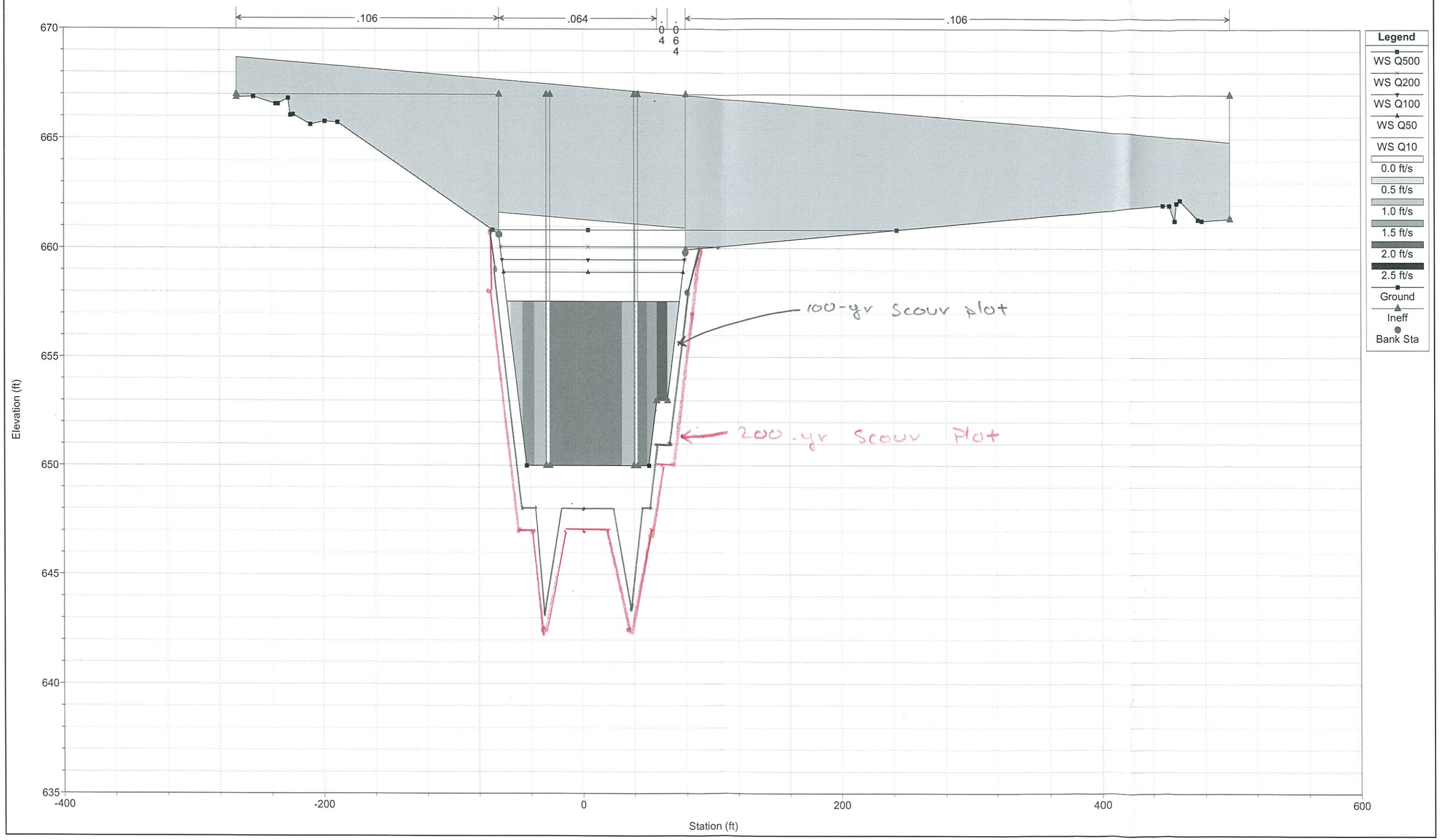
Max Pier

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Warning:	For the final momentum answer at the bridge, the upstream energy was computed lower than the downstream energy.
	This is not physically possible, the momentum answer has been disregarded.
Note:	Manning's n values were composited to a single value in the main channel.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.


Worksheet For
200 yr Local scour
Width of Floodplain
LIM OF 200YR
FLOODPLAIN
XS 62926.52
L= 79.87
L= 365.71
Starting point of embankment normal to flow. Adjustment for skew not needed at this site.
LIM OF 200YR
FLOODPLAIN
665
660
655
N
No Scale
D1 PDPDF5 (02/03/17)

Blackberry Creek_Design Model Plan: Proposed 4/2/2016



D1 PDPDF5 (02/03/17)

Scour Summary

Existing or Proposed Structure (circle one)

Structure Number: 047-0029

Structure Type

☑ **Bridge:** Number of Spans: 2@ 43.25' ea. (note span length; ex 1 @ 60' or 3 @ 60'-90'-60')

Number of Piers*: 1.

Type and width of each pier (feet): 2' Round Nose

Note: * If number of piers is not zero then attach pier scour calculations and summary data

Abutment Type: Open*, Closed, Closed with Wing Walls (Circle one)

Note: *If structure has open abutments, then the total scour does not need to include abutment scour.

☐ **Bottomless Culvert** (Three Sided): Width (feet):

Height (feet):

Wing Walls: Yes or No (circle one)

Describe source of Median Bed Size (D_{50}) estimate used in Phase I scour evaluation:

Boring Logs in Microfilm Show Silty-Sand Soil

Median Bed Size used in scour evaluation (Identify Units): D_{50} = 0.3mm

= 0.00098425 FT

Scour Summary

Existing or Proposed Structure (circle one)

Structure Number: 047-0029

Attach a brief narrative/summary of noting key findings such as the following:

Design Scour Event (such as 10-yr, 50-yr or 100-yr): 100-yr Design

- ✓ Attach Total Scour Plot
- ✓ Superimpose scour check onto total scour plot

  Scour check event (typically 200-yr event): 200-yr Check

- ✓ On plot identify elevation of bed before scour
- ✓ Add any other relevant notes
- Does the use of open abutments allow total scour to be used for design to be reduced: Yes or No*

  Note: *If Yes, then the total scour does not need to include abutment scour.

  If Yes, does the total scour plot reflect and note this adjustment: Yes or No N/A

- ✓ Include a summary table of the computed scour depths

Note: Design Scour Event and Extreme Event II are discussed in the November 7, 2014 All Bridge Designers (ABD) memorandum 14.2

Identify critical scour depths below and in narrative: (identify total scour and components such as contraction, pier...)

Summary: (100 yr Design / 200 yr check)

Contraction = 8.40' / 9.98'

Pier = 3.84' / 4.03' => Cont. + Pier = 12.24' / 14.01'

(L) Abut = 8.96' / 7.86' => Cont + (L) = 17.36' / 17.85'

(R) Abut = 21.22' / 23.77' => Cont + (R) = 29.62' / 33.75'

NCHRP = 11.47' / 13.10'

☑ Existing ☐ Proposed Flood Event: 100 (years) (Design)

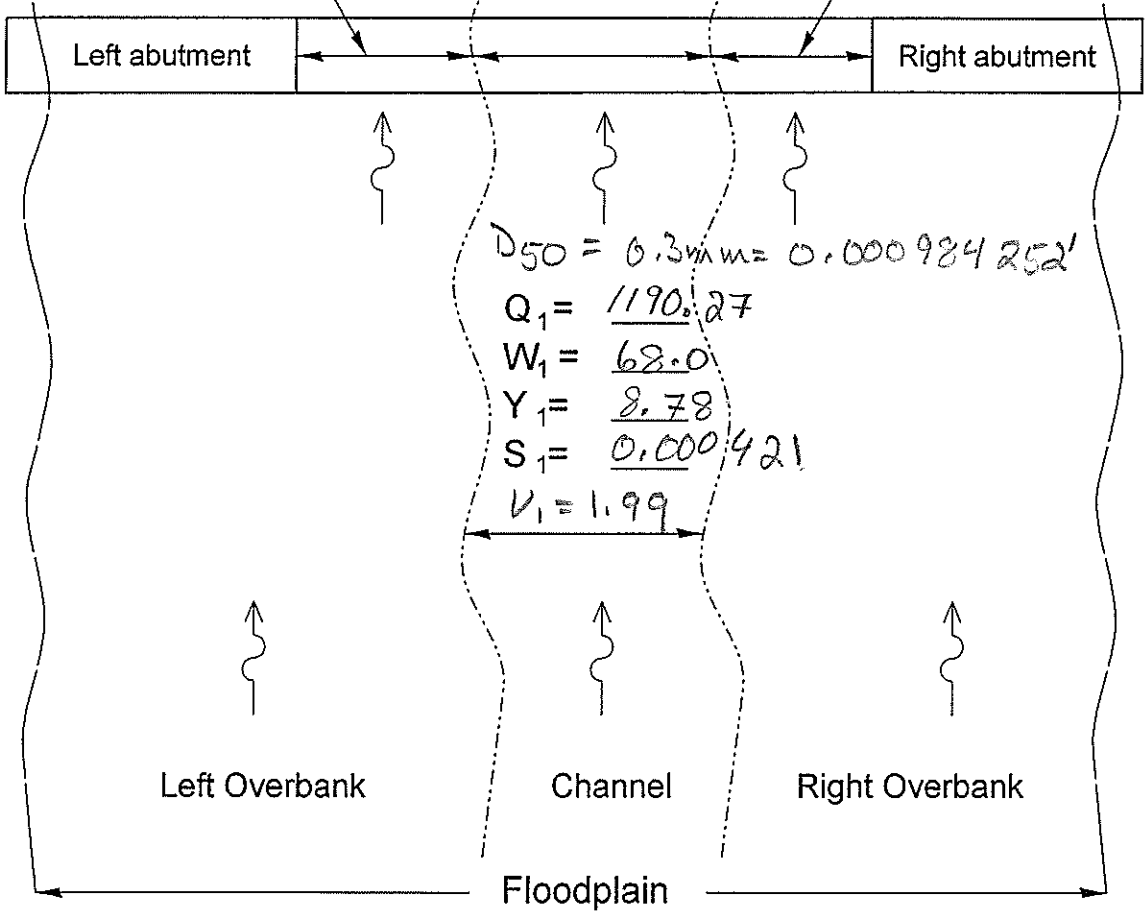
Check bed condition for contraction scour:

Left overbank	Channel	Right overbank
☐ Live bed	☑ Live bed	☐ Live bed
☐ Clear water	☐ Clear water	☐ Clear water
☑ N/A (No flow)		☑ N/A (No flow)

Q_L = N/A
W_{tot} =
W_{piers} =
W =
Y_{0L} =

Q_{2C} = 2808.0
W_{tot} = 83.0
W_{piers} = 2'
W_2 = 81.0
Y_{0C} = 7.82

Q_R = N/A
W_{tot} =
W_{piers} =
W =
Y_{0R} =



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Contraction Scour Data Sheet	ROUTE: US30
		WATERWAY: Rock Creek
		COUNTY: Kane
		STRUCTURE NUMBER: 047-0029

☑ Existing ☐ Proposed Flood Event: 100 (years)

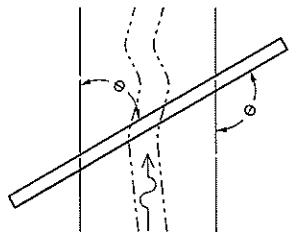
Check method being used for abutment scour:

☑ HIRE Equation* (Right) ☑ Froelich's Equation (Left)

If Item does not apply, write "N/A"

Not to be used for NCHRP 24-20 Approach

*If L/y < 25 HIRE Equation does not apply



Θ = 0 ° Left abutment Direction: N/A

Θ = 0 ° Right abutment Direction: N/A

Direction: Upstream , Downstream or Perpendicular
Θ < 90° if embankment points downstream
Θ > 90° if embankment points upstream
Θ = 90° if embankment is perpendicular to floodplain

L_L = 70.55
V_{1L} = 2.09
y_{1L} = 5.33
L/y_{1L} = 13.24 < 25

Y_{MAX} = 9.22
V_{MAX} = 3.64

L_R = 392.36
V_{1R} = 3.07
y_{1R} = 5.83
L/y_{1R} = 67.30 > 25

Left abutment		Right abutment
Q_{eL} = 241.47		Q_{eR} = N/A
A_{eL} = 304.07		A_{eR} =
V_{eL} = 0.794		V_{eR} =
L = 70.55		L =
y_{aL} = 4.31		y_{aR} =
L = 70.55 (ft)		L = ____ (ft)
L' = 55.36 (ft)		L' = ____ (ft)

Left Overbank | Channel | Right Overbank

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Local Scour Data Sheet For Froelich's or HIRE Equations	ROUTE: US30
		WATERWAY: Blackberry
		COUNTY: Kane
		STRUCTURE NUMBER: 047-0029

☑ Existing ☐ Proposed Flood Event: 100 (years)

Structure Type:

☑ Bridge: # of Spans / Piers 2 / 1

☐ Bottomless Culvert / 3-Sided: Span ____ ft

V_{2L} = N/A
A_{2L} = ____
Q_{2L} = ____
Y_{2L} = ____
q_{2fL} = ____

Set back distance SB_L = ____

V_{2C} = N/A
A_{2C} = N/A
Q_{2C} = 2802
Y_{2C} = 7.92
W_{2C} = 83.12
q_{2C} = 33.78

V_{2R} = N/A
A_{2R} = ____
Q_{2R} = ____
Y_{2R} = ____
q_{2fR} = ____

Set back distance SB_R = ____

Left abutment | Right abutment

Projected lenght of embankment L_L = 70.55

Projected lenght of embankment L_R = 397.36

Left floodplain width, B_{fL} = 75.24

Right floodplain width, B_{fR} = 400.5

L_L/B_{fL} = 0.94 { ☑ Live bed ☐ Clear water

L_R/B_{fR} = 0.98 { ☑ Live bed ☐ Clear water

V_{1L} = N/A
A_{1L} = ____
Q_{1L} = ____
Y_{1L} = ____
W_{1L} = ____
q_{1fL} = ____

V_{1C} = N/A
A_{1C} = N/A
Q_{1C} = 119027
Y_{1C} = 2.72
W_{1C} = 68
q_{1C} = 17.50

V_{1R} = N/A
A_{1R} = ____
Q_{1R} = ____
Y_{1R} = ____
W_{1R} = ____
q_{1fR} = ____

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	NCHRP 24-20 Abutment Scour Approach, Total Scour at an Abutment	ROUTE: US 30 WATERWAY: Blackberry COUNTY: Kane STRUCTURE NUMBER: 047-0029

CALCULATIONS

	BY	DATE
COMPUTED	JJT	2/3/16
CHECKED		

ROUTE US30
LIMITS 0/ Blackberry Cr.
DESCRIPTION scour sample calcs

SHEET NO. 1
TOTAL NO. 5

Contraction Scour

$V_c = 11.17\, g^{1/6}\, D_{50}^{1/3}$

$= 11.17 (8.78)^{1/6} (0.000984252)^{1/3}$

$= 1.596$ FT/SEC

$V = 1.99$ FT/SEC $> V_c$ ∴ Live Bed

$V^* = \sqrt{gyS} = \sqrt{(32.2)(8.78)(0.000421)}$

$= 0.345$

$\omega = 0.04$ mm/s $\times (3.28$ FT/SEC$) = 0.1312$ FT/SEC

$V^* = 2.63$

$\Rightarrow K_1 = 0.69$

$y_2 = y_1 \left(Q_2/Q_1\right)^{6/7} \left(\omega_1/\omega_2\right)^{K_1}$

$= 8.78 \left(\frac{2808}{1190.27}\right)^{6/7} \left(68/81.12\right)^{0.69}$

$= 16.22$

$y_s = y_2 - y_0 = 16.22 - 7.82 = \boxed{8.40 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US30
LIMITS @ Blackberry Ck
DESCRIPTION Scour Sample calcs

SHEET NO. 2
TOTAL NO. 5

Pier Scour

$$y_s/a = 2.0\ K_1\ K_2\ K_3 \left(y_1/a\right)^{0.35} F_r^{0.43}$$

$$F_r = V_1/\sqrt{g\,y_1} = 3.64/\sqrt{(32.2)(9.22)} = 0.211$$

$$y_s/a = (2)(1)(1)(1.1)\left(9.22/2\right)^{0.35}(0.211)^{0.43}$$

$$y_s/a = 1.924 \text{ FT}$$

$$y_s = (2)(1.924) = \boxed{3.84} < 2.4a \checkmark$$ (Eq. 7.2 check)

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US 30
LIMITS @ Blackberry Ck
DESCRIPTION Scour Sample calcs.

SHEET NO. 3
TOTAL NO. 5

From Flow Dist. @ XS 62926.52

EFF F/P Flow From ≈ 99.64 → 155.00 (highlighted)

∴ L' = 55.36'

Ae = 24.97 + 26.70 + 28.36 + 29.38 + 30.26 + 31.13 + 32.01 + 32.88 + 33.75 + 34.63

Ae = 304.07 SF

Qe = 17.29 + 19.33 + 21.38 + 22.69 + 23.83 + 24.99 + 26.17 + 27.37 + 28.59 + 29.83

Qe = 241.47 CFS

Ve = Qe / Ae = 241.47 / 304.07 = 0.794 FT/sec

y_{AL} = Ae / L = 304.07 SF / 70.55 FT = 4.31 FT

Left Abut. use Froelich's Eq.

$y_s / y_a = 2.27\, K_1 K_2 \left(L'/y_a\right)^{0.43} \left(F_v\right)^{0.61} + 1$ $K_1 = 0.82$, $K_2 = 1.0$ ($\theta = 0°$)

$F_v = V_e / (g\, y_a)^{1/2} = 0.794 / [(32.2)(4.31)]^{1/2} = 0.0674$

$y_s / y_a = (2.27)(0.82)(1.0)\left(55.36'/4.31'\right)^{0.43}(0.0674)^{0.61} + 1$

$y_s / y_a = 2.08' \Rightarrow$ $\boxed{y_s = (2.08)(4.31) = 8.96 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US 30
LIMITS of Blackberry Ck.
DESCRIPTION Sample Scour Calcs

SHEET NO. 4
TOTAL NO. 5

For Right Abut use HIRE

$y_s = 4 y_1 F_v^{0.33} \left(K_1/0.55\right) K_2$; $K_1 = 0.82$, $K_2 = 1.0$ $(\theta = 0°)$

$F_v = 3.07/\sqrt{32.2\ 5.83} = 0.224$

$y_s = 4(5.83)(0.224)^{0.33}\left(0.82/0.55\right)(1)$

$\boxed{y_s = 21.22 \text{ FT}}$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	2/3/16
CHECKED		

ROUTE US30
LIMITS @ Blackberry Ck.
DESCRIPTION Sample scour calc.

SHEET NO. 5
TOTAL NO. 5

NCHRP method

(L) L = 70.55' BS = 75.24'
$L/BS = 0.94$
∴ Live Bed

(R) L = 392.36' BS = 400.5'
$L/BS = 0.98$
∴ Live Bed

For Both Abutments:

$Q_{2c} = 2808$ cfs $W_2 = 83.12$ FT ⇒ $q_{2c} = 33.78$

$Q_1 = 1190.27$ cfs (channel only) $W_1 = 68$ FT (channel only) ⇒ $q_1 = 17.50$

$y_c = y_1 \left(q_{2c}/q_1\right)^{6/7} = 8.78 \left(\frac{33.78}{17.50}\right)^{6/7} = 15.43$ FT

$y_{max} = \alpha_A y_c$; $\alpha_A \approx 1.25$ (Fig. 8.10)

$y_{max} = (1.25)(15.43) = 19.29$ FT

$y_s = y_{max} - y_o = 19.29 - 7.82 = \boxed{11.47 \text{ FT}}$

Summary:

Cont: 8.40 FT

Pier: 3.84 FT ⇒ Cont + Pier = 12.24 FT

(L) Abut = 8.96 FT ⇒ (L) Abut + Cont = 17.36

(R) Abut = 21.22 FT ⇒ (R) Abut + Cont = 29.62 FT

NCHRP = 11.47 FT

Plan: EX Blackberry Creek Main before A RS: 62823.34BR U Profile: Q100

E.G. Elev (ft)	659.74	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.29	Wt. n-Val.		0.064	
W.S. Elev (ft)	659.45	Reach Len. (ft)	55.50	55.50	55.50
Crit W.S. (ft)	654.88	Flow Area (sq ft)		650.21	
E.G. Slope (ft/ft)	0.003334	Area (sq ft)		650.21	
Q Total (cfs)	2808.00	Flow (cfs)		2808.00	
Top Width (ft)	83.12	Top Width (ft)		83.12	
Vel Total (ft/s)	4.32	Avg. Vel. (ft/s)		4.32	
Max Chl Dpth (ft)	9.27	Hydr. Depth (ft)		7.82	
Conv. Total (cfs)	48631.2	Conv. (cfs)		48631.2	
Length Wtd. (ft)	55.50	Wetted Per. (ft)		112.46	
Min Ch El (ft)	650.18	Shear (lb/sq ft)		1.20	
Alpha	1.00	Stream Power (lb/ft s)	676.72	0.00	0.00
Frctn Loss (ft)	0.20	Cum Volume (acre-ft)	32.58	27.08	51.87
C & E Loss (ft)	0.01	Cum SA (acres)	7.70	3.78	15.77

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: EX Blackberry Creek Main before A RS: 62823.34 Profile: Q100

E.G. US. (ft)	659.78	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	659.50	E.G. Elev (ft)	659.74	659.53
Q Total (cfs)	2808.00	W.S. Elev (ft)	659.45	659.22
Q Bridge (cfs)	2808.00	Crit W.S. (ft)	654.88	655.12
Q Weir (cfs)		Max Chl Dpth (ft)	9.27	8.99
Weir Sta Lft (ft)		Vel Total (ft/s)	4.32	4.51
Weir Sta Rgt (ft)		Flow Area (sq ft)	650.21	622.51
Weir Submerg		Froude # Chl	0.25	0.27
Weir Max Depth (ft)		Specif Force (cu ft)	3007.65	2792.52
Min El Weir Flow (ft)	666.71	Hydr Depth (ft)	7.82	7.23
Min El Prs (ft)	663.64	W.P. Total (ft)	112.46	110.95
Delta EG (ft)	0.32	Conv. Total (cfs)	48631.2	45637.2
Delta WS (ft)	0.36	Top Width (ft)	83.12	86.25
BR Open Area (sq ft)	974.02	Frctn Loss (ft)	0.20	0.07
BR Open Vel (ft/s)	4.51	C & E Loss (ft)	0.01	0.00
Coef of Q		Shear Total (lb/sq ft)	1.20	1.33
Br Sel Method	Energy only	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: EX Blackberry Creek Main before A RS: 62926.52 Profile: Q100

E.G. Elev (ft)	659.85	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.	0.106	0.064	0.106
W.S. Elev (ft)	659.82	Reach Len. (ft)	53.09	56.86	49.22
Crit W.S. (ft)	655.05	Flow Area (sq ft)	421.37	597.34	1743.57
E.G. Slope (ft/ft)	0.000421	Area (sq ft)	421.37	597.34	1743.57
Q Total (cfs)	2808.00	Flow (cfs)	302.66	1190.27	1315.07
Top Width (ft)	584.35	Top Width (ft)	106.54	68.00	409.81
Vel Total (ft/s)	1.02	Avg. Vel. (ft/s)	0.72	1.99	0.75
Max Chl Dpth (ft)	9.88	Hydr. Depth (ft)	3.95	8.78	4.25
Conv. Total (cfs)	136859.0	Conv. (cfs)	14751.1	58012.6	64095.2
Length Wtd. (ft)	54.87	Wetted Per. (ft)	106.77	69.82	410.58
Min Ch El (ft)	649.94	Shear (lb/sq ft)	0.10	0.22	0.11
Alpha	1.94	Stream Power (lb/ft s)	646.00	0.00	0.00
Frctn Loss (ft)	0.04	Cum Volume (acre-ft)	32.85	28.28	53.27
C & E Loss (ft)	0.03	Cum SA (acres)	7.78	3.94	16.25

Errors Warnings and Notes

Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, energy was used.

Plan: EX Blackberry Creek Main before A RS: 62823.34BR U Profile: Q100

	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(ft)	(ft)	(cfs)	(sq ft)	(ft)	Conv	Depth(ft)	(ft/s)	(lb/sq ft)	(lb/ft s)
1	Chan	177.85	186.24	0.00	0.01	0.00	0.00	4.07	0.00	0.83	0.00
2	Chan	186.24	196.64	165.71	55.42	15.21	5.90	5.33	2.99	0.76	2.27
3	Chan	196.64	207.05	412.74	82.37	10.42	14.70	7.92	5.01	1.65	8.24
4	Chan	207.05	217.45	481.24	90.39	10.44	17.14	8.69	5.32	1.80	9.60
5	Chan	217.45	227.85	341.65	94.60	19.56	12.17	9.09	3.61	1.01	3.64
6	Chan	227.85	229.85					→ Pier		0.00	0.00
7	Chan	229.85	240.28	350.25	96.13	19.61	12.47	9.22	3.64	1.02	3.72
8	Chan	240.28	250.71	508.32	93.51	10.47	18.10	8.97	5.44	1.86	10.11
9	Chan	250.71	261.14	362.40	77.32	10.81	12.91	7.41	4.69	1.49	6.98
10	Chan	261.14	271.57	185.70	60.46	15.94	6.61	5.83	3.07	0.79	2.42

← LT Abut V & y

← RT Abut V & y

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: Ex-FJR Blackberry Creek Main before A RS: 62926.52 Profile: Q100

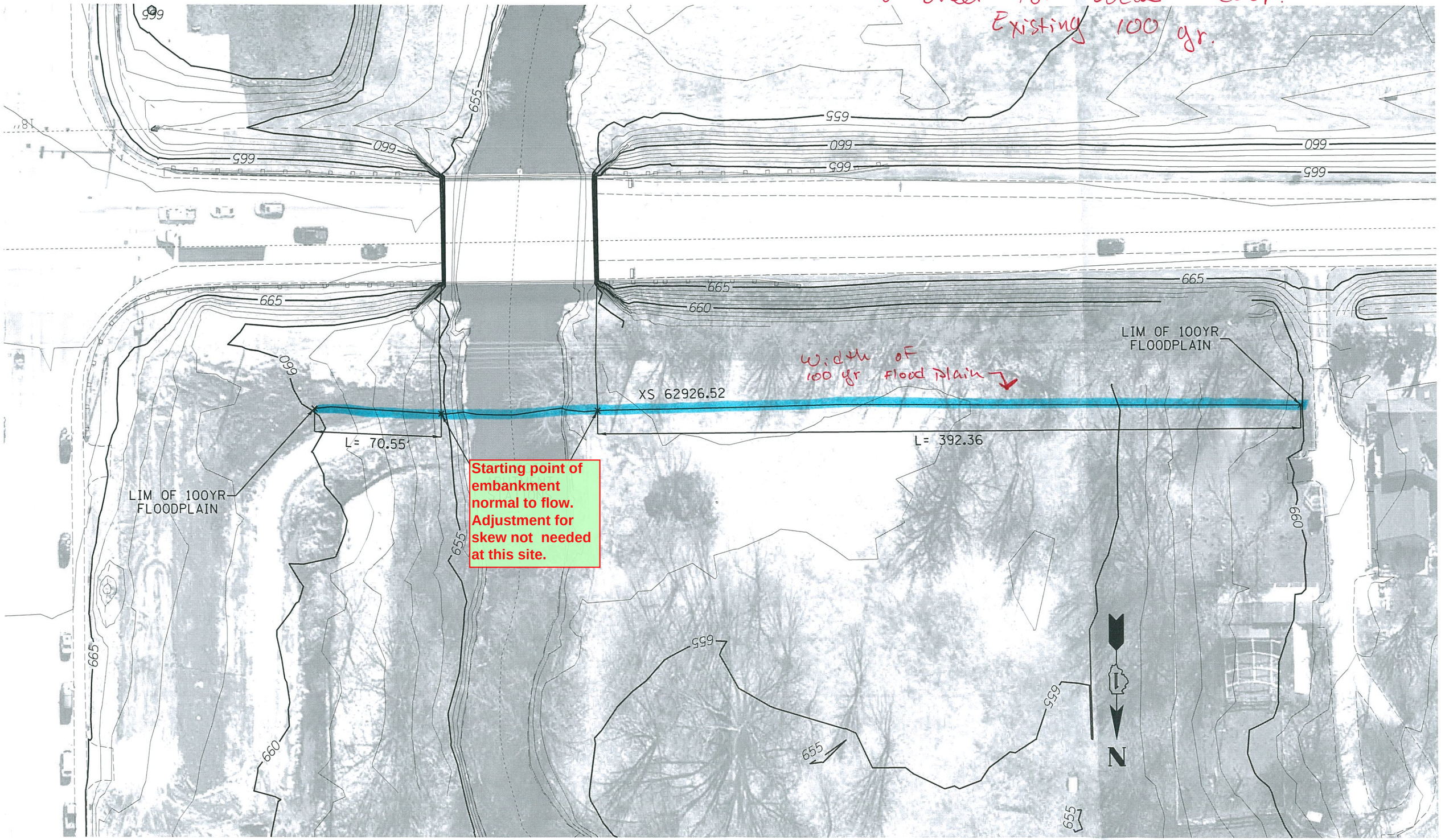
	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(ft)	(ft)	(cfs)	(sq ft)	(ft)	Conv	Depth(ft)	(ft/s)	(lb/sq ft)	(lb/ft s)
1	LOB	44.29	49.82	0.00	0.07	1.37	0.00	0.05	0.04	0.00	0.00
2	LOB	49.82	55.36	0.26	2.02	5.56	0.01	0.36	0.13	0.01	0.00
3	LOB	55.36	60.89	1.11	4.80	5.56	0.04	0.87	0.23	0.02	0.01
4	LOB	60.89	66.43	2.37	7.59	5.56	0.08	1.37	0.31	0.04	0.01
5	LOB	66.43	71.96	3.99	10.37	5.56	0.14	1.87	0.38	0.05	0.02
6	LOB	71.96	77.50	5.93	13.16	5.56	0.21	2.38	0.45	0.06	0.03
7	LOB	77.50	83.04	8.17	15.94	5.56	0.29	2.88	0.51	0.08	0.04
8	LOB	83.04	88.57	10.69	18.73	5.56	0.38	3.38	0.57	0.09	0.05
9	LOB	88.57	94.11	13.33	21.38	5.55	0.47	3.86	0.62	0.10	0.06
10	LOB	94.11	99.64	15.33	23.24	5.54	0.55	4.20	0.66	0.11	0.07
11	LOB	99.64	105.18	17.29	24.97	5.54	0.62	4.51	0.69	0.12	0.08
12	LOB	105.18	110.71	19.33	26.70	5.54	0.69	4.82	0.72	0.13	0.09
13	LOB	110.71	116.25	21.38	28.36	5.54	0.76	5.12	0.75	0.13	0.10
14	LOB	116.25	121.79	22.69	29.38	5.54	0.81	5.31	0.77	0.14	0.11
15	LOB	121.79	127.32	23.83	30.26	5.54	0.85	5.47	0.79	0.14	0.11
16	LOB	127.32	132.86	24.99	31.13	5.54	0.89	5.62	0.80	0.15	0.12
17	LOB	132.86	138.39	26.17	32.01	5.54	0.93	5.78	0.82	0.15	0.12
18	LOB	138.39	143.93	27.37	32.88	5.54	0.97	5.94	0.83	0.16	0.13
19	LOB	143.93	149.46	28.59	33.75	5.54	1.02	6.10	0.85	0.16	0.14
20	LOB	149.46	155.00	29.83	34.63	5.54	1.06	6.26	0.86	0.16	0.14
21	Chan	155.00	161.80	72.16	44.08	6.81	2.57	6.48	1.64	0.17	0.28
22	Chan	161.80	168.60	83.44	50.30	7.61	2.97	7.40	1.66	0.17	0.29
23	Chan	168.60	175.40	118.28	59.31	6.81	4.21	8.72	1.99	0.23	0.46
24	Chan	175.40	182.20	126.24	61.66	6.81	4.50	9.07	2.05	0.24	0.49
25	Chan	182.20	189.00	131.74	63.24	6.80	4.69	9.30	2.08	0.24	0.51
26	Chan	189.00	195.80	133.90	63.86	6.80	4.77	9.39	2.10	0.25	0.52
27	Chan	195.80	202.60	137.94	65.01	6.80	4.91	9.56	2.12	0.25	0.53
28	Chan	202.60	209.40	142.68	66.34	6.80	5.08	9.76	2.15	0.26	0.55
29	Chan	209.40	216.20	138.63	65.33	6.83	4.94	9.61	2.12	0.25	0.53
30	Chan	216.20	223.00	105.28	58.21	7.74	3.75	8.56	1.81	0.20	0.36
31	ROB	223.00	289.48	352.64	398.86	66.51	12.56	6.00	0.88	0.16	0.14
32	ROB	289.48	355.95	329.24	382.69	66.48	11.73	5.76	0.86	0.15	0.13
33	ROB	355.95	422.43	208.50	291.77	66.96	7.43	4.39	0.71	0.11	0.08
34	ROB	422.43	478.32	135.57	209.79	55.99	4.83	3.75	0.65	0.10	0.06
35	ROB	478.32	534.22	195.71	261.35	55.91	6.97	4.68	0.75	0.12	0.09
36	ROB	534.22	590.11	80.83	153.83	55.99	2.88	2.75	0.53	0.07	0.04
37	ROB	590.11	646.00	12.60	45.27	42.75	0.45	1.06	0.28	0.03	0.01

Large part of F/P carrying relative small flow (in-bk)

Errors Warnings and Notes

Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, energy was used.

Worksheet For Local Scour.
Existing 100 yr.



No Scale

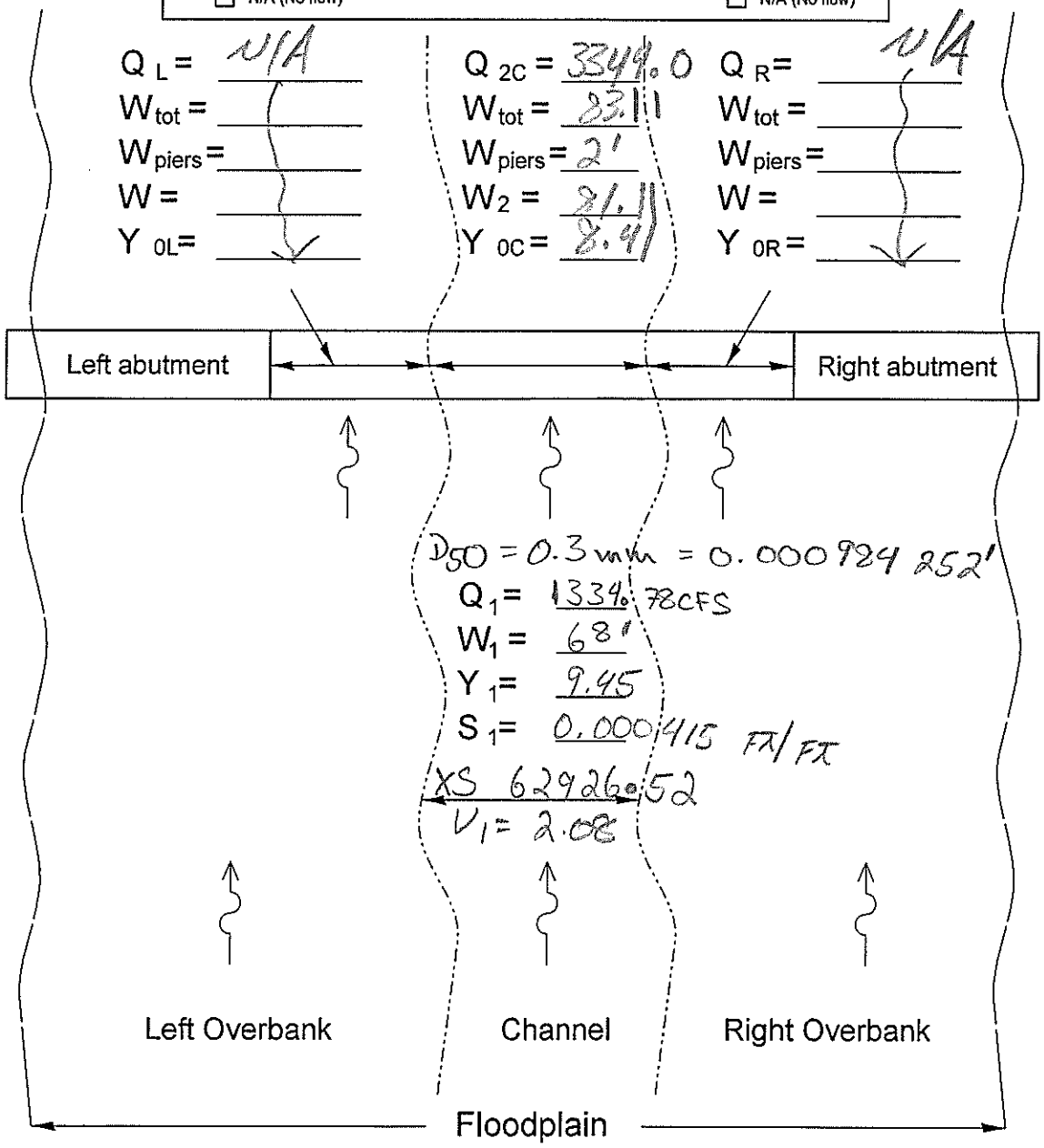
D1 PDPDF5 (02/03/17)

☑ Existing ☐ Proposed Flood Event: 200 (years)

Check bed condition for contraction scour:

Left overbank	Channel	Right overbank
☐ Live bed	☐ Live bed	☐ Live bed
☐ Clear water N/A	☐ Clear water	☐ Clear water N/A
☐ N/A (No flow)		☐ N/A (No flow)

Q_L = N/A	Q_{2C} = 3349.0	Q_R = N/A
W_{tot} =	W_{tot} = 83.11	W_{tot} =
W_{piers} =	W_{piers} = 2'	W_{piers} =
W =	W_2 = 81.11	W =
Y_{0L} =	Y_{0C} = 8.41	Y_{0R} =



Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Contraction Scour Data Sheet	ROUTE: US 30 WATERWAY: Blackberry Cr. COUNTY: Kane STRUCTURE NUMBER: 047-0029

☑ Existing ☐ Proposed Flood Event: 200 (years)

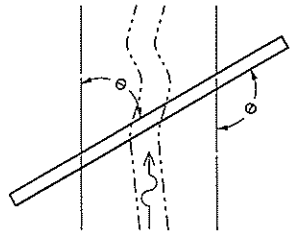
Check method being used for abutment scour:

☑ HIRE Equation* (Right) ☑ Froelich's Equation (Left)

If item does not apply, write "N/A"

Not to be used for NCHRP 24-20 Approach

*If L/y < 25 HIRE Equation does not apply



Θ = 0 ° Left abutment Direction: N/A

Θ = 0 ° Right abutment Direction: N/A

Direction: Upstream , Downstream or Perpendicular
Θ < 90° if embankment points downstream
Θ > 90° if embankment points upstream
Θ = 90° if embankment is perpendicular to floodplain

L_L = 112.99
V_{1L} = 3.33
y_{1L} = 5.91
L/y_{1L} = 19.12 < 25

Y_{MAX} = 9.80
V_{MAX} = 3.97

L_R = 403.72
V_{1R} = 3.41
y_{1R} = 6.41
L/y_{1R} = 62.98 > 25

Left abutment		Right abutment
Q_{eL} = 305.67		Q_{eR} = N/A
A_{eL} = 367.75		A_{eR} =
V_{eL} = 0.831		V_{eR} =
L = 112.99		L =
y_{aL} = 3.25		y_{aR} =
L= 112.99 (ft)		L= (ft)
L'= 60.59 (ft)		L'= (ft)

Left Overbank | Channel | Right Overbank

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	Local Scour Data Sheet For Froelich's or HIRE Equations	ROUTE: US 20
		WATERWAY: Rock Creek
		COUNTY: Knox
		STRUCTURE NUMBER: 047-0029

☑ Existing ☐ Proposed Flood Event: 200 (years)

Structure Type:

☑ Bridge: # of Spans / Piers 2 / 1

☐ Bottomless Culvert / 3-Sided: Span ____ ft

V_{2L} = N/A
A_{2L} = ____
Q_{2L} = ____
Y_{2L} = ____
q_{2fL} = ____

Set back distance SB_L = ____

V_{2C} = N/A
A_{2C} = N/A
Q_{2C} = 3349
Y_{2C} = 8.41
W_{2C} = 83.11
q_{2C} = 40.24

V_{2R} = N/A
A_{2R} = ____
Q_{2R} = ____
Y_{2R} = ____
q_{2fR} = ____

Set back distance SB_R = ____

Left abutment | Right abutment

Projected lenght of embankment L_L = 112.99

Projected lenght of embankment L_R = 403.72

Left floodplain width, B_{fL} = 115.39

Right floodplain width, B_{fR} = 421.68

L_L/B_{fL} = 0.979 { ☑ Live bed ☐ Clear water

L_R/B_{fR} = 0.957 { ☑ Live bed ☐ Clear water

V_{1L} = N/A
A_{1L} = ____
Q_{1L} = ____
Y_{1L} = ____
W_{1L} = ____
q_{1fL} = ____

V_{1C} = N/A
A_{1C} = N/A
Q_{1C} = 1334.78
Y_{1C} = 9.45
W_{1C} = 68
q_{1C} = 19.63

V_{1R} = N/A
A_{1R} = ____
Q_{1R} = ____
Y_{1R} = ____
W_{1R} = ____
q_{1fR} = ____

Floodplain

Note: Attach plot(s) that identifies and depicts the approach and constricted section, appropriate summary tables such as for velocity distribution. Identify how input parameters were obtained.

STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	NCHRP 24-20 Abutment Scour Approach, Total Scour at an Abutment	ROUTE: US 30
		WATERWAY: Blackwing Branch
		COUNTY: Henry
		STRUCTURE NUMBER: 100039

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/9/15
CHECKED		

ROUTE US30
LIMITS o/ Blackberry CK
DESCRIPTION Scour Sample Calcs

SHEET NO. 1
TOTAL NO. 5

Contraction Scour

$V_c = 11.17\, y^{1/6}\, D_{50}^{1/3}$

$= 11.17\,(9.45)^{1/6}\,(0.000984252)^{1/3}$

$\boxed{= 1.616 \text{ FT/sec}}$

$V = 2.08 > V_c$ ∴ Live Bed Condition

$V^* = \sqrt{g y S} = \left[(32.2)(9.45)(0.000415)\right]^{1/2}$

$= 0.3554$

$\omega = 0.04 \text{ m/s} \times \left(3.28 \frac{\text{FT}}{\text{sec}}\right) = 0.1312 \text{ FT/sec}$

$V^*/\omega = 2.71$

$\boxed{= K_1 = 0.69}$

$y_2 = y_1 \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{\omega_1}{\omega_2}\right)^{K_1} = 9.45 \left(\frac{3344}{1334.78}\right)^{6/7} \left(\frac{68}{81.11}\right)^{0.69}$

$y_2 = 18.39'$

$y_s = y_2 - y_0 = 18.39' - 8.41' = \boxed{9.98'}$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/9/15
CHECKED		

ROUTE US 30
LIMITS of Blackberry CK
DESCRIPTION Scour Sample Calcs

SHEET NO. 2
TOTAL NO. 5

Pier Scour

$$y_s/a = 2.0\, K_1 K_2 K_3 \left(y_1/a\right)^{0.35} Fr^{0.43}$$

$K_1 = 1.0$
$K_2 = 1.0 \quad (\theta = 0°)$
$K_3 = 1.1$

$$Fr = \frac{V_1}{\sqrt{g y_1}} = \frac{3.97}{\sqrt{(32.2)(9.8)}} = 0.223$$

$$y_s/a = (2)(1)(1)(1.1)\left(\frac{9.80}{2}\right)^{0.35}(0.223)^{0.43}$$

$$y_s = (2)(2.0126) = \boxed{4.03 \text{ FT}} < 2.4 \times a \quad \text{(eq. 7.2 check)}$$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/9/15
CHECKED		

ROUTE US 30
LIMITS @ Blackberry Ck.
DESCRIPTION Sample Scour calcs

SHEET NO. 3
TOTAL NO. 5

From Flow Dist. @ XS 62926.52

Effect F/P Flow From STA ~ 94.11 → 155 (Highlighted)

$\therefore L' = 60.89'$

$A_e = 26.91 + 28.65 + 30.38 + 32.04 + 33.06 + 33.93 + 34.81 + 35.68 + 36.56 + 37.43 + 38.30$

$A_e = 367.75$ SF

$Q_e = 19.23 + 21.34 + 23.53 + 25.72 + 27.11 + 28.32 + 29.55 + 30.80 + 32.06 + 33.35 + 34.66$

$Q_e = 305.67$ CFS

$V_e = Q_e / A_e = 305.67 / 367.75 = 0.831$ FT/SEC

$y_a = A_e / L = 367.75 / 112.99 = 3.25'$

(4) Abut: Use Froelich's Eq.

$$y_s / y_a = 2.27\, K_1 K_2 \left(L' / y_a\right)^{0.43} F_r^{0.61} + 1 \quad ; \quad K_1 = 0.82,\ K_2 = 1\ (\theta = 0°)$$

$$F_r = V_e / (g y_a)^{1/2} = 0.831 \text{ FT} / \sqrt{(32.2)(3.25)} = 0.0812$$

$$y_s / y_a = 2.27 (0.82)(1.0)\left(60.89 / 3.25\right)^{0.43} (0.0812)^{0.61} + 1$$

$$y_s / y_a = 2.42 \text{ FT} \Rightarrow y_s = (3.25)(2.42) = \boxed{7.865 \text{ FT}}$$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/9/15
CHECKED		

ROUTE US RTE 30
LIMITS @ Blackberry Cr.
DESCRIPTION Sample Scour Calcs.

SHEET NO. 4
TOTAL NO. 5

FOR Right Abutment USE HIRE:

$$y_s = 4 y_1 \, Fr^{0.33} \left(\frac{K_1}{0.55}\right) K_2 \qquad K_1 = 0.82 \quad K_2 = 1 \; (\theta = 0°)$$

$$Fr = V_1 / (g y_1)^{1/2} = 3.41 / (32.2 \times 6.41)^{1/2} = 0.237$$

$$y_s = (4)(6.41)(0.237)^{0.33} \left(\frac{0.82}{0.55}\right)(1)$$

$$\boxed{y_s = 23.77 \text{ FT}}$$

CALCULATIONS

	BY	DATE
COMPUTED	JJ	12/9/15
CHECKED		

ROUTE US 30
LIMITS o/ Blackberry CK
DESCRIPTION Sample Scour Calcs

SHEET NO. 5
TOTAL NO. 5

For NCHRP Method:

(L) $L = 117.99$ $B_f = 115.39$
$L/B_f = 0.98$
$\boxed{\therefore \text{ Live Bed}}$

(R) $L = 403.72$ $B_f = 421.68$
$L/B_f = 0.96$
$\boxed{\therefore \text{ Live Bed}}$

For Both Abut:

$Q_{2c} = 3344$ $w_{2c} = 83.11 \Rightarrow q_{2c} = 40.24$

$Q = 1334.78$ (channel only) $w_1 = 68' \Rightarrow q_1 = 19.63$ (channel only)

$y_c = y_1 \left(q_{2c}/q_1 \right)^{6/7} = 9.45 \left(40.24/19.63 \right)^{6/7} = 17.48$

$y_{max} = \alpha_4 y_c$; $\alpha_4 \approx 1.23$ (Fig. 8.10)

$y_{max} = (1.23)(17.48) = 21.51$

$y_s = y_{max} - y_0 = 21.51 - 8.41 = \boxed{13.10 \text{ ft}}$

Summary:

Cont: 9.98
Pier: 4.03 $\Rightarrow$ Cont + Pier = 14.01 ft
(L) Abut: 7.865 ft Cont + (L) = 17.845 ft
(R) Abut: 23.77 ft Cont + (R) = 33.75 ft
NCHRP: 13.10 ft

Plan: EX Blackberry Creek Main before A RS: 62926.52 Profile: Q200

E.G. Elev (ft)	660.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.	0.106	0.064	0.106
W.S. Elev (ft)	660.49	Reach Len. (ft)	53.09	56.86	49.22
Crit W.S. (ft)	655.33	Flow Area (sq ft)	495.06	642.50	2019.11
E.G. Slope (ft/ft)	0.000415	Area (sq ft)	495.06	642.50	2019.11
Q Total (cfs)	3344.00	Flow (cfs)	372.83	1334.78	1636.39
Top Width (ft)	605.07	Top Width (ft)	115.39	68.00	421.68
Vel Total (ft/s)	1.06	Avg. Vel. (ft/s)	0.75	2.08	0.81
Max Chl Dpth (ft)	10.55	Hydr. Depth (ft)	4.29	9.45	4.79
Conv. Total (cfs)	164109.1	Conv. (cfs)	18296.9	65505.2	80307.0
Length Wtd. (ft)	54.78	Wetted Per. (ft)	115.64	69.82	422.48
Min Ch El (ft)	649.94	Shear (lb/sq ft)	0.11	0.24	0.12
Alpha	1.88	Stream Power (lb/ft s)	646.00	0.00	0.00
Frctn Loss (ft)	0.05	Cum Volume (acre-ft)	37.57	30.61	62.99
C & E Loss (ft)	0.03	Cum SA (acres)	7.95	3.94	16.79

Errors Warnings and Notes

Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, energy was used.

Plan: EX Blackberry Creek Main before A RS: 62823.34BR U Profile: Q200

E.G. Elev (ft)	660.39	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.36	Wt. n-Val.		0.064	
W.S. Elev (ft)	660.03	Reach Len. (ft)	55.50	55.50	55.50
Crit W.S. (ft)	655.32	Flow Area (sq ft)		698.95	
E.G. Slope (ft/ft)	0.003819	Area (sq ft)		698.95	
Q Total (cfs)	3344.00	Flow (cfs)		3344.00	
Top Width (ft)	83.11	Top Width (ft)		83.11	
Vel Total (ft/s)	4.78	Avg. Vel. (ft/s)		4.78	
Max Chl Dpth (ft)	9.85	Hydr. Depth (ft)		8.41	
Conv. Total (cfs)	54108.4	Conv. (cfs)		54108.4	
Length Wtd. (ft)	55.50	Wetted Per. (ft)		114.80	
Min Ch El (ft)	650.18	Shear (lb/sq ft)		1.45	
Alpha	1.00	Stream Power (lb/ft s)	676.72	0.00	0.00
Frctn Loss (ft)	0.22	Cum Volume (acre-ft)	37.24	29.32	61.28
C & E Loss (ft)	0.01	Cum SA (acres)	7.85	3.78	16.28

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: EX Blackberry Creek Main before A RS: 62823.34 Profile: Q200

E.G. US. (ft)	660.44	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	660.09	E.G. Elev (ft)	660.39	660.15
Q Total (cfs)	3344.00	W.S. Elev (ft)	660.03	659.77
Q Bridge (cfs)	3344.00	Crit W.S. (ft)	655.32	655.58
Q Weir (cfs)		Max Chl Dpth (ft)	9.85	9.54
Weir Sta Lft (ft)		Vel Total (ft/s)	4.78	4.99
Weir Sta Rgt (ft)		Flow Area (sq ft)	698.95	670.12
Weir Submerg		Froude # Chl	0.27	0.28
Weir Max Depth (ft)		Specif Force (cu ft)	3523.53	3274.63
Min El Weir Flow (ft)	666.71	Hydr Depth (ft)	8.41	7.78
Min El Prs (ft)	663.64	W.P. Total (ft)	114.80	112.60
Delta EG (ft)	0.37	Conv. Total (cfs)	54108.4	51093.1
Delta WS (ft)	0.41	Top Width (ft)	83.11	86.23
BR Open Area (sq ft)	974.02	Frctn Loss (ft)	0.22	0.08
BR Open Vel (ft/s)	4.99	C & E Loss (ft)	0.01	0.00
Coef of Q		Shear Total (lb/sq ft)	1.45	1.59
Br Sel Method	Energy only	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: EX Blackberry Creek Main before A RS: 62823.34BR U Profile: Q200

	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(ft)	(ft)	(cfs)	(sq ft)	(ft)	Conv	Depth(ft)	(ft/s)	(lb/sq ft)	(lb/ft s)
1	Chan	177.85	186.24	0.00	0.01	0.00	0.00	4.66	0.00	1.09	0.00
2	Chan	186.24	196.64	204.95	61.49	15.79	6.13	5.91	3.33	0.93	3.09
3	Chan	196.64	207.05	495.96	88.47	10.42	14.83	8.51	5.61	2.02	11.35
4	Chan	207.05	217.45	572.40	96.49	10.44	17.12	9.28	5.93	2.20	13.08
5	Chan	217.45	227.85	396.57	100.71	20.15	11.86	9.68	3.94	1.19	4.69
6	Chan	227.85	229.85					→ Aer ←		0.00	0.00
7	Chan	229.85	240.28	406.03	102.24	20.20	12.14	9.80	3.97	1.21	4.79
8	Chan	240.28	250.71	602.64	99.63	10.47	18.02	9.55	6.05	2.27	13.73
9	Chan	250.71	261.14	438.89	83.44	10.81	13.12	8.00	5.26	1.84	9.68
10	Chan	261.14	271.57	226.55	66.49	16.53	6.77	6.41	3.41	0.96	3.27

Errors Warnings and Notes

Warning:	The Yarnell method gave an invalid answer. The upstream energy was less than the downstream energy. The
	program defaulted to the next valid (user selected) method. If the Yarnell method was the only one selected, the
	program will default to an energy based solution.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

Plan: Ex-FJR Blackberry Creek Main before A RS: 62926.52 Profile: Q200

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)
1	LOB	38.75	44.29	0.06	0.82	4.69	0.00	0.18	0.08	0.00	0.00
2	LOB	44.29	49.82	0.52	3.10	5.55	0.02	0.56	0.17	0.01	0.00
3	LOB	49.82	55.36	1.44	5.69	5.56	0.04	1.03	0.25	0.03	0.01
4	LOB	55.36	60.89	2.80	8.48	5.56	0.08	1.53	0.33	0.04	0.01
5	LOB	60.89	66.43	4.50	11.26	5.56	0.13	2.03	0.40	0.05	0.02
6	LOB	66.43	71.96	6.50	14.05	5.56	0.19	2.54	0.46	0.07	0.03
7	LOB	71.96	77.50	8.78	16.83	5.56	0.26	3.04	0.52	0.08	0.04
8	LOB	77.50	83.04	11.34	19.62	5.56	0.34	3.54	0.58	0.09	0.05
9	LOB	83.04	88.57	14.14	22.41	5.56	0.42	4.05	0.63	0.10	0.07
10	LOB	88.57	94.11	17.05	25.05	5.55	0.51	4.53	0.68	0.12	0.08
11	LOB	94.11	99.64	19.23	26.91	5.54	0.58	4.86	0.71	0.13	0.09
12	LOB	99.64	105.18	21.34	28.65	5.54	0.64	5.17	0.74	0.13	0.10
13	LOB	105.18	110.71	23.53	30.38	5.54	0.70	5.49	0.77	0.14	0.11
14	LOB	110.71	116.25	25.72	32.04	5.54	0.77	5.79	0.80	0.15	0.12
15	LOB	116.25	121.79	27.11	33.06	5.54	0.81	5.97	0.82	0.15	0.13
16	LOB	121.79	127.32	28.32	33.93	5.54	0.85	6.13	0.83	0.16	0.13
17	LOB	127.32	132.86	29.55	34.81	5.54	0.88	6.29	0.85	0.16	0.14
18	LOB	132.86	138.39	30.80	35.68	5.54	0.92	6.45	0.86	0.17	0.14
19	LOB	138.39	143.93	32.06	36.56	5.54	0.96	6.60	0.88	0.17	0.15
20	LOB	143.93	149.46	33.35	37.43	5.54	1.00	6.76	0.89	0.18	0.16
21	LOB	149.46	155.00	34.66	38.30	5.54	1.04	6.92	0.90	0.18	0.16
22	Chan	155.00	161.80	84.41	48.60	6.81	2.52	7.15	1.74	0.19	0.32
23	Chan	161.80	168.60	95.75	54.81	7.61	2.86	8.06	1.75	0.19	0.33
24	Chan	168.60	175.40	132.91	63.83	6.81	3.97	9.39	2.08	0.24	0.51
25	Chan	175.40	182.20	141.21	66.18	6.81	4.22	9.73	2.13	0.25	0.54
26	Chan	182.20	189.00	146.95	67.75	6.80	4.39	9.96	2.17	0.26	0.56
27	Chan	189.00	195.80	149.19	68.37	6.80	4.46	10.05	2.18	0.26	0.57
28	Chan	195.80	202.60	153.40	69.53	6.80	4.59	10.22	2.21	0.26	0.58
29	Chan	202.60	209.40	158.32	70.86	6.80	4.73	10.42	2.23	0.27	0.60
30	Chan	209.40	216.20	154.08	69.84	6.83	4.61	10.27	2.21	0.26	0.58
31	Chan	216.20	223.00	118.56	62.72	7.74	3.55	9.22	1.89	0.21	0.40
32	ROB	223.00	289.48	418.49	443.01	66.51	12.51	6.66	0.94	0.17	0.16
33	ROB	289.48	355.95	393.47	426.84	66.48	11.77	6.42	0.92	0.17	0.15
34	ROB	355.95	422.43	262.70	335.92	66.96	7.86	5.05	0.78	0.13	0.10
35	ROB	422.43	478.32	177.19	246.91	55.99	5.30	4.42	0.72	0.11	0.08
36	ROB	478.32	534.22	243.28	298.47	55.91	7.28	5.34	0.82	0.14	0.11
37	ROB	534.22	590.11	115.45	190.95	55.99	3.45	3.42	0.60	0.09	0.05
38	ROB	590.11	646.00	25.83	77.01	54.65	0.77	1.41	0.34	0.04	0.01

~2%

~2%

~2%

~2%

~2%

~2%

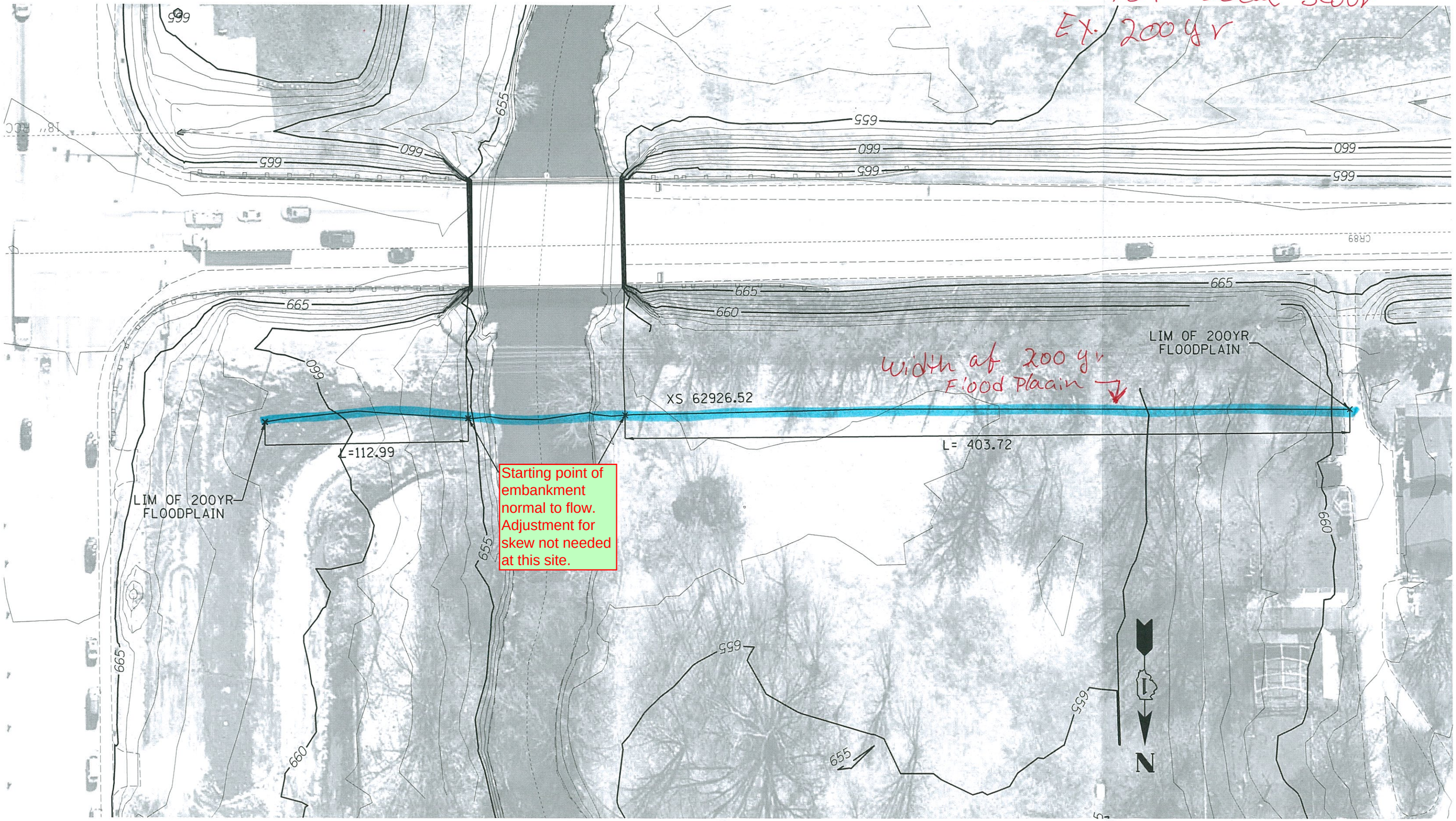
~2%

Large Portion Carrying rel. Small Portion of Q

Errors Warnings and Notes

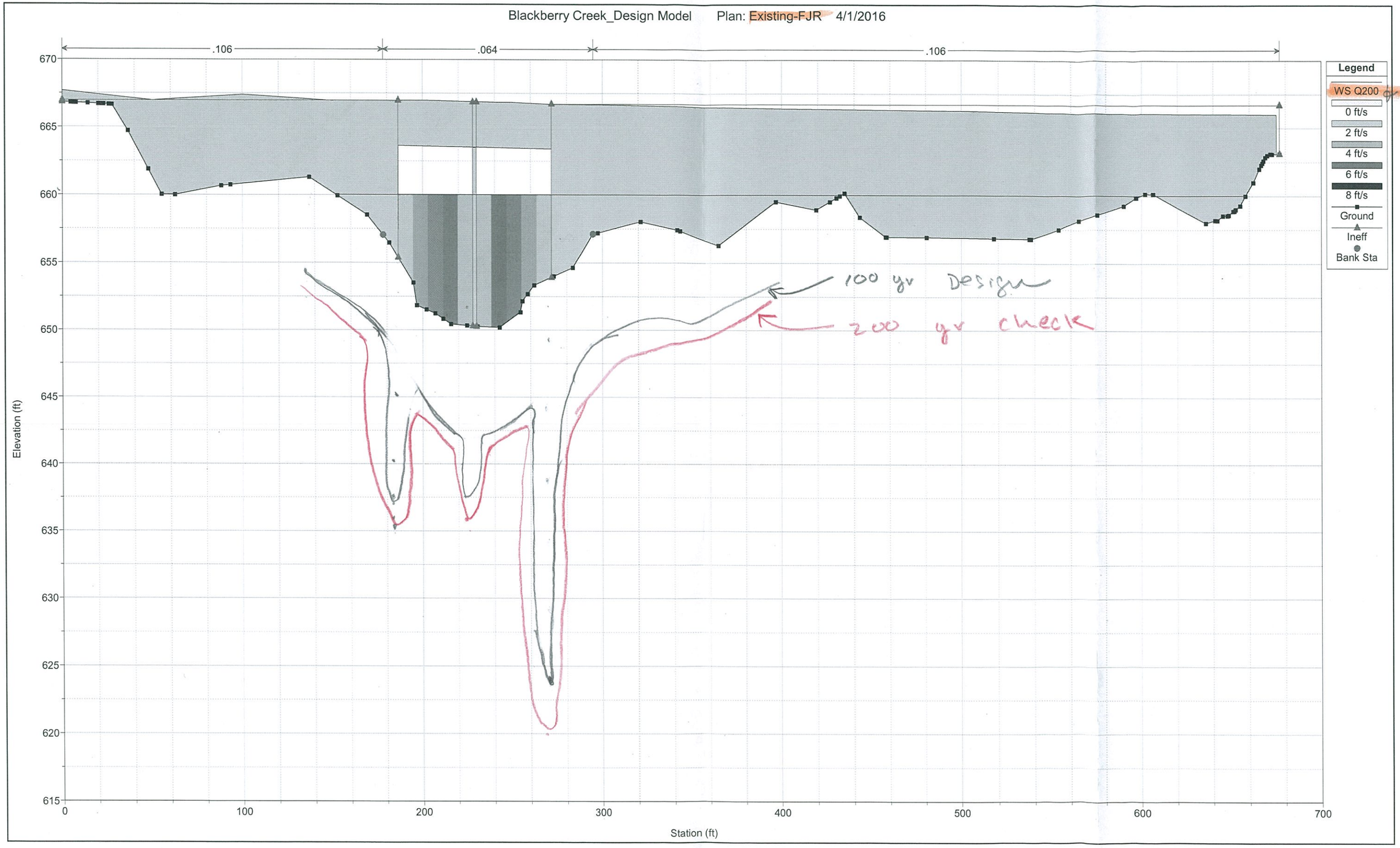
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4.
	This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, energy was used.

Worksheet For Local Scour
Ex. 200 yr



No Scale

D1 PDPDF5 (02/03/17)


Blackberry Creek_Design Model Plan: Existing-FJR 4/1/2016
.106
.064
.106
Legend
WS Q200 or Q100
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Ineff
Bank Sta
100 yr Design
200 yr check
Elevation (ft)
670
665
660
655
650
645
640
635
630
625
620
615
0
100
200
300
400
500
600
700
Station (ft)

Pre-worksheet version of US 30 over Blackberry Creek scour study for the 100-yr event

- **The summary table helps explain the results.**

- **For abutment scour, only the applicable method was used at each abutment.**

- **The spreadsheets clearly show what values were used along with the equations. However, the spreadsheets need to be submitted with the report in order to check the calculations. The values used/applied in each equation are identified on the model output or exhibits. Note the hand calculations done as part of the worksheet submittal yielded very similar results. Either hand calculations or spreadsheet calculations are acceptable.**

Updated: 2016/10/19

TABLE 4: Summary of Bridge Scour Analysis*

A. EXISTING CONDITION

Storm Frequency (Year)	Contraction Scour (CS)	Pier Scour (PS)	Abutment Scour (AS) using HIRE or Froehlich's Method		Total Pier Scour (TPS) (= CS + PS)	Total Abutment Scour (TAS)		
						HIRE or Froehlich's Method		NCHRP
			Left (ASL)	Right (ASR)		Left (TAS_L) (= CS + ASL)	Right (TAS_R) (= CS + ASR)	Left & Right are equal
10	3.27	3.44	6.51	12.91	6.71	9.78	16.18	8.74
50	6.63	4.07	8.60	19.23	10.70	15.23	25.86	10.47
100	8.12	4.31	9.43	22.11	12.43	17.55	30.23	11.45
200	9.63	4.54	19.27	25.02	14.17	28.90	34.65	12.87
500	11.99	4.87	10.98	29.15	16.86	22.97	41.14	14.97

B. PROPOSED CONDITION

Storm Frequency (Year)	Contraction Scour (CS)	Pier 1 Scour (PS)	Pier 2 Scour (PS)	Abutment Scour (AS) using HIRE or Froehlich's Method		Total Pier Scour (TPS) (= CS + PS) (Maximum)	Total Abutment Scour (TAS)		
							HIRE or Froehlich's Method		NCHRP
				Left (ASL)	Right (ASR)		Left (TAS_L) (= CS + ASL)	Right (TAS_R) (= CS + ASR)	Left & Right are equal
10	1.61	2.83	3.20	4.65	9.07	4.81	6.26	10.68	2.03
50	2.50	3.52	3.86	7.04	12.54	6.36	9.54	15.04	2.88
100	3.32	3.79	4.12	7.94	14.03	7.44	11.26	17.35	3.76
200	4.20	4.04	4.35	8.82	15.62	8.55	13.02	19.82	7.61
500	5.39	4.39	4.70	10.04	17.80	10.09	15.43	23.19	11.11

Note: *Recommended Scour Estimate*

1. CONTRACTION SCOUR -- Live Bed or Clear-Water?

Approach XS River Sta. 62926.52

Judgement:

Clear-water contraction scour wil Exist, **If V_c /V > 1**

Check: V_c/V= 0.80 Live Bed scour will exist, go to SHEET 1b_Contraction_Live bed

1). Judge: LIVE BED or CLEAR-WATER Contraction Scour?

A1) $$V_c = K_u\, y^{1/6}\, D^{1/3}$$ (Eq. 6.1)

(assuming D50 >= 0.2 mm)

Eq. 6.1, HEC. No. 18

Where:

V_c =	1.60	ft/sec			*(Critical Velocity above which bed material of Size D and smllaer will be transported, ft/s)*
V =	2.00	ft/sec			*(Mean Velocity of the Flow in the Main Channel or Overbank Area Upstream of the Bridge Opening, ft/s)*
y =	8.77	ft			*(Average Depth of flow Upstream of the Bridge, ft)*
D_{50} =	0.3	mm =	0.000984	ft	*(Particle size in a misture of which 50% are smaller, or Median diameter of bed material, ft) Note: a resonable lower limit of D50 = 0.2 mm can be applied to this equation. For smaller sizes, cohesion tends to increase Vc)*
D =	0.3	mm =	0.000984	ft	*(Particle size for Critical Velocity* ***V*** *$_c$, ft); Assuming D = D50, update if different.*
K_u =	11.17	(English Units) =	6.19	(SI Units)	

RESULTS:

V_c/V =	0.80	<=	**1.0**	**Live Bed Scour**	Applies!

Note:

Input Data	
Calculated Results	
Default/Constants	

1. CONTRACTION SCOUR

B. LIVE BED CONTRACTION SCOUR

B1) $$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1}$$ (Eq. 6.2) *Eq. 6.2, HEC. No. 18*

B2) $y_s = y_2 - y_o$ = (average contraction scour depth) (Eq. 6.3) *Eq. 6.3, HEC. No. 18*

Where:

y_s =	8.12	ft	*(Average Contraction Scour Depth, ft)*
y_1 =	8.77	ft	*(Average Depth in the Upstream Main Channel, ft)*
y_2 =	15.92	ft	*(Average Depth in the Contracted Section, ft)*
y_o =	7.8	ft	*(Existing Depth in the Contracted Section Before Scour, ft, See Note 7)*
Q_1 =	1192.63	ft^3/sec	*(Flow in the Upstream channel transporting sediment, ft^3/s)*
Q_2 =	2808	ft^3/sec	*(Flow in the Contracted channel, ft^3/s)*
W_1 =	68	ft	*(Bottom Width of the Upstream Main Channel that is Transporting Bed Material, ft)*
W_2 =	83	ft	*(Bottom Width of Main Channel in Contracted Section LESS Pier Width(s), ft)*

Exponent K1 Determination (below)

$$V_* = (\vartheta_o/\Delta)^{1/2} = (gy_1 S_1)^{1/2}$$

V* =	0.34	ft/s			*(Shear Velocity in the Upstream Section, ft/s)*
T =	0.13	ft/s =	0.04	m/s	*(Fall Velocity of Bed Material based on the D50, m/s (Fig. 6.8), then Multiply T in m/s by 3.28 to convert to English Unit)*
S_1 =	0.000421	ft/ft			*(Slope of Energy Grade Line of Main Channel, ft/ft)*
ϑ_o =	0.061282	lb/ft^2			*(Shear Stress on the Bed, lb/ft2)*
Δ =	1.94	$slugs/ft^3$			*(Density of Water, 1.94 slugs/ft3, or 1000 kg/m3)*
g =	32.2	ft/s^2			(Acceleration of Gravity, 32.2 ft/s^2, or 9.81 m/s^2)

Calculate K1:

V/T* =	2.63	
K_1 =	0.69	(K1 Exponent Determination)

K1 Exponent Determination Table (below)

V/T*	*K1*	*Mode of Bed Material Transport*
<0.50	*0.59*	*Mostly contracted bed material discharge*
0.50 to 2.0	*0.64*	*Some suspended bed material discharge*
> 2.0	*0.69*	*Mostly suspended bed material discharge*

CALCULATIONS

y_s =	8.12	ft	*(Average Contraction Scour Depth, ft)*
y_2 =	15.92	ft	*(Average Depth in the Contracted Section, ft)*

Note:

Input Data	
Calculated Results	
Default/Constants	

2. PIER SCOUR

B1) $$\frac{y_s}{a} = 2.0\, K_1\, K_2\, K_3 \left(\frac{y_1}{a}\right)^{0.35} Fr_1^{0.43}$$ (Eq. 7.3)

Eq. 7.3, HEC. No. 18

Where:

y_s =	4.31	ft		*(Scour Depth, ft)*
y_1 =	9.25	ft	*(Flow Dist Sta. 229.85-240.28) Sta. 62869.66*	*(Flow Depth directly Upstream of the Pier, ft)*
a =	2	ft		*(Pier Width, ft)*
L =	55	ft		*(Length of Pier, ft)*
V_1 =	4.74	ft/s	*(Flow Dist Sta. 229.85-240.28) Sta. 62869.66*	*(Mean Velocity of Flow Directly Upstream of the Pier, ft/s)*
Pier Nose Shape =	round			***Input Options:*** *a) square, b) round, c) circular, d) group of cylinders, e) sharp. INPUT e.g.,* ***square***
K_1 =	1		*(Fig. 7.3, Tab 7.1)*	*(Correction Factor for* ***Pier Nose Shape*** *from* ***Figure 7.3 and Table 7.1*** *)*
Skew Angle of Flow =	0	°	*= 0*	*(e.g. 0, 15, 30, 45, 90, etc. See Table 7.2 or Eqn. 7.4)*
K_2 =	1.00		*(Tab 7.2 or Eqn 7.4)*	*(Correction Factor for* ***Angle of Attack of Flow*** *from* ***Table 7.2 or Eqn. 7.4*** *)*
Bed Condition =	Small Dunes			***Input Options:*** *a) Clear-water scour; b) Plane Bed and Antidune flow; c) Small Dunes (10 > H >=2 ft); d) Medium Dunes (30>H>=10 ft); e) Large Dunes (H>=30 ft). e.g. Input:* ***Clear-water scour*** *.*
K_3 =	1.1		*(Tab 7.3)*	*(Correction Factor for* ***Bed Condition*** *from* ***Table 7.3*** *)*
g =	32.2	ft/s2		(Acceleration of Gravity, 32.2 ft/s^2, or 9.81 m/s^2)
Fr_1 =	0.27			*(Froude Number Directly Upstream of the Pier, Fr_1* $= V_1/(gy_1)^{1/2}$

CALCULATIONS

y_s =	**4.31**	ft	*(Scour Depth, ft)*
Fr_1 =	**0.27**		*(Froude Number Directly Upstream of the Pier, Fr_1* $= V_1/(gy_1)^{1/2}$

Note:

Input Data
Calculated Results
Default/Constants

3. LOCAL SCOUR - ABUTMENTS LEFT

Constraints:

Froehlich's Eqn, If L/Y_1 < 25

Check: L/Y1 = 6.96 Froehlich's Eqn. Works

A. Froehlich's Abutment Scour Equation

A1)

$$\frac{y_s}{y_a} = 2.27\, K_1\, K_2 \left(\frac{L'}{y_a}\right)^{0.43} Fr^{0.61} + 1$$

(Eq. 8.1)

Eq. 8.1, HEC. No. 18

WSE at bridge face = 659.43

GND Elev at toe of Left Abut = 655.35

y1 = 659.43 - 655.35 = 4.08

Where:

y_1 =	4.08	ft		*(Depth of Flow at the Abutment on the Overbank or in the Main Channel, ft)*
y_s =	9.43	ft		*(Scour Depth, ft)*
y_a =	3.81	ft		*(Average depth of flow on the floodplain (A_e/L'), ft)*
L' =	105.31	ft	XS 62926.52	*(Length of Active Flow Obstructed by the Embankment, ft) See L and L' Ex Sht 3 of 10*
L =	28.39	ft	XS 62869.66	*(Length of Embankment Projected Normal to the Flow, ft) See L and L' Ex Sht 3 of 10*
A_e =	401.02	ft2		*(Flow Area of the Approach Cross Section obstructed by the Embankment, ft2)*
Q_e =	292.09	ft^3/sec		*(Flow Obstructed by the Abutment and Approach Embankment, ft^3/s)*
V_e =	0.73	ft/s		*(= Q_e/A_e, ft/s)*
Fr =	0.066			*(Froude Number of Approach Flow Upstream Embankment, ft^3/s; = V_e/Sqrt(g*y_a))*
Abutment Shape =	Vertical-wall abutment with wing walls			***Input Options*** *: a) Vertical-wall abutment; b) Vertical-wall abutment with wing walls; c) Spill-through abutment. E.g. Vertical-wall abutment*
K_1 =	0.82			*Coefficient of Abutment Shape (Table 8.1);*
Θ =	90	°		*(Angle of Embankment to Flow, Θ in degrees; See **Fig. 8.5:** Θ < 90° if embankment points **down** stream; Θ > 90° if embankment points **ups** tream)*
K_2 =	1.00			*(Coefficient for Angle of Embankment to Flow; See Fig 8.5 for definition of Angle Theta Θ; K2 = (Θ/90)^0.13)*
g =	32.2	ft/s2		(Acceleration of Gravity, 32.2 ft/s^2, or 9.81 m/s^2)

CALCULATIONS

y_s =	9.43	ft	*(Scour Depth, ft)*

Note:

Input Data
Calculated Results
Default/Constants

3. LOCAL SCOUR - ABUTMENTS

RIGHT

Constraints:

HIRE Method, If L/Y_1 > 25

Check: L/Y1 = 69.50 HIRE Eqn. Works!

B. HIRE Equation

B1)

$$\frac{y_s}{y_1} = 4\,Fr^{0.33}\,\frac{K_1}{0.55}\,K_2$$

(Eq. 8.2)

Eq. 8.2, HEC. No. 18

WSE at bridge face = 659.43

GND Elev at toe of Right Abut = 653.90

y1 = 659.43 - 653.90 = 5.53

Where:

y_s =	22.11	ft		*(Scour Depth, ft)*
y_1 =	5.53	ft		*(Depth of Flow at the Abutment on the Overbank or in the Main Channel, ft)*
V_1 =	3.97	ft/sec		*(Velocity of flow at tip of the Abutment, ft/s)*
L =	384.34	ft	XS 62869.66	*(Length of Embankment Projected Normal to the Flow, ft) See L and L' EX sht 3 of 10*
Fr =	0.30			*(Froude Number based on the Veolocity and Depth adjacent to and Upstream of the Abutment,= V_1/Sqrt(g*y_1))*
Abutment Shape =	Vertical-wall abutment with wing walls			***Input Options*** *: a) Vertical-wall abutment; b) Vertical-wall abutment with wing walls; c) Spill-through abutment. e.g. Vertical-wall abutment*
K_1 =	0.82			*Coefficient of Abutment Shape (Table 8.1);*
Θ =	90	^{o}		*(Angle of Embankment to Flow, Θ in degrees; See* ***Fig. 8.5:*** *Θ < 90° if embankment points* ***down*** *stream; Θ > 90 ^{o} if embankment points* ***ups*** *tream)*
K_2 =	1.00			*(Coefficient for Angle of Embankment to Flow; See Fig 8.5 for definition of Angle Theta Θ; K2 = (Θ/90)^0.13)*
g =	32.2	ft/s2		(Acceleration of Gravity, 32.2 ft/s^2, or 9.81 m/s^2)

CALCULATIONS

y_s =	22.11	ft	*(Scour Depth, ft)*

Note:

Input Data
Calculated Results
Default/Constants

3. LOCAL SCOUR - ABUTMENTS

Judgement:	
Live-Bed contraction scour will Exist,	**If $L/B_f > 0.75$**
Left L/Bf=	1.43 Live-Bed
Right L/Bf=	1.06 Live-Bed

C. NCHRP 24-20 Abutment Scour Approach

C1) $y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{6/7}$ (Eq. 8.5) *Eq. 8.5, HEC. No. 18 for live bed conditions*

C2) $y_{max} = \alpha_A\, y_c$ or $y_{max} = \alpha_B\, y_c$ Eq. 8.3, HEC No. 18

C3) $y_s = y_{max} - y_0$ (Eq. 8.4) Eq. 8.4, HEC No. 18

Where:

y_s =	11.45	ft		*(Abutment Scour Depth, ft)*
L_{LABUT} =	28.39	ft		*(Length of Embankment Projected Normal to the Flow, ft) See L and L' Ex Sht 3 of 10*
Bf_{LEFT} =	19.89	ft		*Width of floodplain, Left side, RS 62869.66, See cross section exhibit*
L_{RABUT} =	384.34	ft		*(Length of Embankment Projected Normal to the Flow, ft) See L and L' EX sht 3 of 10*
Bf_{RIGHT} =	360.97	ft		*Width of floodplain, Right side, RS 62869.66, See cross section exhibit*
y_1 =	8.77	ft		*(Upstream flow depth)*
y_0 =	7.80	ft		*(flow depth prior to scour)*
Q_1 =	1192.63	ft^3/sec		*(Flow in the Upstream channel transporting sediment, ft^3/s)*
Q_2 =	2808	ft^3/sec		*(Flow in the Contracted channel, ft^3/s)*
W_1 =	68	ft		*(Bottom Width of the Upstream Main Channel that is Transporting Bed Material, ft)*
W_2 =	83	ft		*(Bottom Width of Main Channel in Contracted Section LESS Pier Widths(s), ft)*
q_1 =	17.54	ft^2/sec	Q_1/W_1	*(Upstream Floodplain Unit Discharge, ft^2/s)*
q_{2c} =	33.83	ft^2/sec	Q_2/W_2	*(Unit Discharge in the Constricted Opening Accouting for Non-uniform flow distribution, or, Abutment Unit Discharge, ft^2/s)*
q_{2c}/q_1 =	1.93			*(Note: Used to find "Amplification Factor" for Live-Bed Conditions in Fig. 8.9 or 8.10)*
y_c =	15.40	ft		*(Flow depth including Live-Bed Contraction Scour, ft)*
α_A =	1.25		*Fig. 8-10 HEC-18*	*(Amplification Factor for Live BedConditions, See Fig. 8.9 (Spill-through Abutments & Live-bed, or 8.10 (Wingwall Abutments & Live-bed))*
y_{max} =	19.25	ft		*(Maximum flow depth resulting from Abutment Scour, ft)*

CALCULATIONS

y_s =	11.45	ft	*(Abutment Scour Depth, ft)*

Note:

Input Data
Calculated Results
Default/Constants

Plan: EX Blackberry Creek Main before A RS: 62823.34 Profile: Q100

E.G. US. (ft)	659.76	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	659.48	E.G. Elev (ft)	659.72	659.53
Q Total (cfs)	2808.00	W.S. Elev (ft)	659.43	659.21
Q Bridge (cfs)	2808.00	Crit W.S. (ft)	654.89	655.12
Q Weir (cfs)		Max Chl Dpth (ft)	9.25	8.98
Weir Sta Lft (ft)		Vel Total (ft/s)	4.34	4.51
Weir Sta Rgt (ft)		Flow Area (sq ft)	647.60	621.95
Weir Submerg		Froude # Chl	0.25	0.27
Weir Max Depth (ft)		Specif Force (cu ft)	2993.67	2790.61
Min El Weir Flow (ft)	666.71	Hydr Depth (ft)	7.80	7.23
Min El Prs (ft)	663.64	W.P. Total (ft)	102.64	106.82
Delta EG (ft)	0.30	Conv. Total (cfs)	51339.1	46735.7
Delta WS (ft)	0.34	Top Width (ft)	83.00	86.09
BR Open Area (sq ft)	973.55	Frctn Loss (ft)	0.18	0.07
BR Open Vel (ft/s)	4.51	C & E Loss (ft)	0.01	0.00
Coef of Q		Shear Total (lb/sq ft)	1.18	1.31
Br Sel Method	Energy only	Power Total (lb/ft s)	0.00	0.00

Q Bridge - 2808 cfs = Q2

Hydr Depth - 7.80 ft = Y0

Top Width - 83.00 ft = W2

Plan: EX Blackberry Creek Main before A RS: 62926.52 Profile: Q100

E.G. Elev (ft)	659.83	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.	0.106	0.064	0.106
W.S. Elev (ft)	659.80	Reach Len. (ft)	53.09	56.86	49.22
Crit W.S. (ft)	655.05	Flow Area (sq ft)	419.34	596.04	1735.77
E.G. Slope (ft/ft)	0.000426	Area (sq ft)	419.34	596.04	1735.77
Q Total (cfs)	2808.00	Flow (cfs)	302.40	1192.63	1312.97
Top Width (ft)	583.92	Top Width (ft)	106.29	68.00	409.64
Vel Total (ft/s)	1.02	Avg. Vel. (ft/s)	0.72	2.00	0.76
Max Chl Dpth (ft)	9.86	Hydr. Depth (ft)	3.95	8.77	4.24
Conv. Total (cfs)	136094.9	Conv. (cfs)	14656.4	57803.2	63635.4
Length Wtd. (ft)	54.87	Wetted Per. (ft)	106.52	69.82	410.41
Min Ch El (ft)	649.94	Shear (lb/sq ft)	0.10	0.23	0.11
Alpha	1.94	Stream Power (lb/ft s)	646.00	0.00	0.00
Frctn Loss (ft)	0.05	Cum Volume (acre-ft)	32.85	28.27	53.26
C & E Loss (ft)	0.03	Cum SA (acres)	7.78	3.94	16.25

Channel Flow - 1192.63 cfs

Top Width - 68.00 ft = W1

Hydr Depth - 8.77 ft = Y1

Avg. Vel. - 2.00 ft/s = V

SCOUR: EX 100 YR

Flow Distribution Output
Used for Pier Scour

River: Blackberry Creek **Profile:** Q100
Reach: Main before A **RS:** 62869.66

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)
1	LOB	142.28	160.07	0.00	0.19	2.11	0.00	0.09	0.00	0.01	0.00
2	LOB	160.07	177.85	0.00	20.17	17.94	0.00	1.13	0.00	0.16	0.00
3	Chan	177.85	186.24	0.00	26.96	8.56	0.00	3.21	0.00	0.44	0.00
4	Chan	186.24	196.64	175.06	55.84	11.24	6.23	5.37	3.13	0.70	2.18
5	Chan	196.64	207.05	354.25	82.69	10.42	12.62	7.95	4.28	1.11	4.77
6	Chan	207.05	217.45	412.81	90.70	10.44	14.70	8.72	4.55	1.22	5.55
7	Chan	217.45	227.85	446.32	94.92	10.40	15.89	9.12	4.70	1.28	6.02
8	Chan	227.85	229.85	0.00	18.40	2.00	0.00	9.20	0.00	1.29	0.00 <-- 0 flow due to IAOs at Pier
9	Chan	229.85	240.28	457.53	96.45	10.43	16.29	9.25	4.74	1.30	6.15
10	Chan	240.28	250.71	435.96	93.83	10.47	15.53	9.00	4.65	1.26	5.84
11	Chan	250.71	261.14	311.18	77.64	10.81	11.08	7.44	4.01	1.01	4.04
12	Chan	261.14	271.57	214.89	61.36	10.46	7.65	5.88	3.50	0.82	2.88
13	Chan	271.57	283.10	0.00	60.05	11.55	0.00	5.21	0.00	0.73	0.00
14	Chan	283.10	294.62	0.00	41.85	11.79	0.00	3.63	0.00	0.50	0.00
15	ROB	294.62	332.83	0.00	69.60	38.23	0.00	1.82	0.00	0.26	0.00
16	ROB	332.83	371.04	0.00	95.76	38.27	0.00	2.51	0.00	0.35	0.00
17	ROB	371.04	409.25	0.00	33.29	36.26	0.00	0.92	0.00	0.13	0.00
18	ROB	409.25	447.46	0.00	14.46	26.38	0.00	0.55	0.00	0.08	0.00
19	ROB	447.46	485.67	0.00	92.37	38.26	0.00	2.42	0.00	0.34	0.00
20	ROB	485.67	523.88	0.00	99.70	38.21	0.00	2.61	0.00	0.37	0.00
21	ROB	523.88	562.09	0.00	87.89	38.24	0.00	2.30	0.00	0.32	0.00
22	ROB	562.09	600.30	0.00	23.11	30.52	0.00	0.76	0.00	0.11	0.00
23	ROB	600.30	638.51	0.00	18.98	23.33	0.00	0.82	0.00	0.11	0.00
24	ROB	638.51	676.72	0.00	14.83	17.27	0.00	0.86	0.00	0.12	0.00

Existing Centerline of Pier at Sta. 62869.66 = 228.85

y1 = 9.25 ft
V_1 = 4.74 ft/sec

SCOUR: EX 100 YR

Flow Distribution Output
Used for Left Abut - Froelich Equation

River: Blackberry Creek **Profile:** Q100
Reach: Main before A **RS:** 62926.52

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)	
1	LOB	46.50	62.00	1.44	7.93	13.34	0.05	0.60	0.18	0.02	0.00	*<-- Negligible Flow, Disregard*
2	LOB	62.00	77.50	11.59	29.53	15.56	0.41	1.91	0.39	0.05	0.02	<-- 100%
3	LOB	77.50	93.00	29.12	51.32	15.56	1.04	3.31	0.57	0.09	0.05	<-- 100%
4	LOB	93.00	108.50	46.81	68.16	15.52	1.67	4.40	0.69	0.12	0.08	<-- 100%
5	LOB	108.50	124.00	61.58	80.33	15.51	2.19	5.18	0.77	0.14	0.11	<-- 100%
6	LOB	124.00	139.50	71.18	87.61	15.51	2.53	5.65	0.81	0.15	0.12	<-- 100%
7	LOB	139.50	155.00	80.69	94.46	15.51	2.87	6.09	0.85	0.16	0.14	*<-- 89% of Flow*
8	Chan	155.00	161.80	72.20	43.95	6.81	2.57	6.46	1.64	0.17	0.28	
9	Chan	161.80	168.60	83.55	50.17	7.61	2.98	7.38	1.67	0.18	0.29	
10	Chan	168.60	175.40	118.51	59.18	6.81	4.22	8.70	2.00	0.23	0.46	
11	Chan	175.40	182.20	126.50	61.53	6.81	4.50	9.05	2.06	0.24	0.49	
12	Chan	182.20	189.00	132.02	63.11	6.80	4.70	9.28	2.09	0.25	0.52	
13	Chan	189.00	195.80	134.19	63.73	6.80	4.78	9.37	2.11	0.25	0.52	
14	Chan	195.80	202.60	138.25	64.88	6.80	4.92	9.54	2.13	0.25	0.54	
15	Chan	202.60	209.40	143.01	66.21	6.80	5.09	9.74	2.16	0.26	0.56	
16	Chan	209.40	216.20	138.94	65.20	6.83	4.95	9.59	2.13	0.25	0.54	
17	Chan	216.20	223.00	105.47	58.08	7.74	3.76	8.54	1.82	0.20	0.36	
18	ROB	223.00	262.89	213.57	241.20	39.92	7.61	6.05	0.89	0.16	0.14	
19	ROB	262.89	302.77	202.33	233.43	39.89	7.21	5.85	0.87	0.16	0.13	
20	ROB	302.77	342.66	194.64	228.06	39.89	6.93	5.72	0.85	0.15	0.13	
21	ROB	342.66	382.54	198.02	230.53	39.93	7.05	5.78	0.86	0.15	0.13	
22	ROB	382.54	422.43	81.95	136.31	40.32	2.92	3.42	0.60	0.09	0.05	
23	ROB	422.43	467.14	101.60	161.75	44.81	3.62	3.62	0.63	0.10	0.06	
24	ROB	467.14	511.86	143.63	198.94	44.72	5.12	4.45	0.72	0.12	0.09	
25	ROB	511.86	556.57	135.33	192.09	44.79	4.82	4.30	0.70	0.11	0.08	
26	ROB	556.57	601.29	34.75	84.93	44.75	1.24	1.90	0.41	0.05	0.02	
27	ROB	601.29	646.00	7.14	28.53	31.40	0.25	0.91	0.25	0.02	0.01	

Left Abut L' Limit = Sta. 48.71 to Sta. 153.24

Q_e = 292.09

A_e = 401.02

SCOUR: EX 100 YR

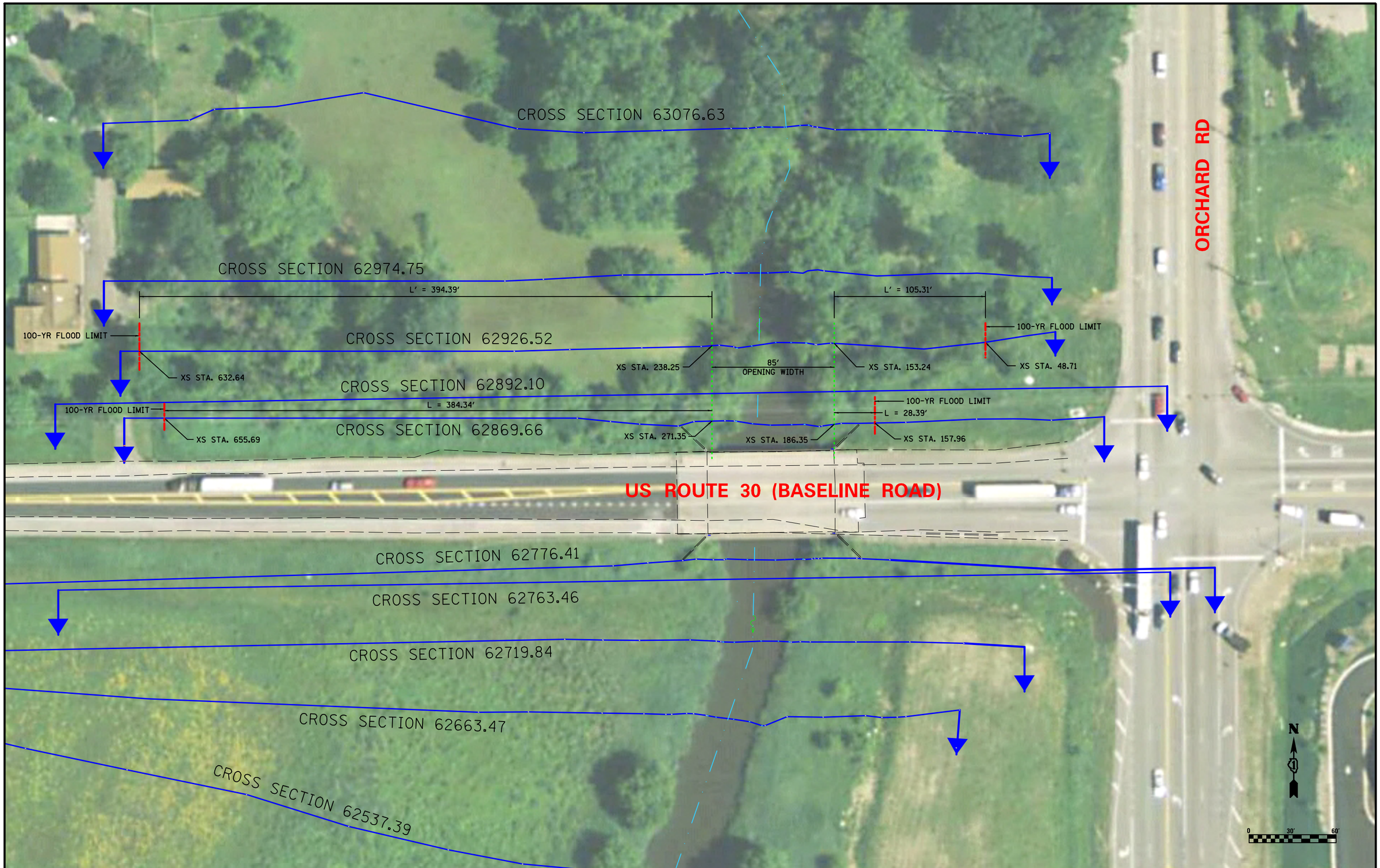
Flow Distribution Output
Used for Right Abut - HIRE Equation

River: Blackberry Creek **Profile:** Q100
Reach: Main before A **RS:** 62823.34BR U

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)	
1	Chan	177.85	186.24	0.00	0.01	0.00	0.00	4.07	0.00	0.83	0.00	
2	Chan	186.24	196.64	194.89	54.88	11.13	6.94	5.33	3.55	0.92	3.27	
3	Chan	196.64	207.05	399.10	82.17	10.42	14.21	7.90	4.86	1.47	7.15	
4	Chan	207.05	217.45	465.51	90.18	10.44	16.58	8.67	5.16	1.61	8.33	
5	Chan	217.45	227.85	330.76	94.40	19.54	11.78	9.07	3.50	0.90	3.16	
6	Chan	227.85	229.85							0.00	0.00	
7	Chan	229.85	240.28	339.10	95.92	19.59	12.08	9.20	3.54	0.91	3.23	
8	Chan	240.28	250.71	491.76	93.31	10.47	17.51	8.95	5.27	1.66	8.77	
9	Chan	250.71	261.14	350.33	77.12	10.81	12.48	7.39	4.54	1.33	6.05	
10	Chan	261.14	271.57	236.56	59.62	10.24	8.42	5.84	3.97	1.09	4.31	*<-- Velocity at tip of Right Abut*

Right Abutment Sta. 271.35

V_1 = 3.97 ft/s



FILE NAME = $FILEL$	USER NAME = $USER$	DESIGNED - SGL	REVISED - _____
		DRAWN - SGL	REVISED - _____
	PLOT SCALE = $SCALE$	CHECKED - _____	REVISED - _____
$MODELNAME$	PLOT DATE = $DATE$	DATE - 5/10/2016	REVISED - _____

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

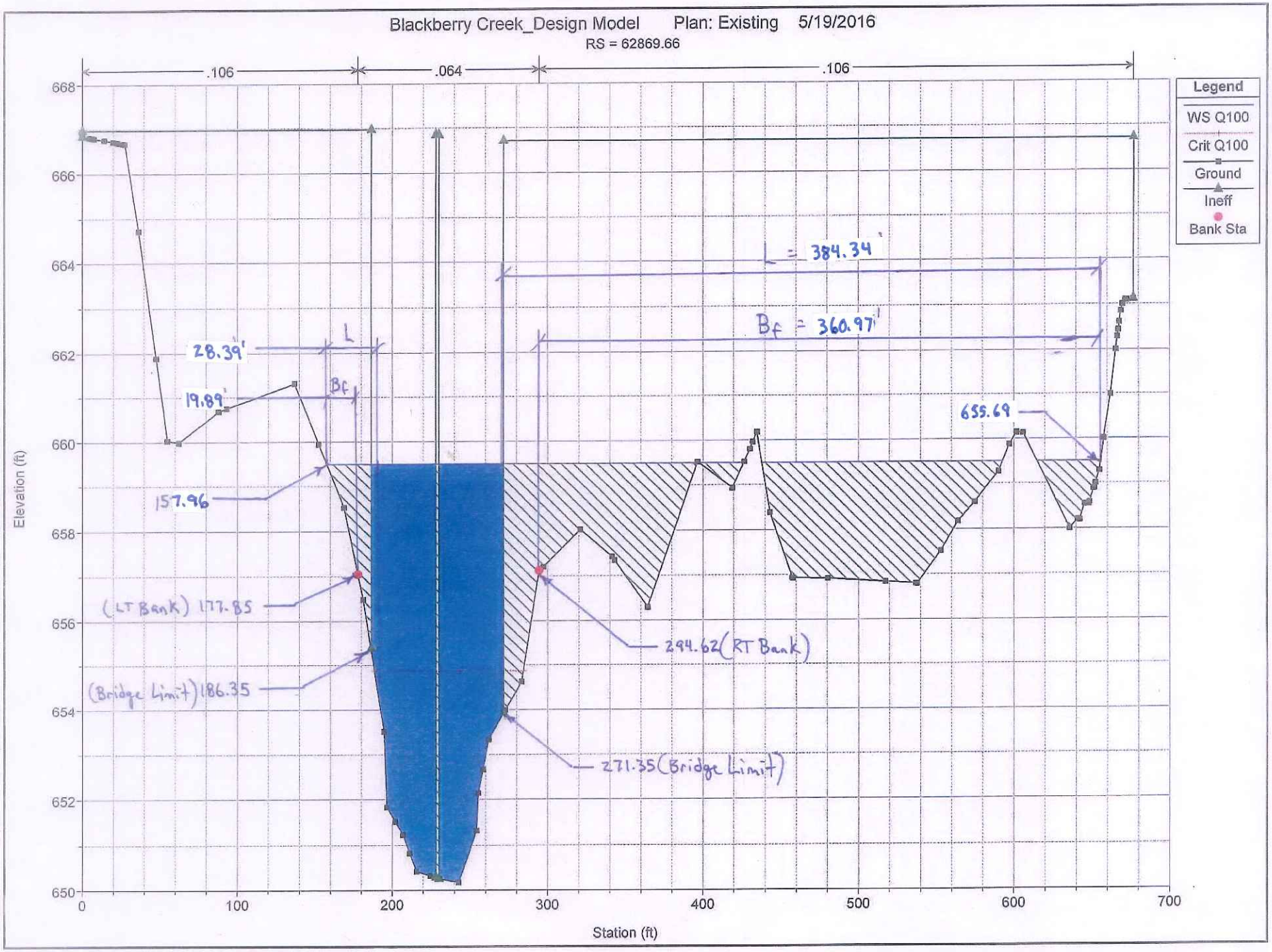
EXHIBIT L – EXISTING 100-YEAR L AND L' VARIABLES
US ROUTE 30 (BASELINE ROAD)

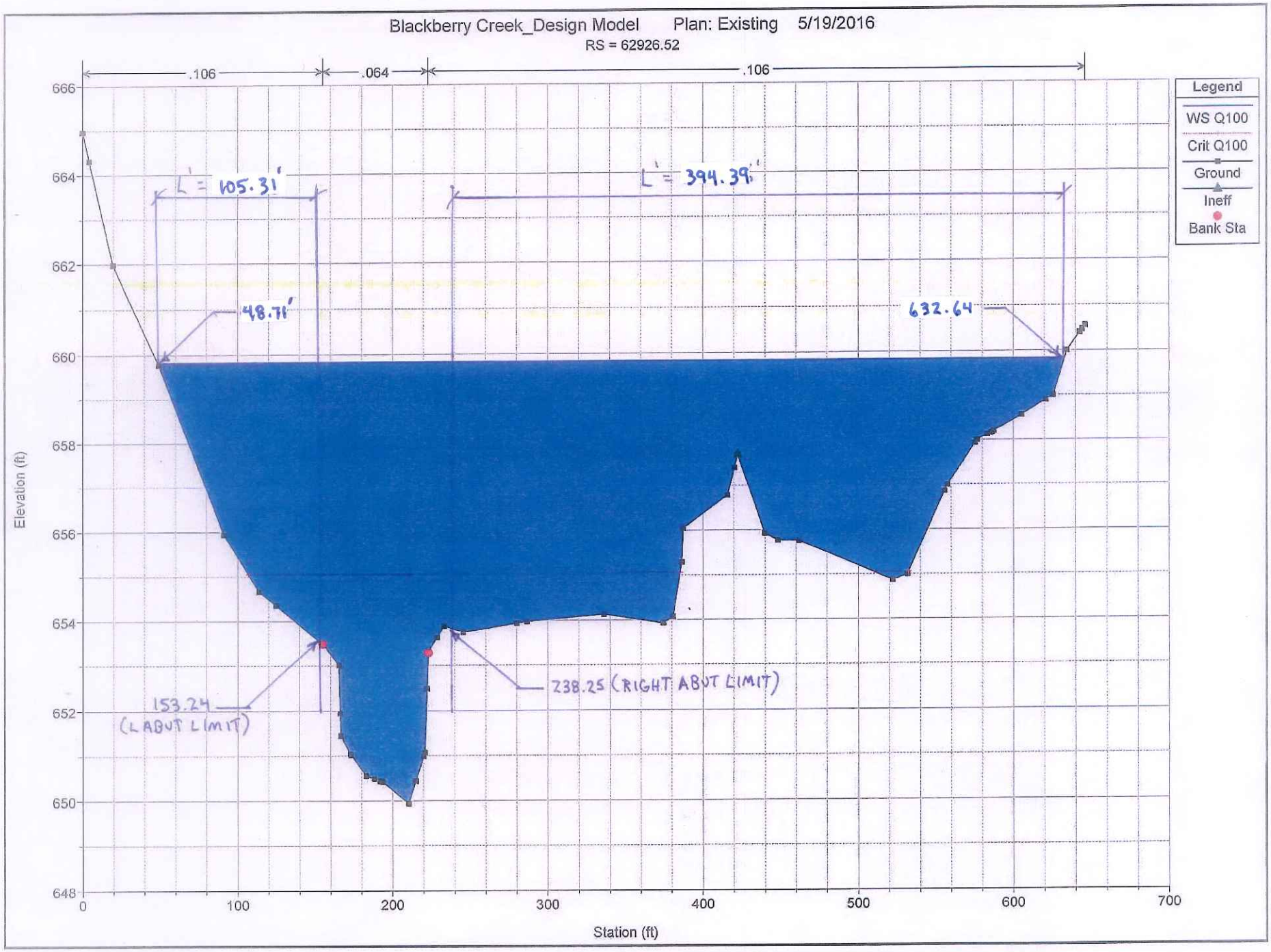
SCALE: 1" = 30' | SHEET 3 OF 10 SHEETS | STA. _____ TO STA. _____

F.A.P. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
349	10-B	KANE/KENDALL	10	3

JOB NO. P-91-403-11

ILLINOIS FED. AID PROJECT (02/03/17)


Blackberry Creek_Design Model Plan: Existing 5/19/2016
RS = 62869.66
.106
.064
.106
Legend
WS Q100
Crit Q100
Ground
Ineff
Bank Sta
L = 384.34'
Bf = 360.97'
28.39'
L
19.89'
Bf
655.69
157.96
(LT Bank) 177.85
(Bridge Limit) 186.35
294.62 (RT Bank)
271.35 (Bridge Limit)
Elevation (ft)
Station (ft)
668
666
664
662
660
658
656
654
652
650
0
100
200
300
400
500
600
700


Blackberry Creek_Design Model Plan: Existing 5/19/2016
RS = 62926.52
.106
.064
.106
L' = 105.31'
L' = 394.39'
48.71'
632.64
153.24
(L ABUT LIMIT)
238.25 (RIGHT ABUT LIMIT)
Legend
WS Q100
Crit Q100
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
666
664
662
660
658
656
654
652
650
648
0
100
200
300
400
500
600
700

Pre-worksheet calculations showing all frequencies for a proposed structure

- The summary table shows the recommended values for scour for each frequency.

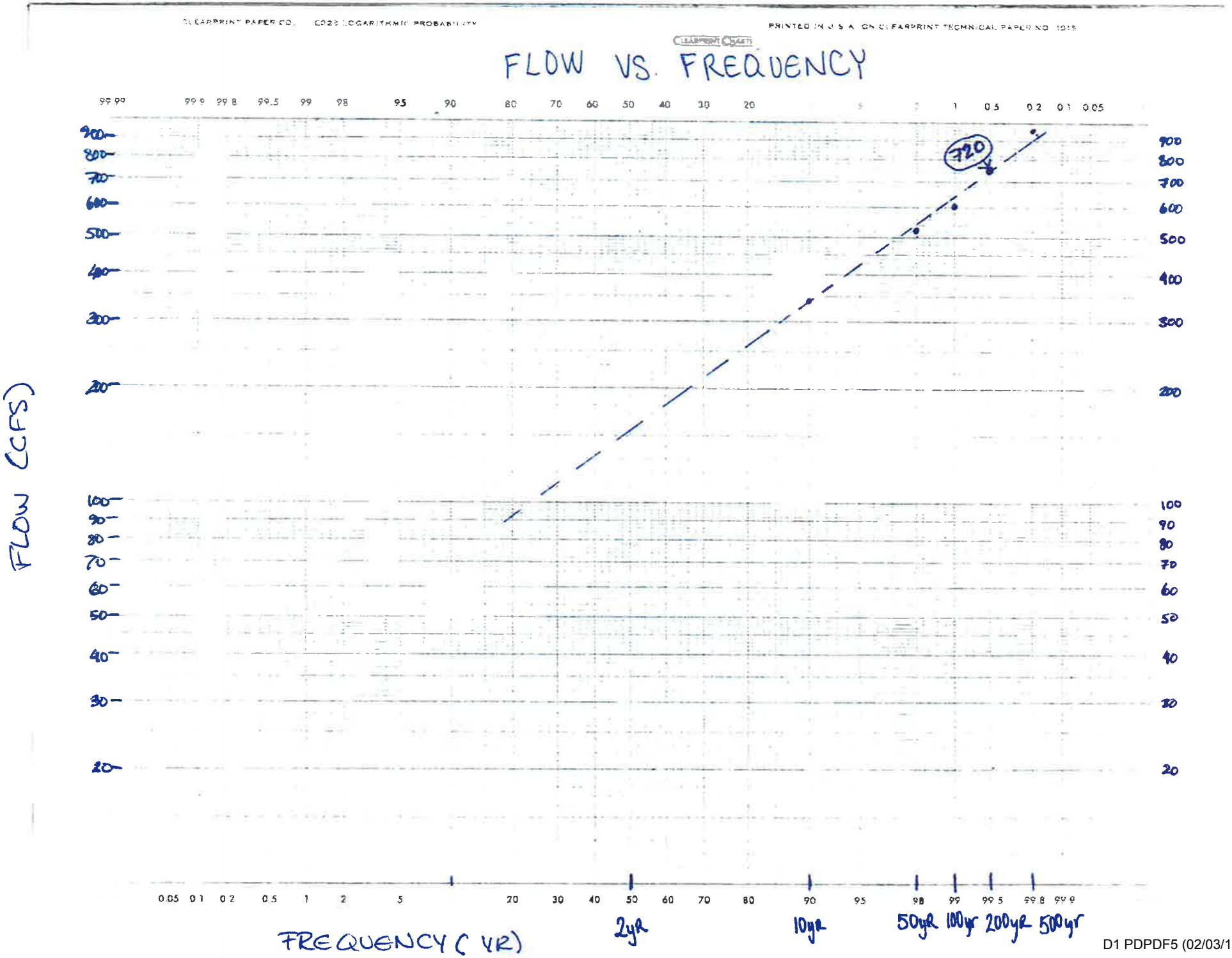
- The spreadsheet would be needed to check the calculations.

- The work is clearly shown along with how the variables were selected. However, for brevity the NCHRP supporting exhibits are not shown for items such as L_{Abut} and B_f which determines Live-Bed versus Clearwater.

Hydraulic Report No. 2 for Outlet No. 7B
Illinois Route 47 (US Route 14 to Reed Road)
IL-47 over the Kishwaukee Creek (South)

Scour Calculations

Summary of Scour				
Type of Scour	**Scour (ft)**			
	10-year	**50-year**	**100-year**	**200-year**
Contraction	0.37	2.43	5.18	0.78
Abutment				
Left	4.25	1.62	1.94	2.46
Right	5.58	5.58	5.00	4.85
Total Left	**4.62**	**4.05**	**7.12**	**3.24**
Total Right	**5.95**	**8.01**	**10.19**	**5.63**


CLEARPRINT PAPER CO. C023 LOGARITHMIC PROBABILITY
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015
FLOW VS. FREQUENCY
FLOW (CFS)
FREQUENCY (YR)
720
2yr
10yr
50yr
100yr
200yr
500yr

10 Year Scour Analysis

10 YR Contraction Scour Calculation

where: $V_C = K_u y_1^{1/6} D^{1/3}$

Vc	=	Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y	=	Average depth of flow upstream of the bridge, ft (m)
D	=	Particle size for Vc, ft (m)
D50	=	Particle size in a mixture of which 50 percent are smaller, ft (m)
Ku	=	6.19 SI units
Ku	=	11.17 English units

If the critical velocity of the bed material is larger than the mean velocity (Vc > V), then clear-water contraction scour will exist. If the critical velocity is less than the mean velocity (Vc < V), then live-bed contraction scour will exist. To calculate the critical velocity use the equation derived in the Appendix C.

From upstream cross section 168:

Hydraulic Depth (y1)=		5.08	ft		Velocity Total (V)=		1.94	ft/s	
1	Vc=	1.273	f/s	using	0.200	mm		Vc < V	Live-Bed
2	Vc=	0.802	f/s	using	0.050	mm		Vc < V	Live-Bed

Live-Bed Contraction Scour

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1}$$

y1	=	Average depth in the upstream main channel, ft (m)
y2	=	Average depth in the contracted section, ft (m)
yo	=	Existing depth in the contracted section before scour, ft (m)
Q1	=	Flow in the upstream channel transporting sediment, ft3/s (m3/s)
Q2	=	Flow in the contracted channel, ft3/s (m3/s)
W1	=	Bottom width of the upstream main channel that is transporting bed material, ft (m)
W2	=	Bottom width of main channel in contracted section less pier width(s), ft (m)
k1	=	Exponent determined below

V*/ω	k1	Mode of Bed Material Transport
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

V*	=	(ϑo/Δ)½ = (gy1 S1)½, shear velocity in the upstream section, ft/s (m/s)
ω	=	Fall velocity of bed material based on the D50, m/s (Figure 6.8)
		For fall velocity in English units (ft/s) multiply ω in m/s by 3.28
g	=	Acceleration of gravity (32.2 ft/s2) (9.81 m/s2)
S1	=	Slope of energy grade line of main channel, ft/ft (m/m)
ϑo	=	Shear stress on the bed, (lb/ft2) (Pa (N/m2))
Δ	=	Density of water (1.94 slugs/ft3) (1000 kg/m3)

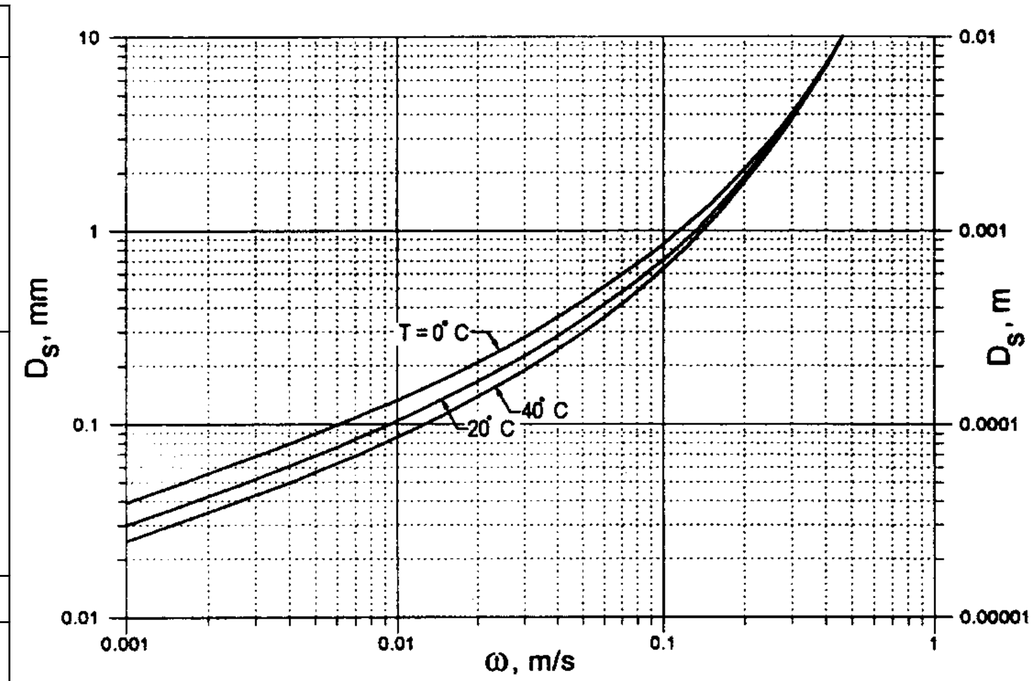


Figure 6.8 from HEC-18

From upstream cross section 168:

Shear (ϑo) =		0.16	lb/sq ft						
Hydr. Depth (y1) =		5.08	ft						
E.G. Slope (S1) =		0.0006							
V* =	(ϑo/Δ)½	=	(gy1 S1)½ft/s (m/s)						
V*=	0.287	=	0.312						
Using figure 6.8 @ T = 20 °:									
1	using	0.200	mm	ω	=	0.028	m/s	0.092	ft/s
2	using	0.050	mm	ω	=	0.003	m/s	0.010	ft/s
1	V*/ω	=	3.4		k1=	0.69			
2	V*/ω	=	31.7		k1=	0.69			

From upstream cross section 168:

Channel Flow (Q1) =	339.88	cfs
Hydr. Depth (y1) =	5.08	ft
Top Width (W1) =	34.60	ft

From bridge cross section 166:

Channel Flow (Q2) =	340.00	cfs
Top Width (W2) =	19.27	ft
Depth Before Scour (y0) =	7.24	ft

1	y2=	7.61	ft	
2	y2=	7.61	ft	

ys=y2-y0

1	ys=	0.37	ft	w/ 0.20 mm	*
2	ys=	0.37	ft	w/ 0.05 mm	

*Reasonable Lower limit for D50 used for comparison (HEC-18 Manual, Pg 6.2, Section 2.2.1, Paragraph 2)

10 YR Abutment Scour Calculation

Cross Section Data for bridge cross section for LT

L=	7.04	ft	Abutment Length	**L/y0 =**	1.0	< 25
y0=	7.24	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

Cross Section Data for bridge cross section for RT

L=	6.85	ft	Abutment Length	**L/y0 =**	0.9	< 25
y0=	7.24	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

K1	**=**	**Coefficient for abutment shape (Table 8.1)**
K2	**=**	**Coefficient for angle of embankment to flow**
K2	**=**	**(θ/90)0.13 (see Figure 8.5 for definition of θ)**
		θ<90° if embankment points downstream
		θ>90° if embankment points upstream
L´	**=**	**Length of active flow obstructed by the embankment, ft (m) (From Flow Distribution Table)**
Ae	**=**	**Flow area of the approach cross section obstructed by the embankment, ft2 (m2)**
Fr	**=**	**Froude Number of approach flow upstream of the abutment: Ve/((g*ya)^1/2))**
Ve	**=**	**Qe/Ae, ft/s (m/s)**
Qe	**=**	**Flow obstructed by the abutment and approach embankment, ft3/s (m3/s)**
ya	**=**	**Average depth of flow on the floodplain (Ae/L), ft (m)**
L	**=**	**Length of embankment projected normal to the flow, ft (m) (From Bridge Cross Section)**
ys	**=**	**Scour depth, ft (m)**

$$\frac{y_s}{y_a} = 2.27\, K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} Fr^{0.61} + 1$$

Table 8.1. Abutment Shape Coefficients

Description	K1
Vertical-wall abutment	1
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

LEFT						RIGHT					
K1=	0.82		**ya=**	2.26	ft	**K1=**	0.82		**ya=**	3.25	ft
K2=	1.00		**Fr=**	0.13		**K2=**	1.00		**Fr=**	0.12	
L=	7.04	ft	**Ve=**	1.13	ft/s	**L=**	6.85	ft	**Ve=**	1.27	ft/s
L´=	7.04	ft	**Qe=**	17.90	ft3/s	**L´=**	6.85	ft	**Qe=**	28.24	ft3/s
			Ae=	15.88	ft2				**Ae=**	22.23	ft2
ys =	**4.25**	**ft**				**ys =**	**5.58**	**ft**			

Combined Scour Depths

Left Abutment Scour + Contraction Scour	**4.62**	**ft**
Right Abutment Scour + Contraction Scour	**5.95**	**ft**

NCHRP Live-Bed Scour Calculation

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{\frac{6}{7}}$$

$$y_{max} = \alpha_A y_c$$

$$y_s = y_{max} - y_0$$

y1=	5.08	Hydr. Depth - Upstream Section
q2c=	17.00	Total Q at BR/width of BR
q1=	9.82	Total Q at US XS / width of US XS
α_A **=**	1.27	
y0=	7.24	

yc=	**8.13**	ft
ymax=	**10.32**	ft
ys=	**3.08**	**ft**

10 YR CROSS SECTION 168

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q010

E.G. Elev (ft)	857.49	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.06	Wt. n-Val.	0.070	0.050	
W.S. Elev (ft)	857.44	Reach Len. (ft)	13.78	13.78	13.78
Crit W.S. (ft)	852.77	Flow Area (sq ft)	0.84	175.62	
E.G. Slope (ft/ft) S_1	0.000596	Area (sq ft)	1.96	175.62	
Q Total (cfs)	340.00	Flow (cfs) Q_1	0.12	339.88	
Top Width (ft)	55.27	Top Width (ft) W_1	20.67	34.60	
Vel Total (ft/s)	1.93	Avg. Vel. (ft/s) V	0.14	1.94	
Max Chl Dpth (ft)	8.24	Hydr. Depth (ft) y_1	0.14	5.08	
Conv. Total (cfs)	13922.5	Conv. (cfs)	4.7	13917.8	
Length Wtd. (ft)	13.78	Wetted Per. (ft)	6.13	40.33	
Min Ch El (ft)	849.19	Shear (lb/sq ft) τ	0.01	0.16	
Alpha	1.01	Stream Power (lb/ft s)	1367.34	0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)	7.36	5.76	
C & E Loss (ft)		Cum SA (acres)	4.39	1.20	

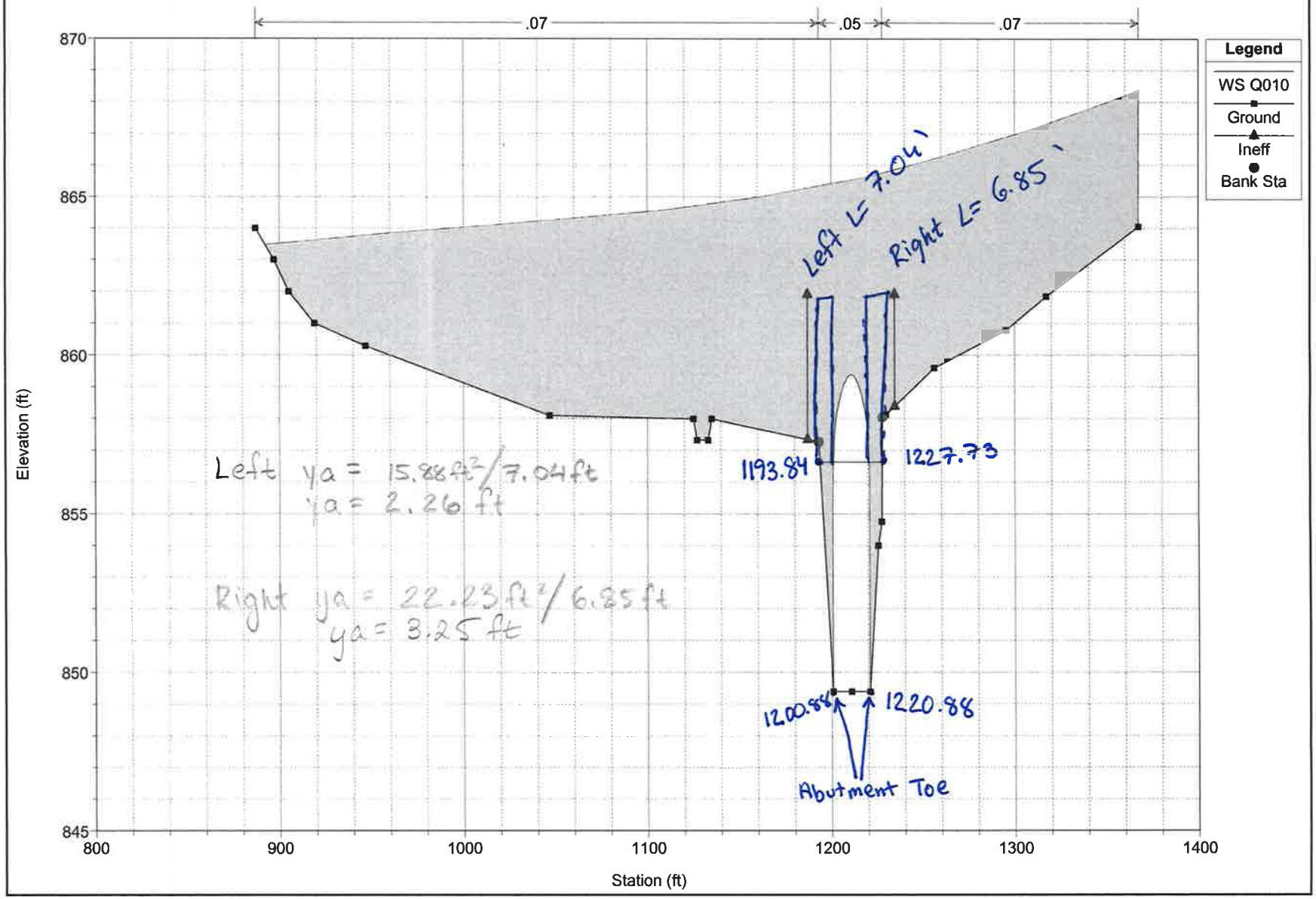
Bridge Output 10yr2

Plan: Prop 3S Scour 2 7b RS: 166 Profile: Q010

E.G. US. (ft)	857.49	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	857.44	E.G. Elev (ft)	856.72	856.47
Q Total (cfs)	340.00	W.S. Elev (ft)	856.63	856.38
Q Bridge (cfs)	Q 340.00	Crit W.S. (ft)	851.47	851.38
Q Weir (cfs)		Max Chl Dpth (ft)	yo, y 7.24	7.07
Weir Sta Lft (ft)		Vel Total (ft/s)	2.36	2.41
Weir Sta Rgt (ft)		Flow Area (sq ft)	144.26	141.05
Weir Submerg		Froude # Chl	0.15	0.16
Weir Max Depth (ft)		Specif Force (cu ft)	548.24	525.15
Min El Weir Flow (ft)	863.50	Hydr Depth (ft)	7.49	7.25
Min El Prs (ft)	859.39	W.P. Total (ft)	34.58	34.19
Delta EG (ft)	0.16	Conv. Total (cfs)	11111.2	10781.9
Delta WS (ft)	0.18	Top Width (ft)	W2 19.27	19.46
BR Open Area (sq ft)	184.26	Frctn Loss (ft)		
BR Open Vel (ft/s)	2.41	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)	0.24	0.26
Br Sel Method	Momentum	Power Total (lb/ft s)	887.00	849.02

10yr - Bridge

IL47 Outlet 7B Plan: Proposed Design 3-sided Scour 4/5/2016



168 – 10yr Flow distribution

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q010

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)
1	LOB	1097.07	1127.08	0.00	0.03	0.44	0.00	0.07	0.00	0.00	0.00
2	LOB	1127.08	1157.09	0.00	0.70	6.28	0.00	0.11	0.00	0.00	0.00
3	LOB	1157.09	1187.10	0.00	0.39	7.85	0.00	0.05	0.00	0.00	0.00
4	LOB	1187.10	1193.23	0.12	0.84	6.13	0.03	0.14	0.14	0.01	0.00
5	Chan	1193.23	1194.96	0.54	1.22	2.03	0.16	0.70	0.45	0.02	0.01
6	Chan	1194.96	1196.70	2.51	3.05	2.03	0.74	1.76	0.82	0.06	0.05
7	Chan	1196.70	1198.43	5.50	4.89	2.03	1.62	2.82	1.13	0.09	0.10
8	Chan	1198.43	1200.16	9.35	6.72	2.03	2.75	3.88	1.39	0.12	0.17
9	Chan	1200.16	1201.90	14.13	8.42	1.92	4.16	4.86	1.68	0.16	0.27
10	Chan	1201.90	1203.63	16.26	9.70	2.22	4.78	5.60	1.68	0.16	0.27
11	Chan	1203.63	1205.37	24.67	12.10	2.06	7.26	6.98	2.04	0.22	0.45
12	Chan	1205.37	1207.10	29.82	12.74	1.77	8.77	7.35	2.34	0.27	0.63
13	Chan	1207.10	1208.83	32.11	13.32	1.77	9.44	7.68	2.41	0.28	0.68
14	Chan	1208.83	1210.57	34.45	13.89	1.76	10.13	8.01	2.48	0.29	0.73
15	Chan	1210.57	1212.30	33.89	13.93	1.82	9.97	8.04	2.43	0.28	0.69
16	Chan	1212.30	1214.03	29.76	12.92	1.83	8.75	7.45	2.30	0.26	0.60
17	Chan	1214.03	1215.77	26.15	11.91	1.82	7.69	6.87	2.19	0.24	0.54
18	Chan	1215.77	1217.50	22.96	11.01	1.81	6.75	6.35	2.09	0.23	0.47
19	Chan	1217.50	1219.23	17.23	9.66	2.01	5.07	5.57	1.78	0.18	0.32
20	Chan	1219.23	1220.97	12.30	7.89	2.01	3.62	4.55	1.56	0.15	0.23
21	Chan	1220.97	1222.70	9.88	6.60	1.79	2.91	3.81	1.50	0.14	0.21
22	Chan	1222.70	1224.43	8.51	6.01	1.77	2.50	3.46	1.42	0.13	0.18
23	Chan	1224.43	1226.17	7.15	5.41	1.77	2.10	3.12	1.32	0.11	0.15
24	Chan	1226.17	1227.90	2.70	4.21	4.07	0.79	2.54	0.64	0.04	0.02

Left Q_E : 17.90 cfs
Left A_E : 15.88 ft^2

Right Q_E : 28.24 cfs
Right A_E : 22.23 ft^2

Left L' : 1200.88' – 1193.84' = 7.04'

Right L' : 1227.73' – 1220.88' = 6.85'

L' Calculation for 10 YR

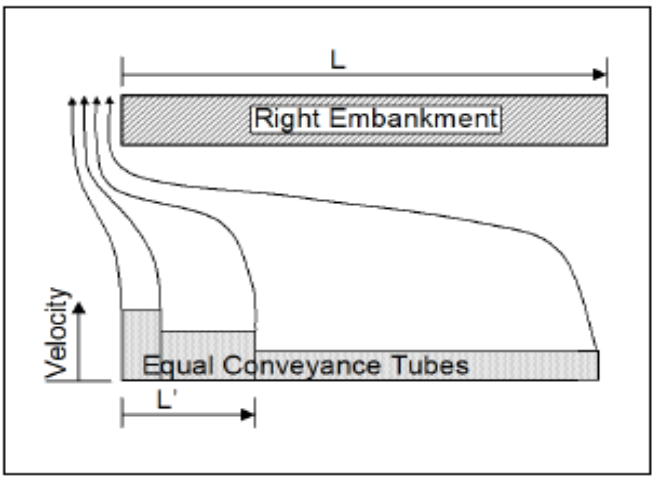


Figure 8.4. Determination of length of embankment blocking live flow for abutment scour estimation.

When examining the flow distribution table for cross section 168, there is no significant flow in the left or right overbanks to consider as active flow obstructed by embankment. As seen in the flow distribution table, there is zero flow in the embankment outside of the abutment. This judgement is made by utilizing the methods used in section 8.2.2 in the HEC-18 Manual as well as Figure 8.4 shown above. The 10 yr event has a short embankment length, therefore the L' was set equal to the embankment length projected normal to the flow (L).

50 Year Scour Analysis

50 YR Contraction Scour Calculation

where: $V_C = K_u y_1^{1/6} D^{1/3}$

Vc	=	Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y	=	Average depth of flow upstream of the bridge, ft (m)
D	=	Particle size for Vc, ft (m)
D50	=	Particle size in a mixture of which 50 percent are smaller, ft (m)
Ku	=	6.19 SI units
Ku	=	11.17 English units

If the critical velocity of the bed material is larger than the mean velocity (Vc > V), then clear-water contraction scour will exist. If the critical velocity is less than the mean velocity (Vc < V), then live-bed contraction scour will exist. To calculate the critical velocity use the equation derived in the Appendix C.

From upstream cross section 168:

Hydraulic Depth (y1) =		6.06	ft		Velocity Total (V) =		2.40	ft/s	
1	Vc=	1.31	f/s	using	0.200	mm		Vc < V	Live-Bed
2	Vc=	0.83	f/s	using	0.050	mm		Vc < V	Live-Bed

Live-Bed Contraction Scour

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7}\left(\frac{W_1}{W_2}\right)^{k_1}$$

y1	=	Average depth in the upstream main channel, ft (m)
y2	=	Average depth in the contracted section, ft (m)
yo	=	Existing depth in the contracted section before scour, ft (m)
Q1	=	Flow in the upstream channel transporting sediment, ft3/s (m3/s)
Q2	=	Flow in the contracted channel, ft3/s (m3/s)
W1	=	Bottom width of the upstream main channel that is transporting bed material, ft (m)
W2	=	Bottom width of main channel in contracted section less pier width(s), ft (m)
k1	=	Exponent determined below

V*/ω	k1	Mode of Bed Material Transport
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

V*	=	(ϑo/Δ)½ = (gy1 S1)½, shear velocity in the upstream section, ft/s (m/s)
ω	=	Fall velocity of bed material based on the D50, m/s (Figure 6.8)
		For fall velocity in English units (ft/s) multiply ω in m/s by 3.28
g	=	Acceleration of gravity (32.2 ft/s2) (9.81 m/s2)
S1	=	Slope of energy grade line of main channel, ft/ft (m/m)
ϑo	=	Shear stress on the bed, (lb/ft2) (Pa (N/m2))
Δ	=	Density of water (1.94 slugs/ft3) (1000 kg/m3)

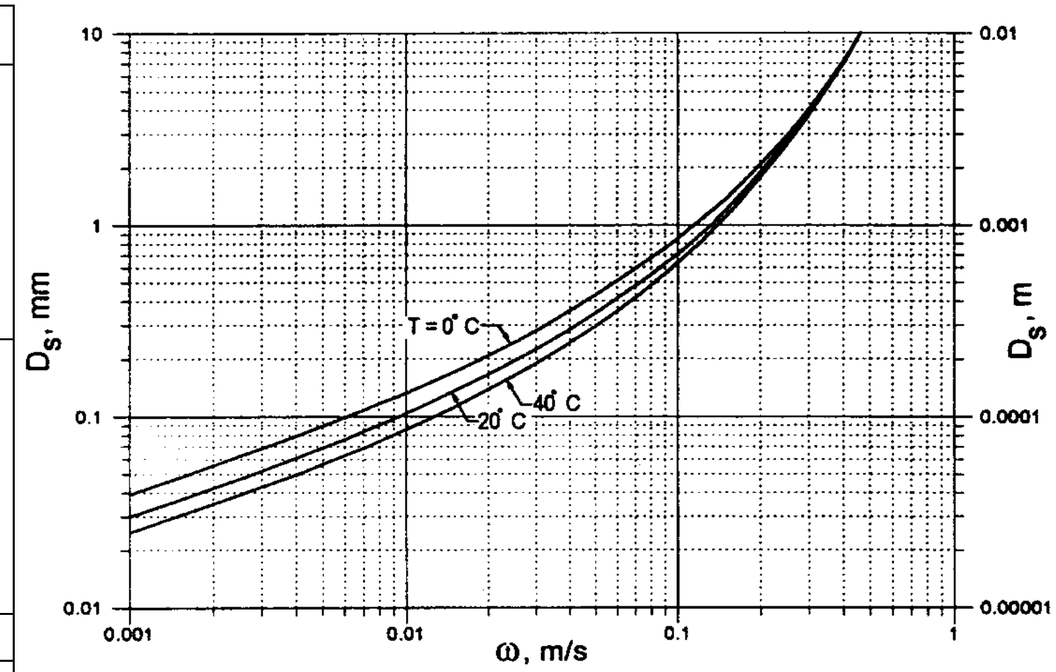


Figure 6.8 from HEC-18

From upstream cross section 168:

Shear (ϑo) =		0.24	lb/sq ft					
Hydr. Depth (y1) =		6.06	ft					
E.G. Slope (S1) =		0.00074						
V* =	(ϑo/Δ)½	=	(gy1 S1)½ft/s (m/s)					
V*=	0.352	=	0.380					

Using figure 6.8 @ T = 20 °:

1	using	0.200	mm	ω	=	0.028	m/s	0.092	ft/s
2	using	0.050	mm	ω	=	0.003	m/s	0.010	ft/s
1	V*/ω	=	4.1		k1=	0.69			
2	V*/ω	=	38.6		k1=	0.69			

From upstream cross section 168:

Channel Flow (Q1) =	505.31	cfs
Hydr. Depth (y1) =	6.06	ft
Top Width (W1) =	34.67	ft

From bridge cross section 166:

Channel Flow (Q2) =	510.00	cfs
Top Width (W2) =	14.01	ft
Depth Before Scour (y0) =	8.98	ft

1	y2=	11.41	ft
2	y2=	11.41	ft

ys=y2-y0

1	ys=	2.43	ft	w/ 0.20 mm	*
2	ys=	2.43	ft	w/ 0.05 mm	

*Reasonable Lower limit for D50 used for comparison (HEC-18 Manual, Pg 6.2, Section 2.2.1, Paragraph 2)

50 YR Abutment Scour Calculation

Cross Section Data for bridge cross section for LT

L=	166.77	ft	Abutment Length	**L/y0=**	18.6	< 25
y0=	8.98	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

Cross Section Data for bridge cross section for RT

L=	13.39	ft	Abutment Length	**L/y0 =**	1.5	< 25
y0=	8.98	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

K1	**=**	**Coefficient for abutment shape (Table 8.1)**
K2	**=**	**Coefficient for angle of embankment to flow**
K2	**=**	**(θ/90)0.13 (see Figure 8.5 for definition of θ)**
		θ<90° if embankment points downstream
		θ>90° if embankment points upstream
L´	**=**	**Length of active flow obstructed by the embankment, ft (m) (From Flow Distribution Table)**
Ae	**=**	**Flow area of the approach cross section obstructed by the embankment, ft2 (m2)**
Fr	**=**	**Froude Number of approach flow upstream of the abutment: Ve/((g*ya)^1/2))**
Ve	**=**	**Qe/Ae, ft/s (m/s)**
Qe	**=**	**Flow obstructed by the abutment and approach embankment, ft3/s (m3/s)**
ya	**=**	**Average depth of flow on the floodplain (Ae/L), ft (m)**
L	**=**	**Length of embankment projected normal to the flow, ft (m) (From Bridge Cross Section)**
ys	**=**	**Scour depth, ft (m)**

$$\frac{y_s}{y_a} = 2.27\, K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} Fr^{0.61} + 1$$

Table 8.1. Abutment Shape Coefficients

Description	K1
Vertical-wall abutment	1
Vertical-wall abutment with wing	0.82
Spill-through abutment	0.55

LEFT						RIGHT					
K1=	0.82		**ya=**	0.68	ft	**K1=**	0.82		**ya=**	2.29	ft
K2=	1.00		**Fr=**	0.07		**K2=**	1.00		**Fr=**	0.19	
L=	166.77	ft	**Ve=**	0.35	ft/s	**L=**	13.39	ft	**Ve=**	1.62	ft/s
L´=	13.78	ft	**Qe=**	39.12	ft3/s	**L´=**	13.39	ft	**Qe=**	49.61	ft3/s
			Ae=	112.73	ft2				**Ae=**	30.65	ft2
ys =	**1.62**	**ft**				**ys =**	**5.58**	**ft**			

Combined Scour Depths

Left Abutment Scour + Contraction Scour	**4.05**	**ft**
Right Abutment Scour + Contraction Scour	**8.01**	**ft**

NCHRP Live-Bed Scour Calculation

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{\frac{6}{7}}$$

$$y_{max} = \alpha_A y_c$$

$$y_s = y_{max} - y_0$$

y1=	6.06	Hydr. Depth - Upstream Section
q2c=	25.50	Total Q at BR/width of BR
q1=	14.57	Total Q at US XS / width of US XS
α_A =	1.25	
y0=	8.98	

yc=	**9.79**	ft
ymax=	**12.24**	ft
ys=	**3.26**	**ft**

50 YR CROSS SECTION 168

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q050

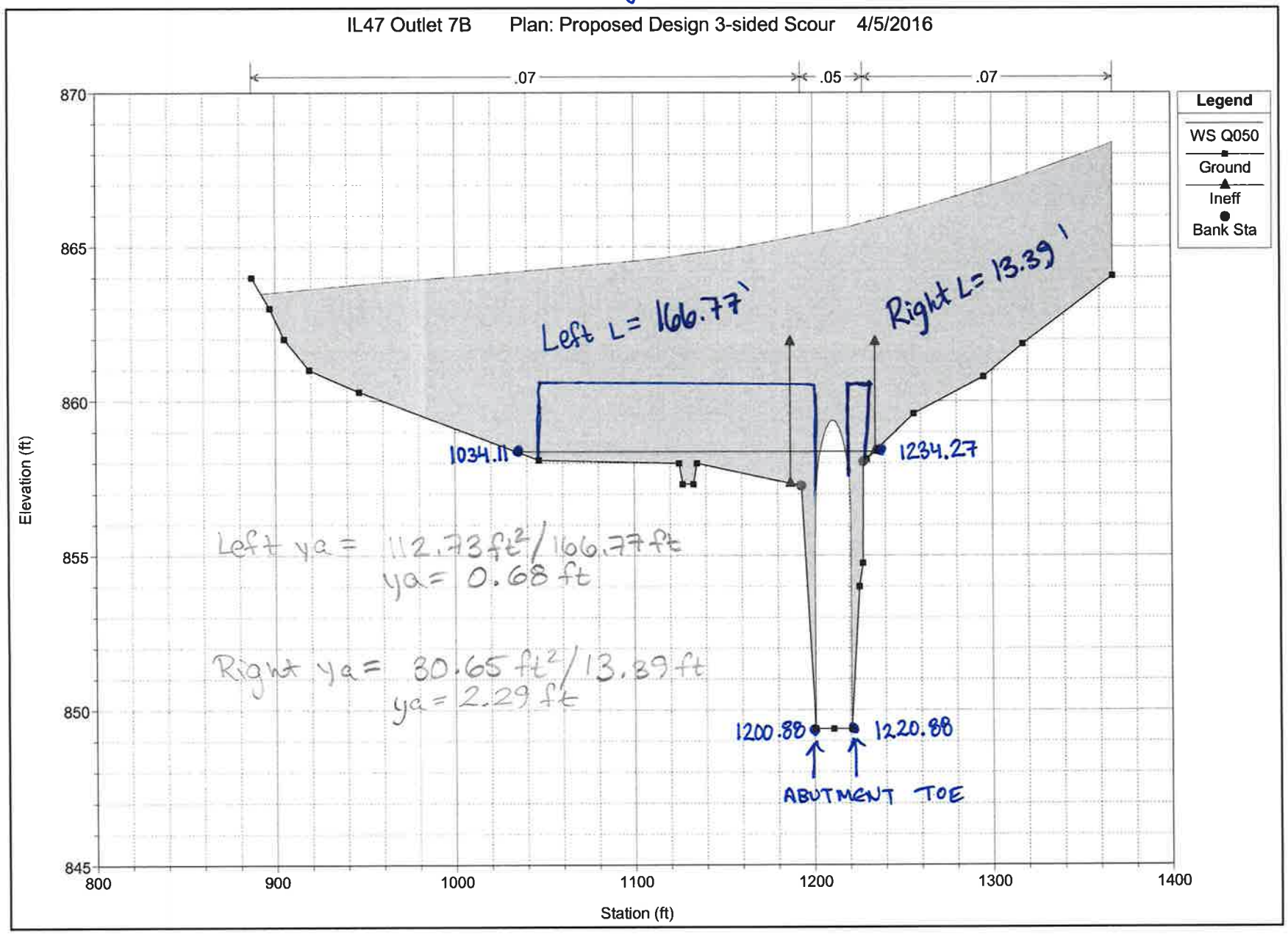
E.G. Elev (ft)	858.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.09	Wt. n-Val.	0.070	0.050	0.070
W.S. Elev (ft)	858.43	Reach Len. (ft)	13.78	13.78	13.78
Crit W.S. (ft)	853.52	Flow Area (sq ft)	6.95	210.14	1.53
E.G. Slope (ft/ft) S_1	0.000740	Area (sq ft)	89.95	210.14	1.54
Q Total (cfs)	510.00	Flow (cfs) Q_1	4.36	505.31	0.33
Top Width (ft)	204.05	Top Width (ft) W_1	161.91	34.67	7.46
Vel Total (ft/s)	2.33	Avg. Vel. (ft/s) V	0.63	2.40	0.21
Max Chl Dpth (ft)	9.24	Hydr. Depth (ft) Y_1	1.13	6.06	0.23
Conv. Total (cfs)	18753.0	Conv. (cfs)	160.3	18580.7	12.0
Length Wtd. (ft)	13.78	Wetted Per. (ft)	6.13	40.95	6.77
Min Ch El (ft)	849.19	Shear (lb/sq ft) τ_d	0.05	0.24	0.01
Alpha	1.05	Stream Power (lb/ft s)	1367.34	0.00	0.00
Frctn Loss (ft)	0.01	Cum Volume (acre-ft)	13.09	6.78	0.00
C & E Loss (ft)	0.00	Cum SA (acres)	10.81	1.26	0.02

50yr Bridge Output

Plan: Prop 3S Scour 2 7b RS: 166 Profile: Q050

E.G. US. (ft)	858.52	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	858.43	E.G. Elev (ft)	858.50	858.27
Q Total (cfs)	510.00	W.S. Elev (ft)	858.37	858.13
Q Bridge (cfs)	Q2 510.00	Crit W.S. (ft)	852.12	852.04
Q Weir (cfs)		Max Chl Dpth (ft)	Yo(4) 8.98	8.82
Weir Sta Lft (ft)		Vel Total (ft/s)	2.92	2.96
Weir Sta Rgt (ft)		Flow Area (sq ft)	174.75	172.42
Weir Submerg		Froude # Chl	0.17	0.18
Weir Max Depth (ft)		Specif Force (cu ft)	848.56	821.42
Min El Weir Flow (ft)	863.50	Hydr Depth (ft)	12.47	11.37
Min El Prs (ft)	859.39	W.P. Total (ft)	41.12	39.93
Delta EG (ft)	0.28	Conv. Total (cfs)	13625.5	13587.9
Delta WS (ft)	0.32	Top Width (ft)	W2 14.01	15.16
BR Open Area (sq ft)	184.26	Frctn Loss (ft)	0.24	0.02
BR Open Vel (ft/s)	2.96	C & E Loss (ft)	0.00	0.00
Coef of Q		Shear Total (lb/sq ft)	0.37	0.38
Br Sel Method	Energy only	Power Total (lb/ft s)	887.00	849.02

50yr - Bridge


IL47 Outlet 7B Plan: Proposed Design 3-sided Scour 4/5/2016
.07
.05
.07
Legend
WS Q050
Ground
Ineff
Bank Sta
Left L= 166.77'
Right L= 13.39'
1034.11
1234.27
Left ya = 112.73 ft²/166.77 ft
ya = 0.68 ft
Right ya = 30.65 ft²/13.39 ft
ya = 2.29 ft
1200.88
1220.88
ABUTMENT TOE
Elevation (ft)
870
865
860
855
850
845
800
900
1000
1100
1200
1300
1400
Station (ft)

168 - 50yr Flow distribution

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q050

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)
1	LOB	1007.04	1037.05	0.00	0.36	5.73	0.00	0.06	0.00	0.00	0.00
2	LOB	1037.05	1067.06	0.00	9.42	30.01	0.00	0.31	0.00	0.01	0.00
3	LOB	1067.06	1097.07	0.00	11.58	30.01	0.00	0.39	0.00	0.02	0.00
4	LOB	1097.07	1127.08	0.00	13.47	30.12	0.00	0.45	0.00	0.02	0.00
5	LOB	1127.08	1157.09	0.00	20.95	30.12	0.00	0.70	0.00	0.03	0.00
6	LOB	1157.09	1187.10	0.00	27.21	30.01	0.00	0.91	0.00	0.04	0.00
7	LOB	1187.10	1193.23	4.36	6.95	6.13	0.85	1.13	0.63	0.05	0.03
8	Chan	1193.23	1194.96	2.70	2.95	2.03	0.53	1.70	0.92	0.07	0.06
9	Chan	1194.96	1196.70	6.05	4.78	2.03	1.19	2.76	1.27	0.11	0.14
10	Chan	1196.70	1198.43	10.39	6.61	2.03	2.04	3.82	1.57	0.15	0.24
11	Chan	1198.43	1200.16	15.62	8.45	2.03	3.06	4.87	1.85	0.19	0.36
12	Chan	1200.16	1201.90	22.00	10.15	1.92	4.31	5.85	2.17	0.24	0.53
13	Chan	1201.90	1203.63	24.37	11.43	2.22	4.78	6.59	2.13	0.24	0.51
14	Chan	1203.63	1205.37	35.16	13.83	2.06	6.89	7.98	2.54	0.31	0.79
15	Chan	1205.37	1207.10	42.06	14.47	1.77	8.25	8.35	2.91	0.38	1.10
16	Chan	1207.10	1208.83	44.89	15.05	1.77	8.80	8.68	2.98	0.39	1.17
17	Chan	1208.83	1210.57	47.78	15.62	1.76	9.37	9.01	3.06	0.41	1.25
18	Chan	1210.57	1212.30	46.98	15.66	1.82	9.21	9.03	3.00	0.40	1.19
19	Chan	1212.30	1214.03	41.85	14.65	1.83	8.21	8.45	2.86	0.37	1.05
20	Chan	1214.03	1215.77	37.39	13.64	1.82	7.33	7.87	2.74	0.35	0.95
21	Chan	1215.77	1217.50	33.40	12.73	1.81	6.55	7.35	2.62	0.32	0.85
22	Chan	1217.50	1219.23	25.86	11.39	2.01	5.07	6.57	2.27	0.26	0.59
23	Chan	1219.23	1220.97	19.52	9.62	2.01	3.83	5.55	2.03	0.22	0.45
24	Chan	1220.97	1222.70	16.60	8.33	1.79	3.26	4.81	1.99	0.21	0.43
25	Chan	1222.70	1224.43	14.79	7.73	1.77	2.90	4.46	1.91	0.20	0.39
26	Chan	1224.43	1226.17	12.95	7.14	1.77	2.54	4.12	1.81	0.19	0.34
27	Chan	1226.17	1227.90	4.94	5.92	4.69	0.97	3.41	0.83	0.06	0.05
28	ROB	1227.90	1234.66	0.33	1.53	6.77	0.06	0.23	0.21	0.01	0.00
29	ROB	1234.66	1247.93	0.00	0.01	0.71	0.00	0.02	0.00	0.00	0.00

Left Q_E: 39.12 cfs

Left A_E: 112.73 ft^2

Right Q_E: 49.61 cfs

Right A_E: 30.65 ft^2

Left L': 1200.88' − 1187.10' = 13.78'

Right L': 1234.27' − 1220.88' = 13.39'

L' Calculation for 50 YR

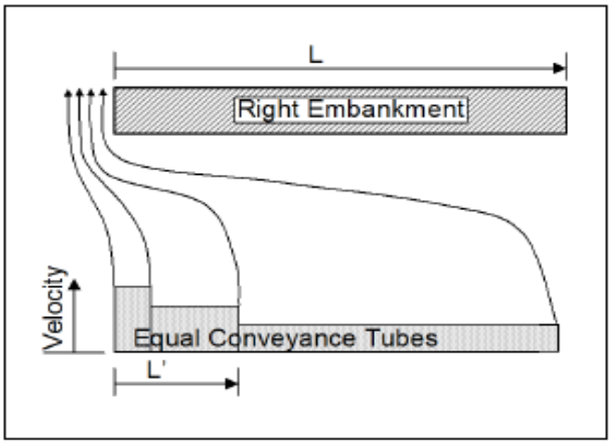


Figure 8.4. Determination of length of embankment blocking live flow for abutment scour estimation.

The flow distribution table for cross section 168 was used to get an approximate value for the L'. The column labeled "Flow" represents the volume of flow in each flow tube. The flow significantly increases at station 1187.10; this station was used to measure the left overbank. The L' for the left side would be the station at the toe of the left abutment 1200.88 subtracted by 1187.10 found from the flow distribution tables. Since the right overbank does not have a significantly wide L distance, L' for the right overbank equals the legnth L. This judgement is based off of section 8.2.2 and Figure 8.4 in the HEC-18 Manual.

100 Year Scour Analysis

100 YR Contraction Scour Calculation

where: $V_C = K_u y_1^{1/6} D^{1/3}$

Vc	=	Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y	=	Average depth of flow upstream of the bridge, ft (m)
D	=	Particle size for Vc, ft (m)
D50	=	Particle size in a mixture of which 50 percent are smaller, ft (m)
Ku	=	6.19 SI units
Ku	=	11.17 English units

If the critical velocity of the bed material is larger than the mean velocity (Vc > V), then clear-water contraction scour will exist. If the critical velocity is less than the mean velocity (Vc < V), then live-bed contraction scour will exist. To calculate the critical velocity use the equation derived in the Appendix C.

From upstream cross section 168:

Hydraulic Depth (y1) = 6.49 ft Velocity Total (V) = 2.62 ft/s

1	Vc=	1.33	f/s	using	0.200	mm	Vc < V	Live-Bed
2	Vc=	0.84	f/s	using	0.050	mm	Vc < V	Live-Bed

Live-Bed Contraction Scour

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7}\left(\frac{W_1}{W_2}\right)^{k_1}$$

y1	=	Average depth in the upstream main channel, ft (m)
y2	=	Average depth in the contracted section, ft (m)
yo	=	Existing depth in the contracted section before scour, ft (m)
Q1	=	Flow in the upstream channel transporting sediment, ft3/s (m3/s)
Q2	=	Flow in the contracted channel, ft3/s (m3/s)
W1	=	Bottom width of the upstream main channel that is transporting bed material, ft (m)
W2	=	Bottom width of main channel in contracted section less pier width(s), ft (m)
k1	=	Exponent determined below

V*/ω	k1	Mode of Bed Material Transport
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

V*	=	(ϑo/Δ)½ = (gy1 S1)½, shear velocity in the upstream section, ft/s (m/s)
ω	=	Fall velocity of bed material based on the D50, m/s (Figure 6.8)
		For fall velocity in English units (ft/s) multiply ω in m/s by 3.28
g	=	Acceleration of gravity (32.2 ft/s2) (9.81 m/s2)
S1	=	Slope of energy grade line of main channel, ft/ft (m/m)
ϑo	=	Shear stress on the bed, (lb/ft2) (Pa (N/m2))
Δ	=	Density of water (1.94 slugs/ft3) (1000 kg/m3)

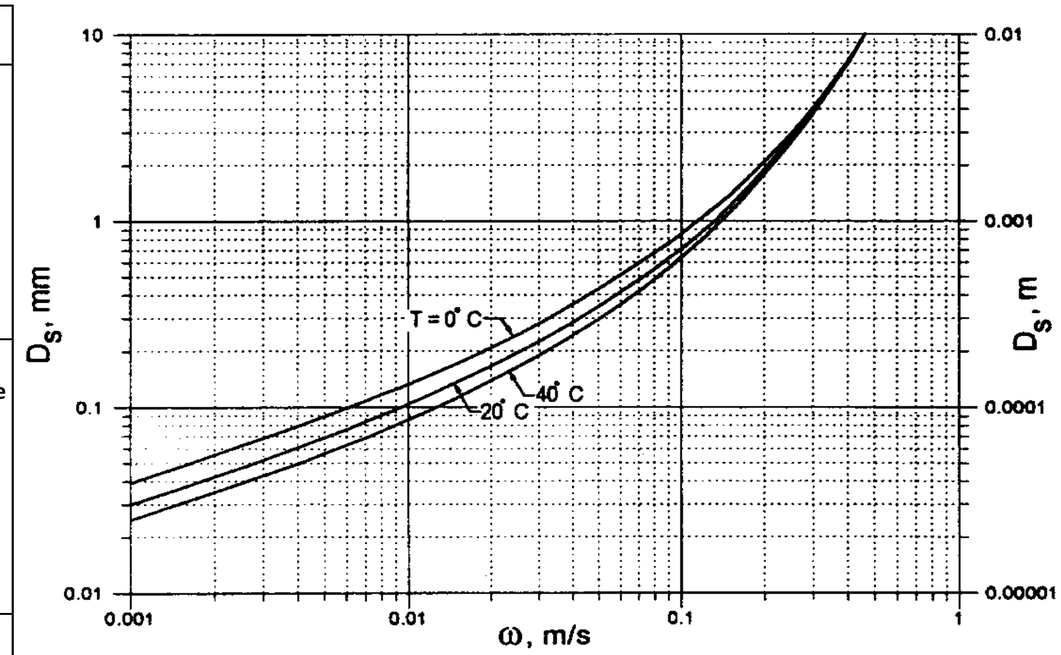


Figure 6.8 from HEC-18

From upstream cross section 168:

Shear (ϑo) =	0.28	lb/sq ft
Hydr. Depth (y1) =	6.49	ft
E.G. Slope (S1) =	0.0008	

V* = (ϑo/Δ)½ = (gy1 S1)½ft/s (m/s)

V*= 0.380 = 0.410

Using figure 6.8 @ T = 20 °:

1	using	0.200	mm	ω	=	0.028	m/s	0.092	ft/s
2	using	0.050	mm	ω	=	0.003	m/s	0.010	ft/s
1	V*/ω	=	4.5		k1=	0.69			
2	V*/ω	=	41.6		k1=	0.69			

From upstream cross section 168:

Channel Flow (Q1) =	590.22	cfs
Hydr. Depth (y1) =	6.49	ft
Top Width (W1) =	34.67	ft

From bridge cross section 166:

Channel Flow (Q2) =	600.00	cfs
Top Width (W2) =	10.97	ft
Depth Before Scour (y0) =	9.38	ft

1	y2=	14.56	ft
2	y2=	14.56	ft

ys=y2-y0

1	ys=	5.18	ft	w/ 0.20 mm *
2	ys=	5.18	ft	w/ 0.05 mm

*Reasonable Lower limit for D50 used for comparison (HEC-18 Manual, Pg 6.2, Section 2.2.1, Paragraph 2)

100 YR Abutment Scour Calculation

Cross Section Data for bridge cross section for LT

L=	185.03	ft	Abutment Length	**L/y0 =**	19.7	< 25
y0=	9.38	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

Cross Section Data for bridge cross section for RT

L=	20.58	ft	Abutment Length	**L/y0 =**	2.2	< 25
y0=	9.38	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

K1	**=**	**Coefficient for abutment shape (Table 8.1)**
K2	**=**	**Coefficient for angle of embankment to flow**
K2	**=**	**(θ/90)0.13 (see Figure 8.5 for definition of θ)**
		θ<90° if embankment points downstream
		θ>90° if embankment points upstream
L´	**=**	**Length of active flow obstructed by the embankment, ft (m) (From Flow Distribution Table)**
Ae	**=**	**Flow area of the approach cross section obstructed by the embankment, ft2 (m2)**
Fr	**=**	**Froude Number of approach flow upstream of the abutment: Ve/((g*ya)^1/2))**
Ve	**=**	**Qe/Ae, ft/s (m/s)**
Qe	**=**	**Flow obstructed by the abutment and approach embankment, ft3/s (m3/s)**
ya	**=**	**Average depth of flow on the floodplain (Ae/L), ft (m)**
L	**=**	**Length of embankment projected normal to the flow, ft (m) (From Bridge Cross Section)**
ys	**=**	**Scour depth, ft (m)**

$$\frac{y_s}{y_a} = 2.27\, K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} Fr^{0.61} + 1$$

Table 8.1. Abutment Shape Coefficients

Description	K1
Vertical-wall abutment	1
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

LEFT						RIGHT					
K1=	0.82		**ya=**	1.03	ft	**K1=**	0.82		**ya=**	1.78	ft
K2=	1.00		**Fr=**	0.05		**K2=**	1.00		**Fr=**	0.23	
L=	185.03	ft	**Ve=**	0.27	ft/s	**L=**	20.58	ft	**Ve=**	1.72	ft/s
L´=	13.78	ft	**Qe=**	52.03	ft3/s	**L´=**	13.78	ft	**Qe=**	62.74	ft3/s
			Ae=	189.68	ft2				**Ae=**	36.55	ft2
ys =	**1.94**	**ft**				**ys =**	**5.00**	**ft**			

Combined Scour Depths

Left Abutment Scour + Contraction Scour	**7.12**	**ft**
Right Abutment Scour + Contraction Scour	**10.19**	**ft**

NCHRP Live-Bed Scour Calculation

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{\frac{6}{7}}$$

$$y_{max} = \alpha_A y_c$$

$$y_s = y_{max} - y_0$$

y1=	6.49	Hydr. Depth - Upstream Section
q2c=	30.00	Total Q at BR/width of BR
q1=	17.02	Total Q at US XS / width of US XS
α_A =	1.23	
y0=	9.38	

yc=	**10.55**	ft
ymax=	**12.97**	ft
ys=	**3.59**	**ft**

100 YR CROSS SECTION 168

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q100

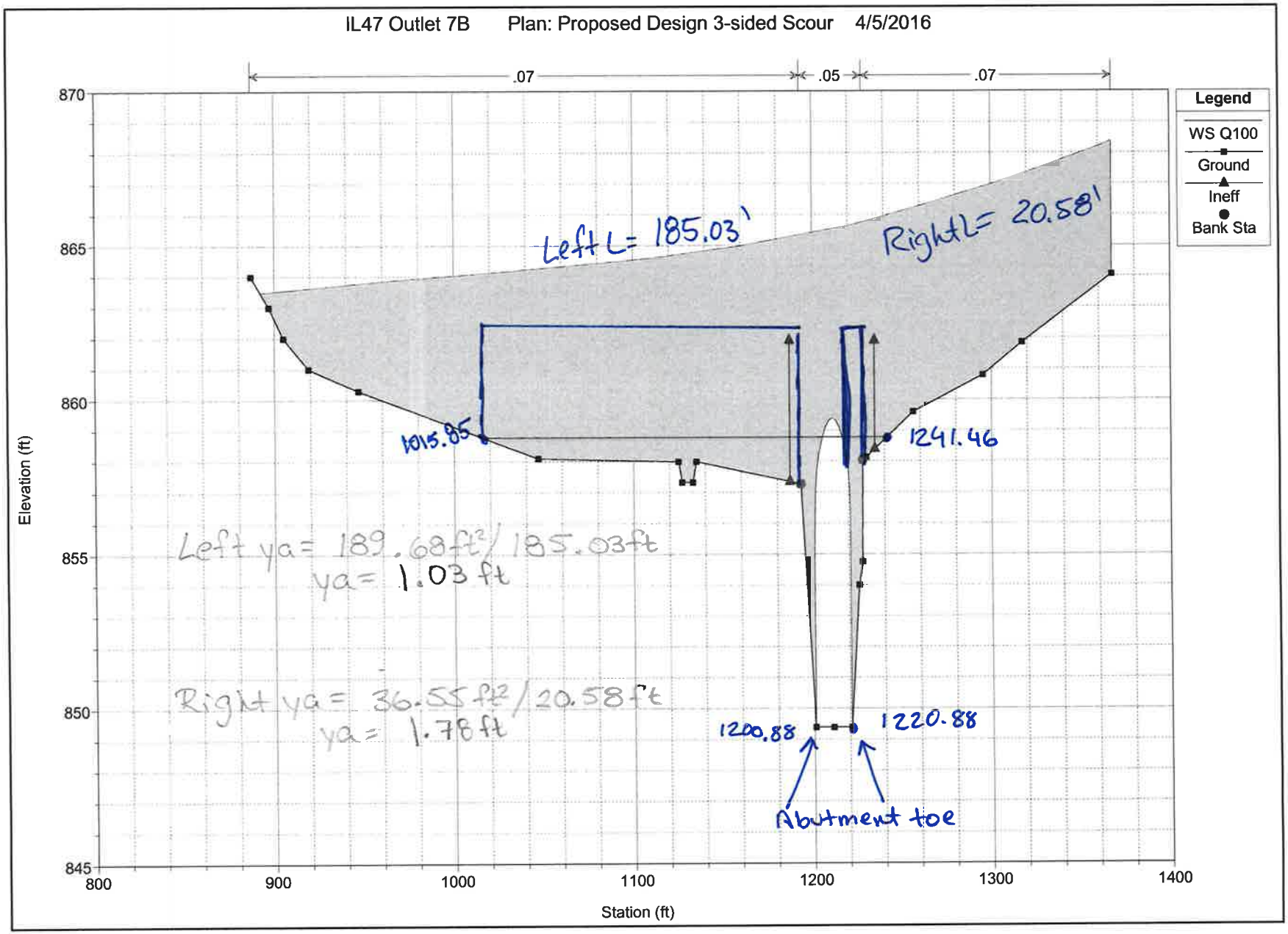
E.G. Elev (ft)	858.97	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.11	Wt. n-Val.	0.070	0.050	0.070
W.S. Elev (ft)	858.86	Reach Len. (ft)	13.78	13.78	13.78
Crit W.S. (ft)	853.89	Flow Area (sq ft)	9.59	225.07	4.44
E.G. Slope (ft/ft) S_1	0.000803	Area (sq ft)	163.91	225.07	6.42
Q Total (cfs)	600.00	Flow (cfs) Q_1	7.77	590.22	2.01
Top Width (ft)	231.37	Top Width (ft) W_1	181.52	34.67	15.19
Vel Total (ft/s)	2.51	Avg. Vel. (ft/s) V	0.81	2.62	0.45
Max Chl Dpth (ft)	9.67	Hydr. Depth (ft) y_1	1.56	6.49	0.66
Conv. Total (cfs)	21178.4	Conv. (cfs)	274.2	20833.1	71.1
Length Wtd. (ft)	13.78	Wetted Per. (ft)	6.13	40.95	6.77
Min Ch El (ft)	849.19	Shear (lb/sq ft) τ_0	0.08	0.28	0.03
Alpha	1.08	Stream Power (lb/ft s)	1367.34	0.00	0.00
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	16.11	7.12	0.01
C & E Loss (ft)	0.01	Cum SA (acres)	12.01	1.27	0.03

100 yr - Bridge Output

Plan: Prop 3S Scour 2 7b RS: 166 Profile: Q100

E.G. US. (ft)	858.97	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	858.86	E.G. Elev (ft)	858.94	858.62
Q Total (cfs)	600.00	W.S. Elev (ft)	858.77	858.44
Q Bridge (cfs)	Q_2 600.00	Crit W.S. (ft)	852.43	852.35
Q Weir (cfs)		Max Chl Dpth (ft)	y_0, y 9.38	9.13
Weir Sta Lft (ft)		Vel Total (ft/s)	3.34	3.39
Weir Sta Rgt (ft)		Flow Area (sq ft)	179.79	176.75
Weir Submerg		Froude # Chl	0.19	0.20
Weir Max Depth (ft)		Specif Force (cu ft)	935.66	891.69
Min El Weir Flow (ft)	863.50	Hydr Depth (ft)	16.39	13.65
Min El Prs (ft)	859.39	W.P. Total (ft)	44.27	42.23
Delta EG (ft)	0.38	Conv. Total (cfs)	13601.0	13642.6
Delta WS (ft)	0.44	Top Width (ft)	W_2 10.97	12.95
BR Open Area (sq ft)	184.26	Frctn Loss (ft)	0.33	0.03
BR Open Vel (ft/s)	3.39	C & E Loss (ft)	0.00	0.00
Coef of Q		Shear Total (lb/sq ft)	0.49	0.51
Br Sel Method	Energy only	Power Total (lb/ft s)	887.00	849.02

100yr - Bridge



168- 100yr Flow distribution

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q100

	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)
1	LOB	1007.04	1037.05	0.00	7.05	25.34	0.00	0.28	0.00	0.01	0.00
2	LOB	1037.05	1067.06	0.00	22.35	30.01	0.00	0.74	0.00	0.04	0.00
3	LOB	1067.06	1097.07	0.00	24.50	30.01	0.00	0.82	0.00	0.04	0.00
4	LOB	1097.07	1127.08	0.00	26.40	30.12	0.00	0.88	0.00	0.04	0.00
5	LOB	1127.08	1157.09	0.00	33.88	30.12	0.00	1.13	0.00	0.06	0.00
6	LOB	1157.09	1187.10	0.00	40.14	30.01	0.00	1.34	0.00	0.07	0.00
7	LOB	1187.10	1193.23	7.77	9.59	6.13	1.29	1.56	0.81	0.08	0.06
8	Chan	1193.23	1194.96	4.14	3.69	2.03	0.69	2.13	1.12	0.09	0.10
9	Chan	1194.96	1196.70	8.11	5.53	2.03	1.35	3.19	1.47	0.14	0.20
10	Chan	1196.70	1198.43	13.07	7.36	2.03	2.18	4.25	1.78	0.18	0.32
11	Chan	1198.43	1200.16	18.94	9.19	2.03	3.16	5.30	2.06	0.23	0.47
12	Chan	1200.16	1201.90	26.07	10.89	1.92	4.34	6.28	2.39	0.28	0.68
13	Chan	1201.90	1203.63	28.50	12.18	2.22	4.75	7.02	2.34	0.27	0.64
14	Chan	1203.63	1205.37	40.40	14.58	2.06	6.73	8.41	2.77	0.35	0.98
15	Chan	1205.37	1207.10	48.14	15.22	1.77	8.02	8.78	3.16	0.43	1.37
16	Chan	1207.10	1208.83	51.22	15.79	1.77	8.54	9.11	3.24	0.45	1.45
17	Chan	1208.83	1210.57	54.37	16.37	1.76	9.06	9.44	3.32	0.46	1.54
18	Chan	1210.57	1212.30	53.44	16.40	1.82	8.91	9.46	3.26	0.45	1.47
19	Chan	1212.30	1214.03	47.86	15.39	1.83	7.98	8.88	3.11	0.42	1.31
20	Chan	1214.03	1215.77	43.01	14.39	1.82	7.17	8.30	2.99	0.40	1.19
21	Chan	1215.77	1217.50	38.66	13.48	1.81	6.44	7.78	2.87	0.37	1.07
22	Chan	1217.50	1219.23	30.26	12.14	2.01	5.04	7.00	2.49	0.30	0.75
23	Chan	1219.23	1220.97	23.27	10.37	2.01	3.88	5.98	2.24	0.26	0.58
24	Chan	1220.97	1222.70	20.16	9.08	1.79	3.36	5.24	2.22	0.25	0.56
25	Chan	1222.70	1224.43	18.15	8.48	1.77	3.03	4.89	2.14	0.24	0.51
26	Chan	1224.43	1226.17	16.09	7.89	1.77	2.68	4.55	2.04	0.22	0.46
27	Chan	1226.17	1227.90	6.33	6.66	4.69	1.06	3.84	0.95	0.07	0.07
28	ROB	1227.90	1234.66	2.01	4.44	6.77	0.34	0.66	0.45	0.03	0.01
29	ROB	1234.66	1247.93	0.00	1.98	8.44	0.00	0.23	0.00	0.01	0.00

Left Q_E: 52.03 cfs

Left A_E: 189.68 ft^2

Right Q_E: 62.74 cfs

Right A_E: 36.55 ft^2

Left L': 1200.88' − 1187.10' = 13.78'

Right L': 1234.66' − 1220.88' = 13.78'

L' Calculation for 100 YR

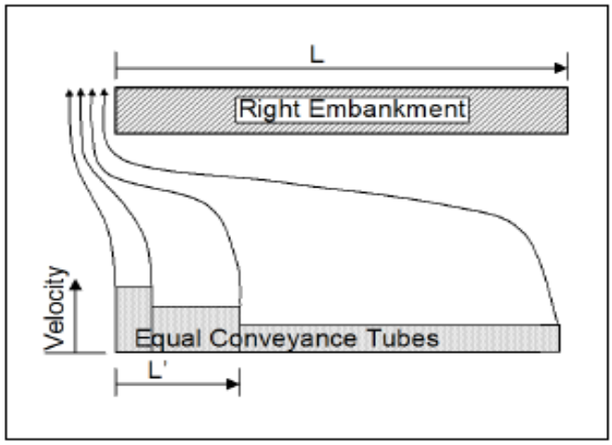


Figure 8.4. Determination of length of embankment blocking live flow for abutment scour estimation.

Cross section 168 just upstream of the bridge was used to examine the flow distributions in the channel. The column labeled "Flow" represents the volume of flow in each flow tube. The flow significantly increases between stations 1187.10 to 1200.88, therefore station 1187.10 was used to measure the L' for the left overbank. The L' for the left side would be the station at the toe of the left abutment 1200.88 subtracted by 1187.10 found from the flow distribution tables. For the right overbank, stations 1234.66 to 1220.88 at the abutment toe showed significant flow. The distance between them was used as the L'. This judgement is based off of section 8.2.2 and Figure 8.4 in the HEC-18 Manual.

200 Year Scour Analysis

200 YR Contraction Scour Calculation

where: $V_C = K_u y_1^{1/6} D^{1/3}$

Vc	=	Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y	=	Average depth of flow upstream of the bridge, ft (m)
D	=	Particle size for Vc, ft (m)
D50	=	Particle size in a mixture of which 50 percent are smaller, ft (m)
Ku	=	6.19 SI units
Ku	=	11.17 English units

If the critical velocity of the bed material is larger than the mean velocity (Vc > V), then clear-water contraction scour will exist. If the critical velocity is less than the mean velocity (Vc < V), then live-bed contraction scour will exist. To calculate the critical velocity use the equation derived in the Appendix C.

From upstream cross section 168:

Hydraulic Depth (y1) = 7.19 ft Velocity Total (V) = 2.80 ft/s

1	Vc=	1.35	f/s	using	0.200	mm	Vc < V	Live-Bed
2	Vc=	0.85	f/s	using	0.050	mm	Vc < V	Live-Bed

Live-Bed Contraction Scour

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7}\left(\frac{W_1}{W_2}\right)^{k_1}$$

y1	=	Average depth in the upstream main channel, ft (m)
y2	=	Average depth in the contracted section, ft (m)
yo	=	Existing depth in the contracted section before scour, ft (m)
Q1	=	Flow in the upstream channel transporting sediment, ft3/s (m3/s)
Q2	=	Flow in the contracted channel, ft3/s (m3/s)
W1	=	Bottom width of the upstream main channel that is transporting bed material, ft (m)
W2	=	Bottom width of main channel in contracted section less pier width(s), ft (m)
k1	=	Exponent determined below

V*/ω	k1	Mode of Bed Material Transport
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

V*	=	(ϑo/Δ)½ = (gy1 S1)½, shear velocity in the upstream section, ft/s (m/s)
ω	=	Fall velocity of bed material based on the D50, m/s (Figure 6.8)
		For fall velocity in English units (ft/s) multiply ω in m/s by 3.28
g	=	Acceleration of gravity (32.2 ft/s2) (9.81 m/s2)
S1	=	Slope of energy grade line of main channel, ft/ft (m/m)
ϑo	=	Shear stress on the bed, (lb/ft2) (Pa (N/m2))
Δ	=	Density of water (1.94 slugs/ft3) (1000 kg/m3)

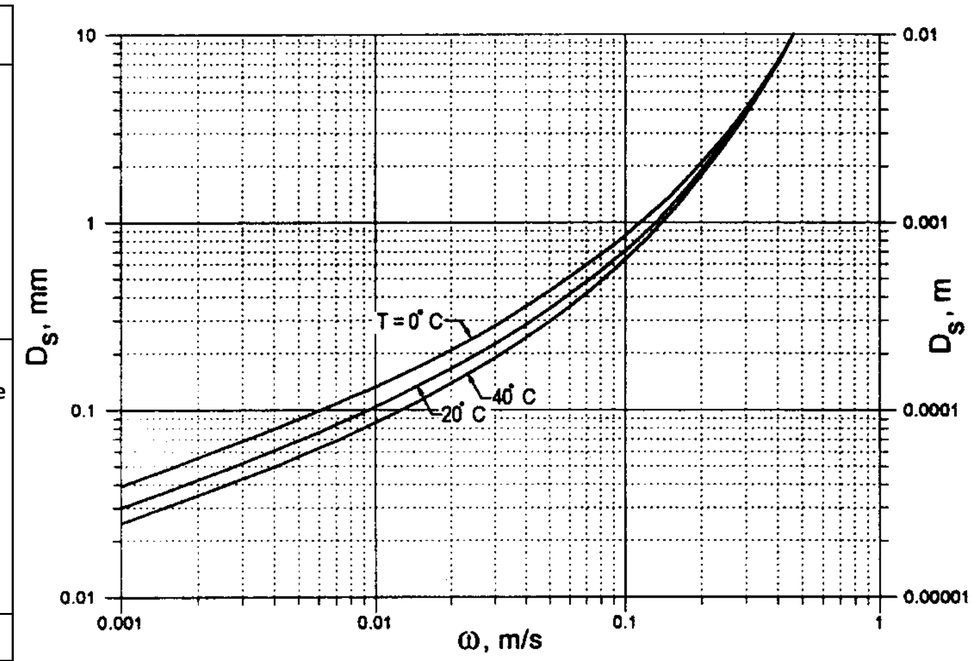


Figure 6.8 from HEC-18

From upstream cross section 168:

Shear (ϑo) =	0.3	lb/sq ft
Hydr. Depth (y1) =	7.19	ft
E.G. Slope (S1) =	0.0008	

V* = (ϑo/Δ)½ = (gy1 S1)½ft/s (m/s)

V*= 0.393 = 0.430

Using figure 6.8 @ T = 20 °:

1	using	0.200	mm	ω	=	0.028	m/s	0.092	ft/s
2	using	0.050	mm	ω	=	0.003	m/s	0.010	ft/s
1	V*/ω	=	4.7		k1=	0.69			
2	V*/ω	=	43.7		k1=	0.69			

From upstream cross section 168:

Channel Flow (Q1) =	698.87	cfs
Hydr. Depth (y1) =	7.19	ft
Top Width (W1) =	34.67	ft

From bridge cross section 166:

Channel Flow (Q2) =	720.00	cfs
Top Width (W2) =	20.00	ft
Depth Before Scour (y0) =	10.00	ft

1	y2=	10.78	ft
2	y2=	10.78	ft

ys=y2-y0

1	ys=	0.78	ft	w/ 0.20 mm *
2	ys=	0.78	ft	w/ 0.05 mm

*Reasonable Lower limit for D50 used for comparison (HEC-18 Manual, Pg 6.2, Section 2.2.1, Paragraph 2)

200 YR Abutment Scour Calculation

Cross Section Data for bridge cross section for LT

L=	212.61	ft	Abutment Length	**L/y0 =**	21.3	< 25
y0=	10.00	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

Cross Section Data for bridge cross section for RT

L=	30.50	ft	Abutment Length	**L/y0 =**	3.1	< 25
y0=	10.00	ft	Depth of flow in main channel	**HIRE equation is not applicable: use Froehlich's**		

K1	**=**	**Coefficient for abutment shape (Table 8.1)**
K2	**=**	**Coefficient for angle of embankment to flow**
K2	**=**	**(θ/90)0.13 (see Figure 8.5 for definition of θ)**
		θ<90° if embankment points downstream
		θ>90° if embankment points upstream
L´	**=**	**Length of active flow obstructed by the embankment, ft (m) (From Flow Distribution Table)**
Ae	**=**	**Flow area of the approach cross section obstructed by the embankment, ft2 (m2)**
Fr	**=**	**Froude Number of approach flow upstream of the abutment: Ve/((g*ya)^1/2))**
Ve	**=**	**Qe/Ae, ft/s (m/s)**
Qe	**=**	**Flow obstructed by the abutment and approach embankment, ft3/s (m3/s)**
ya	**=**	**Average depth of flow on the floodplain (Ae/L), ft (m)**
L	**=**	**Length of embankment projected normal to the flow, ft (m) (From Bridge Cross Section)**
ys	**=**	**Scour depth, ft (m)**

$$\frac{y_s}{y_a} = 2.27\, K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} Fr^{0.61} + 1$$

Table 8.1. Abutment Shape Coefficients

Description	K1
Vertical-wall abutment	1
Vertical-wall abutment with wing	0.82
Spill-through abutment	0.55

LEFT						RIGHT					
K1=	0.82		**ya=**	1.57	ft	**K1=**	0.82		**ya=**	1.86	ft
K2=	1.00		**Fr=**	0.03		**K2=**	1.00		**Fr=**	0.19	
L=	212.61	ft	**Ve=**	0.22	ft/s	**L=**	30.50	ft	**Ve=**	1.48	ft/s
L´=	13.78	ft	**Qe=**	73.16	ft3/s	**L´=**	13.78	ft	**Qe=**	83.99	ft3/s
			Ae=	333.15	ft2				**Ae=**	56.79	ft2
ys =	**2.46**	**ft**				**ys =**	**4.85**	**ft**			

Combined Scour Depths

Left Abutment Scour + Contraction Scour	**3.24**	**ft**
Right Abutment Scour + Contraction Scour	**5.63**	**ft**

NCHRP Live-Bed Scour Calculation

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{\frac{6}{7}}$$

$$y_{max} = \alpha_A y_c$$

$$y_s = y_{max} - y_0$$

y1=	7.19	Hydr. Depth - Upstream Section
q2c=	30.00	Total Q at BR/width of BR
q1=	20.16	Total Q at US XS / width of US XS
α_A =	1.23	
y0=	10.00	

yc=	**10.11**	ft
ymax=	**12.43**	ft
ys=	**2.43**	**ft**

200 YR FLOW CROSS SECTION 168

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q200

E.G. Elev (ft)	859.68	Element		Left OB	Channel	Right OB
Vel Head (ft)	0.12	Wt. n-Val.		0.070	0.050	0.070
W.S. Elev (ft)	859.56	Reach Len. (ft)		13.78	13.78	13.78
Crit W.S. (ft)	854.33	Flow Area (sq ft)		13.89	249.41	9.18
E.G. Slope (ft/ft) S_1	0.000799	Area (sq ft)		302.51	249.41	21.49
Q Total (cfs)	720.00	Flow (cfs)	Q_1	14.38	698.87	6.75
Top Width (ft)	275.90	Top Width (ft)	W_1	213.46	34.67	27.77
Vel Total (ft/s)	2.64	Avg. Vel. (ft/s)	V	1.04	2.80	0.74
Max Chl Dpth (ft)	10.37	Hydr. Depth (ft)	Y_1	2.27	7.19	1.36
Conv. Total (cfs)	25468.1	Conv. (cfs)		508.6	24720.6	238.9
Length Wtd. (ft)	13.78	Wetted Per. (ft)		6.13	40.95	6.77
Min Ch El (ft)	849.19	Shear (lb/sq ft)	τ_o	0.11	0.30	0.07
Alpha	1.10	Stream Power (lb/ft s)		1367.34	0.00	0.00
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)		22.40	7.74	0.08
C & E Loss (ft)	0.01	Cum SA (acres)		14.19	1.28	0.31

200 yr - Bridge Output

Plan: Prop 3S Scour 2 7b RS: 166 Profile: Q200

E.G. US. (ft)	859.68	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	859.56	E.G. Elev (ft)	859.65	859.12
Q Total (cfs)	720.00	W.S. Elev (ft)	859.41	858.88
Q Bridge (cfs)	Q2 720.00	Crit W.S. (ft)	852.83	852.75
Q Weir (cfs)		Max Chl Dpth (ft)	10.02	9.57
Weir Sta Lft (ft)		Vel Total (ft/s)	3.91	3.96
Weir Sta Rgt (ft)		Flow Area (sq ft)	184.26	181.65
Weir Submerg		Froude # Chl	0.22	0.23
Weir Max Depth (ft)		Specif Force (cu ft)	1078.13	995.69
Min El Weir Flow (ft)	863.50	Hydr Depth (ft)		20.03
Min El Prs (ft)	859.39	W.P. Total (ft)	55.33	46.21
Delta EG (ft)	0.61	Conv. Total (cfs)	12210.8	13446.8
Delta WS (ft)	0.70	Top Width (ft)		9.07
BR Open Area (sq ft)	184.26	Frctn Loss (ft)	0.53	0.04
BR Open Vel (ft/s)	3.96	C & E Loss (ft)	0.00	0.01
Coef of Q		Shear Total (lb/sq ft)	0.72	0.70
Br Sel Method	Energy only	Power Total (lb/ft s)	887.00	849.02

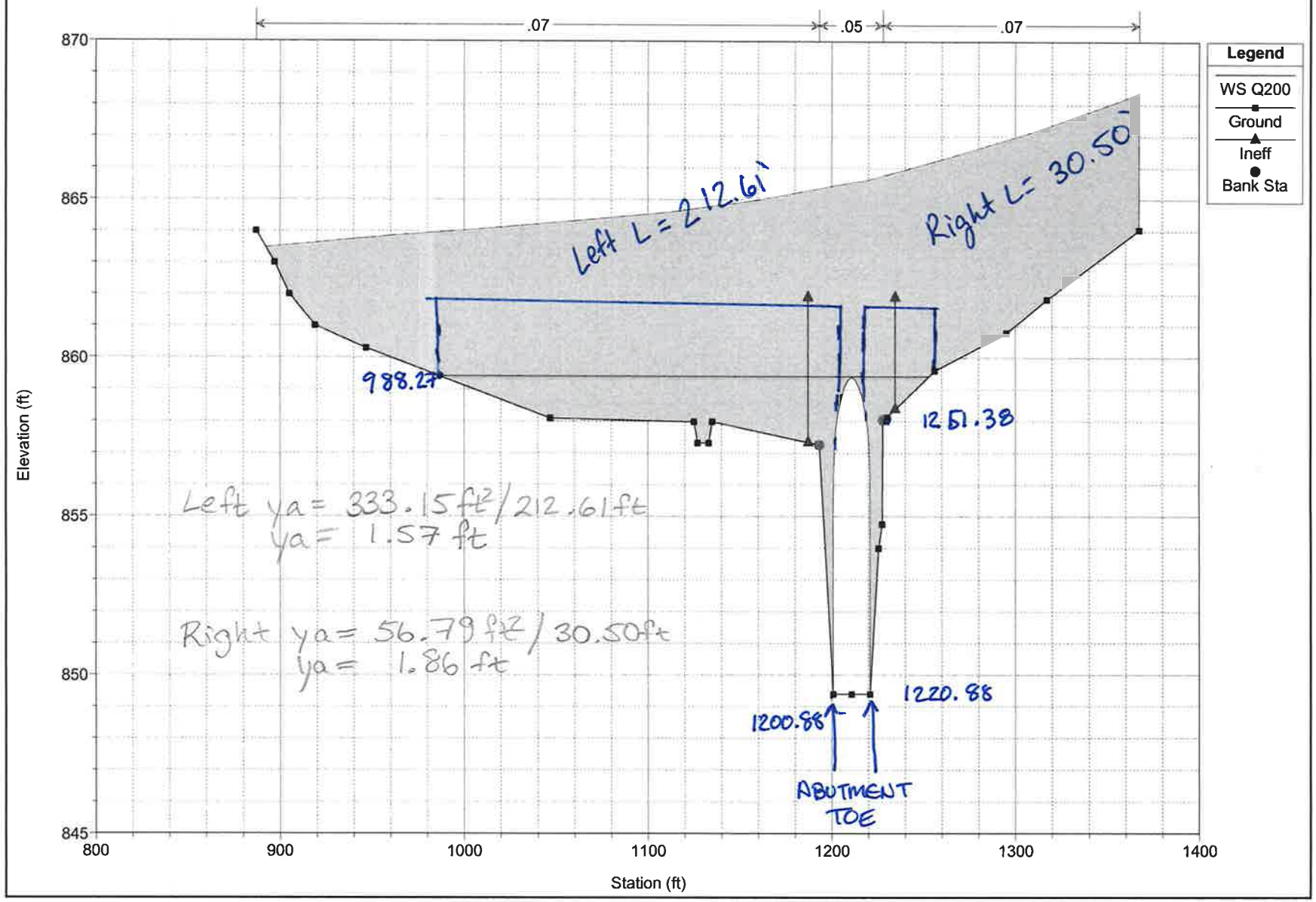
$y_o = 10ft$

$y = 10ft$

$W_2 = 20ft$

* pressure flow

IL47 Outlet 7B Plan: Proposed Design 3-sided Scour 4/5/2016



168 200 yr Flow Distribution

Plan: Prop 3S Scour 2 7b RS: 168 Profile: Q200

	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(ft)	(ft)	(cfs)	(sq ft)	(ft)	Conv	Depth(ft)	(ft/s)	(lb/sq ft)	(lb/ft s)
1	LOB	977.03	1007.04	0.00	8.17	27.27	0.00	0.30	0.00	0.01	0.00
2	LOB	1007.04	1037.05	0.00	27.87	30.02	0.00	0.93	0.00	0.05	0.00
3	LOB	1037.05	1067.06	0.00	43.41	30.01	0.00	1.45	0.00	0.07	0.00
4	LOB	1067.06	1097.07	0.00	45.57	30.01	0.00	1.52	0.00	0.08	0.00
5	LOB	1097.07	1127.08	0.00	47.46	30.12	0.00	1.58	0.00	0.08	0.00
6	LOB	1127.08	1157.09	0.00	54.94	30.12	0.00	1.83	0.00	0.09	0.00
7	LOB	1157.09	1187.10	0.00	61.20	30.01	0.00	2.04	0.00	0.10	0.00
8	LOB	1187.10	1193.23	14.38	13.89	6.13	2.00	2.27	1.04	0.11	0.12
9	Chan	1193.23	1194.96	6.73	4.91	2.03	0.94	2.83	1.37	0.12	0.17
10	Chan	1194.96	1196.70	11.43	6.74	2.03	1.59	3.89	1.69	0.17	0.28
11	Chan	1196.70	1198.43	17.06	8.58	2.03	2.37	4.95	1.99	0.21	0.42
12	Chan	1198.43	1200.16	23.56	10.41	2.03	3.27	6.01	2.26	0.26	0.58
13	Chan	1200.16	1201.90	31.45	12.11	1.92	4.37	6.99	2.60	0.31	0.82
14	Chan	1201.90	1203.63	33.78	13.39	2.22	4.69	7.73	2.52	0.30	0.76
15	Chan	1203.63	1205.37	46.70	15.79	2.06	6.49	9.11	2.96	0.38	1.13
16	Chan	1205.37	1207.10	55.35	16.43	1.77	7.69	9.48	3.37	0.46	1.56
17	Chan	1207.10	1208.83	58.62	17.01	1.77	8.14	9.81	3.45	0.48	1.66
18	Chan	1208.83	1210.57	61.96	17.58	1.76	8.61	10.14	3.52	0.50	1.75
19	Chan	1210.57	1212.30	60.89	17.62	1.82	8.46	10.16	3.46	0.48	1.67
20	Chan	1212.30	1214.03	54.94	16.61	1.83	7.63	9.58	3.31	0.45	1.50
21	Chan	1214.03	1215.77	49.80	15.61	1.82	6.92	9.00	3.19	0.43	1.37
22	Chan	1215.77	1217.50	45.16	14.70	1.81	6.27	8.48	3.07	0.40	1.24
23	Chan	1217.50	1219.23	35.89	13.35	2.01	4.98	7.70	2.69	0.33	0.89
24	Chan	1219.23	1220.97	28.32	11.58	2.01	3.93	6.68	2.44	0.29	0.70
25	Chan	1220.97	1222.70	25.15	10.29	1.79	3.49	5.94	2.44	0.29	0.70
26	Chan	1222.70	1224.43	22.96	9.70	1.77	3.19	5.59	2.37	0.27	0.65
27	Chan	1224.43	1226.17	20.66	9.10	1.77	2.87	5.25	2.27	0.26	0.58
28	Chan	1226.17	1227.90	8.47	7.88	4.69	1.18	4.55	1.08	0.08	0.09
29	ROB	1227.90	1234.66	6.75	9.18	6.77	0.94	1.36	0.74	0.07	0.05
30	ROB	1234.66	1247.93	0.00	10.64	13.29	0.00	0.80	0.00	0.04	0.00
31	ROB	1247.93	1261.20	0.00	1.67	7.75	0.00	0.22	0.00	0.01	0.00

Left Q_E : 73.16 cfs

Right Q_E = 83.99 cfs

Left A_E : 333.15 ft^2

Right A_E = 56.79 ft^2

Left L' : 1200.88' − 1187.10' = 13.78'

Right L' : 1234.66' − 1220.88' = 13.78'

L' Calculation for 200 YR

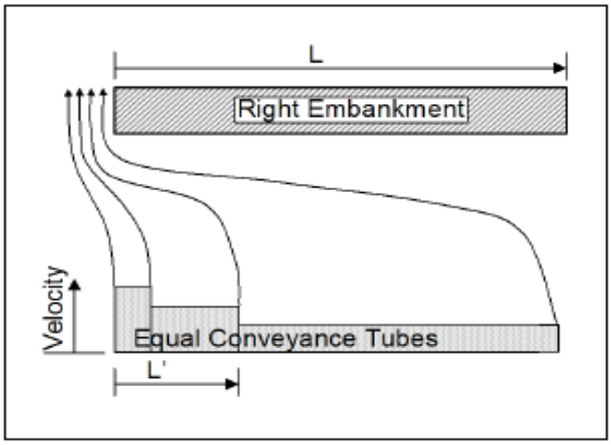


Figure 8.4. Determination of length of embankment blocking live flow for abutment scour estimation.

Cross section 168 just upstream of the bridge was used to examine the flow distributions in the channel. The column labeled "Flow" represents the volume of flow in each flow tube. The flow significantly increases between stations 1187.10 to 1200.88 (the left abutment toe), therefore station 1187.10 was used to measure the L' for the left overbank. For the right overbank, there is significant flow from station 1234.66 to the right abutment toe at 1220.88. This judgement is based off of section 8.2.2 and Figure 8.4 in the HEC-18 Manual.