Final Design, Hydrology/Hydraulics and Scour Report

Covered Bridge # 3738

Over Little Androscoggin River, Oxford, Maine

Northstar Hydro, Inc.

For

Becker Structural Engineers

And Maine Dept. of Transportation

November, 2013

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STATE OF MAINE
ELLEN
KNIGHT O'BRIEN
No. 7945
LICENSED
PROFESSIONAL ENGINEER

1.0 Introduction

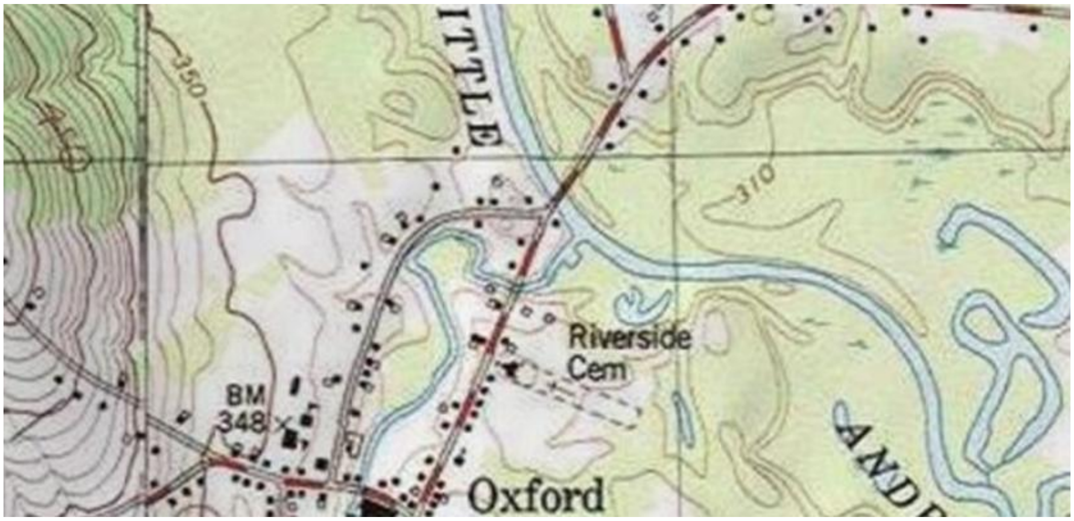
The bridge that carries Route 121 in Oxford over the Little Androscoggin River is known as the Oxford Covered Bridge, Maine DOT # 3738. This report details hydrologic, hydraulic and scour analyses performed as part of the preliminary design process.

The existing bridge is a 170' long, three span steel girder bridge with spans of 47'-6", 75' and 47'-6". The abutments and easterly pier are founded on timber piles. The westerly pier was revised from pile supported to a spread footing during construction. This bridge is listed as scour critical by Maine DOT. The pictures below show the easterly and westerly piers, respectively. Note the evidence of soil erosion near the piers.

Easterly pier above, westerly pier below.

The site location is shown on the topographic map below. Route 121 crosses from northeast to southwest. The floodplain is widest on the easterly side of the bridge. A home on the easterly downstream side of the bridge has experienced flooding from the river in the past, but this flooding is not caused by the bridge. The home is located in a low area about 275’ east of the bridge along route 121. The property floods from river backwater before water overtops Route 121 in front of the home. According to local residents, flood waters did overtop Route 121 but not the bridge in 1953 and 1987.

The bridge is about 400’ upstream of the Thompson Lake Stream confluence.



2.0 Existing Data Review

Existing data reviewed for this site includes:

- Air photos (GIS based)

- Topographic maps
- Historical flood records for the 1987 and 1936 floods published by the U.S. Geological Survey is shown in Table 1 below.

Flood	Approx Frequency	Elevation D.S. of Bridge, NAVD	Elevation U.S. of Bridge, NAVD	Notes
1936	>100	310.8	312.2	Old Bridge
1987	250	311.0	311.1	Existing Bridge

Table 1. Historical Flood Data.

- Maine DOT Scour Plan of Action (POA), prepared by T.Y.Lin International in 2010. This report identified this bridge as “scour critical” and recommended bridge monitoring during floods when water level reaches within 5’ of the low chord of the bridge and bridge closure when water level reaches within 3’ of the low chord. The low chord of the bridge ranges from 312.1 to 314.8, so monitoring would occur around elevation 307, and closure at about 309.2’. (The 100-year flood elevation at the existing bridge is calculated to be 310.3 downstream and 311.5’ upstream – see hydraulics section below).

  The photo below shows the placard installed by MDOT to indicate water levels that would trigger monitoring (yellow) and/or closure (red).

The scour POA report identifies both piers as scour critical, but not the abutments. The Scour POA used the following flow distribution (slightly lower than FEMA or MDOT).

Frequency	Flow, cfs
10-yr	6,397
50-yr	9,470
100-yr	10,834
500-yr	14,260

Table 2. Scour POA flow data

- Federal Emergency Management Agency, Flood Insurance Study for Oxford County, prepared in July of 2009. According to FEMA, the 1936, 1953 and 1987 floods had recurrence intervals of 50, 100 and greater than 100-years respectively.

  FEMA lists the drainage basin at this location as 152.0 square miles and publishes the following data for this location:

Frequency	Flow, cfs	Downstream Elevation, NAVD	Upstream Elevation, NAVD
10-yr	5,650	307.	308.0
50-yr	8,940	310.	310.5
100-yr	10,600	310.3	311.5
500-yr	15,300	314.	314.3

Table 3. FEMA Flow and elevation data

Flows from Thompson Lake outlet stream are listed by FEMA as 1880 cfs for the 50-year storm and 2200 cfs for the 100-year storm, with a drainage area of 47.7 square mile. This represents about 20% of the flow in the Little Androscoggin River, although times of peak may not coincide. As described in the hydrology section below, flows recommended by MDOT were used for the HECRAS model. For final design, the impact of slightly higher flows at the first model cross section (Q100 and 500 only) should be checked. For this model, the impact was accounted for in the starting water surface elevations based on FEMA flood profile data.

3.0 Hydrology

Maine DOT provided the flow-frequency analysis for this bridge, with a drainage area of 152.3 square miles. MDOT flows are more conservative than FEMA and the scour POA (i.e. the 100-year MDOT flows are larger than the FEMA and scour POA flows).

Frequency	MDOT Flow, cfs	Comparable to FEMA frequency/flow	Scour POA frequency
1.1-yr	2093.2		
2-yr	3935.9		
5-yr	5835.5	10-year (5,650 cfs)	
10-yr	7211.7		
25-yr	8991.6	50-year (8,940 cfs)	
50-yr	10367.1	100-year (10,600 cfs)	100-year (10,834 cfs)
100-yr	11811.3		
500-yr	15351.6	500-year (15,300 cfs)	

Table 4. Maine DOT Flow Data comparison to FEMA and POA

Table 5 summarizes hydrologic data for this bridge:

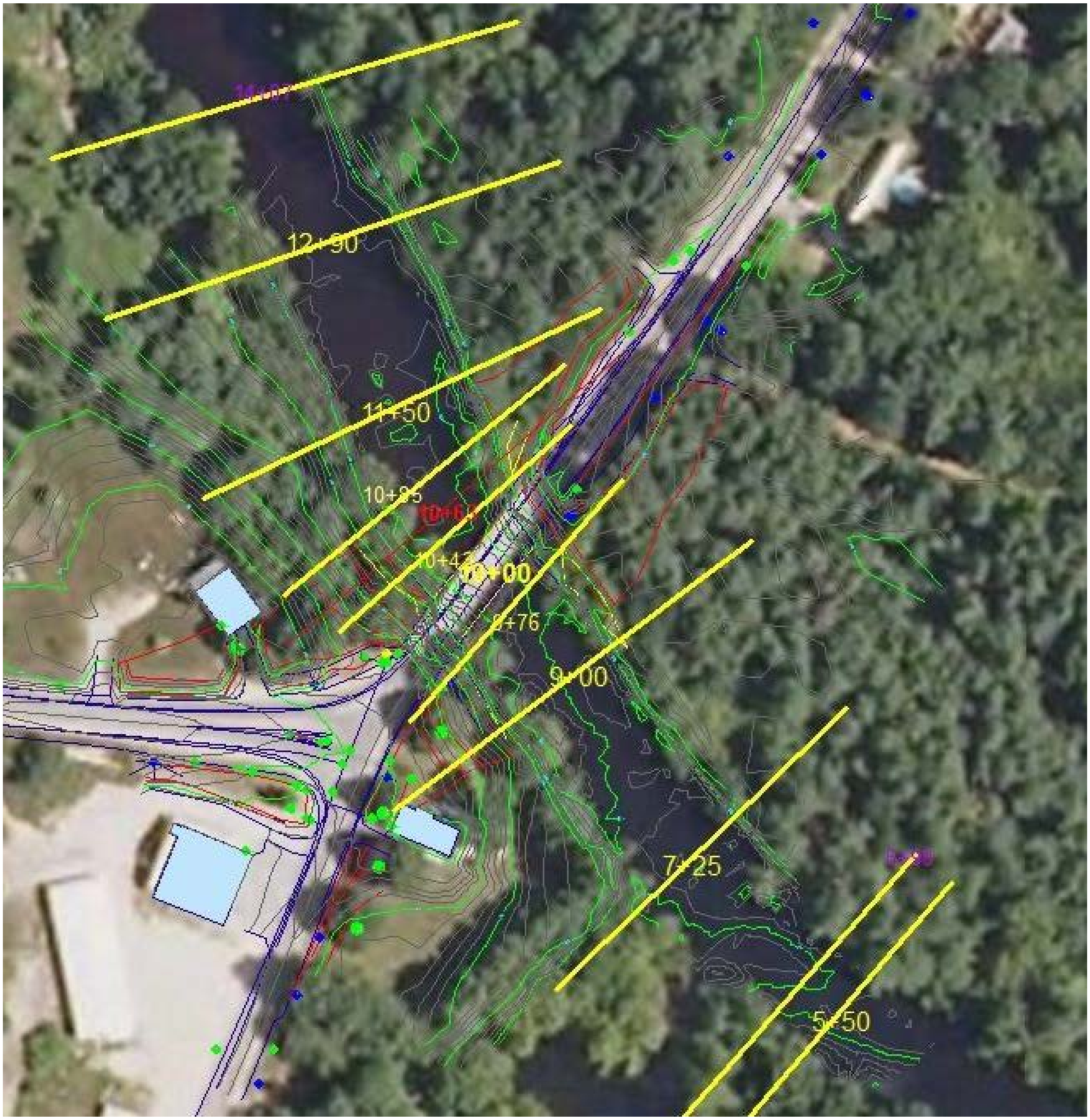
Drainage Area	152.3 square miles
Design Discharge (Q50)	10367 cfs
Check Discharge (Q100)	11811 cfs
Scour Check Discharge (Q500)	15352 cfs
Ordinary High Water (Q1.1)	2093 cfs
Flood of Record (>Q100)	1987 flood, discharge at site not known

Table 5.

4.0 Hydraulics

The goal of the hydraulic analysis is to provide information on water levels, flow velocities and scour variables at the Oxford Bridge. The hydraulic information assists in design of bridge elevations and foundation components. A hydraulic model of the Oxford Covered Bridge was developed to simulate existing and proposed conditions at the bridge. Model HECRAS was used to model flow conditions through the bridge. Model cross sections were compiled using data from field survey, project plans and USGS topographic maps. Cross section locations are shown in the air photo on the following page.

The new bridge will have two 85’ spans centered on a pile bent pier. The bridge abutments are skewed approximately 13^{o} to the flow. The pile bent pier will be skewed 7.5 degrees to the flow, as shown in the appendix.



Model sections are shown in yellow. The existing bridge is at station 10+00 and the new bridge centerline is at station 10+63. Sections were compiled from data provided as part of the Scour POA and from project survey. The existing bridge section is based on the scour POA and existing bridge plans. This photo also shows the constriction in the flood plain caused by the existing bridge, easterly abutment. The low area on the easterly approach is at about elevation 310.96’. Contours and potential flooded areas are shown on the following page. The river “backs” into this location from downstream, rather than crossing the road upstream and flowing over the road, unless flood elevation is higher than 310.96’.

In this drawing, the river flows from top to bottom of the picture and the easterly abutment is in the upper right corner. Elevation 308 is shaded in. Elevation 310 is shown as a red contour.

Existing and proposed bridges were modeled. Detailed model information is included in the appendix. The following table summarizes design data for the 170’ twin span bridge as well as for the existing bridge.

Location	**Existing Bridge**				**Proposed Bridge – two 85’ spans**			
	Elevation	Ave Velocity	Max Velocity	Flow Area	Elevation	Ave Velocity	Max Velocity	Flow Area
	ft NAVD	fps	fps	sq ft	ft, NAVD	fps	fps	sq ft
100' DS of existing Bridge								
Model Section	900				900			
1.1-yr	302				302			
10-yr	308.7				308.7			
25-yr	309.5				309.5			
50-yr	309.5				309.5			
100-yr	310.2				310.2			
500-yr	312.6				312.6			
DS Face of Bridge								
Model Section	1000 DS				1063 DS			
1.1-yr	302.1	3.4			302.1	3.3		
10-yr	308.8	5.6			308.9	4.8		
25-yr	309.6	6.5			309.8	5.5		
50-yr	309.6	7.4	9.2	1461	309.9	6.3	8.2	1643
100-yr	310.3	8	9.8	1557	310.6	6.7	8.7	1759
500-yr	312.9	8.3			313.1	7.2		
US Face of Bridge								
Model Section	1000 US				1063 US			
1.1-yr	302.1	3.3			302.7	3.2		
10-yr	308.8	5.6			309.4	4.8		
25-yr	309.6	6.5			309.8	5.5		
50-yr	309.7	7.5	8.8	1442	309.9	6.4	8.0	1630
100-yr	310.4	8.1	9.5	1532	310.6	6.9	8.5	1745
500-yr	312.9	8.5			313.1	7.5		
150' US of Existing Bridge								
Model Section	1150				1150			
1.1-yr	302.2				302.8			
10-yr	309.1				309.5			
25-yr	310				310.0			
50-yr	310.2				310.2			
100-yr	311				311.0			
500-yr	313.5				313.5			

Table 6. Hydraulic Data

Hydraulic data is summarized below. Elevation data is listed for a common point, 150’ upstream of the existing bridge, and at the upstream face of each bridge. Note that the new bridge is upstream of the existing bridge, so elevations at the face of each bridge may differ.

	Existing Bridge (section 1000)	Proposed Bridge (section 1063)
Headwater at Q50 (section 1150)	310.2	310.2
Headwater at Upstream face (Q50)	309.7	309.9
Headwater at Q100 (section 1150)	311.0	311.0
Headwater at Upstream face (Q100)	310.4	310.6
Discharge Velocity at Q50	9.2	6.9
Discharge Velocity at Q100	9.8	7.3
Ordinary High Water Elevation (Q1.1)	302.1	302.7
Discharge Velocity at Q1.1, fps	3.4	3.4
Clearance @ Q50	2.4 - 5.1’ Left to Right	2.2-5.6’ Left to Right
Clearance @ Q100	1.3 – 4.0’ Left to Right	1.2-4.6’ Left to Right
Bridge Opening Area, ft^2	1904	2085
Flow Area at Q100	1530	1632

Table 7. Summary of Hydraulic Data

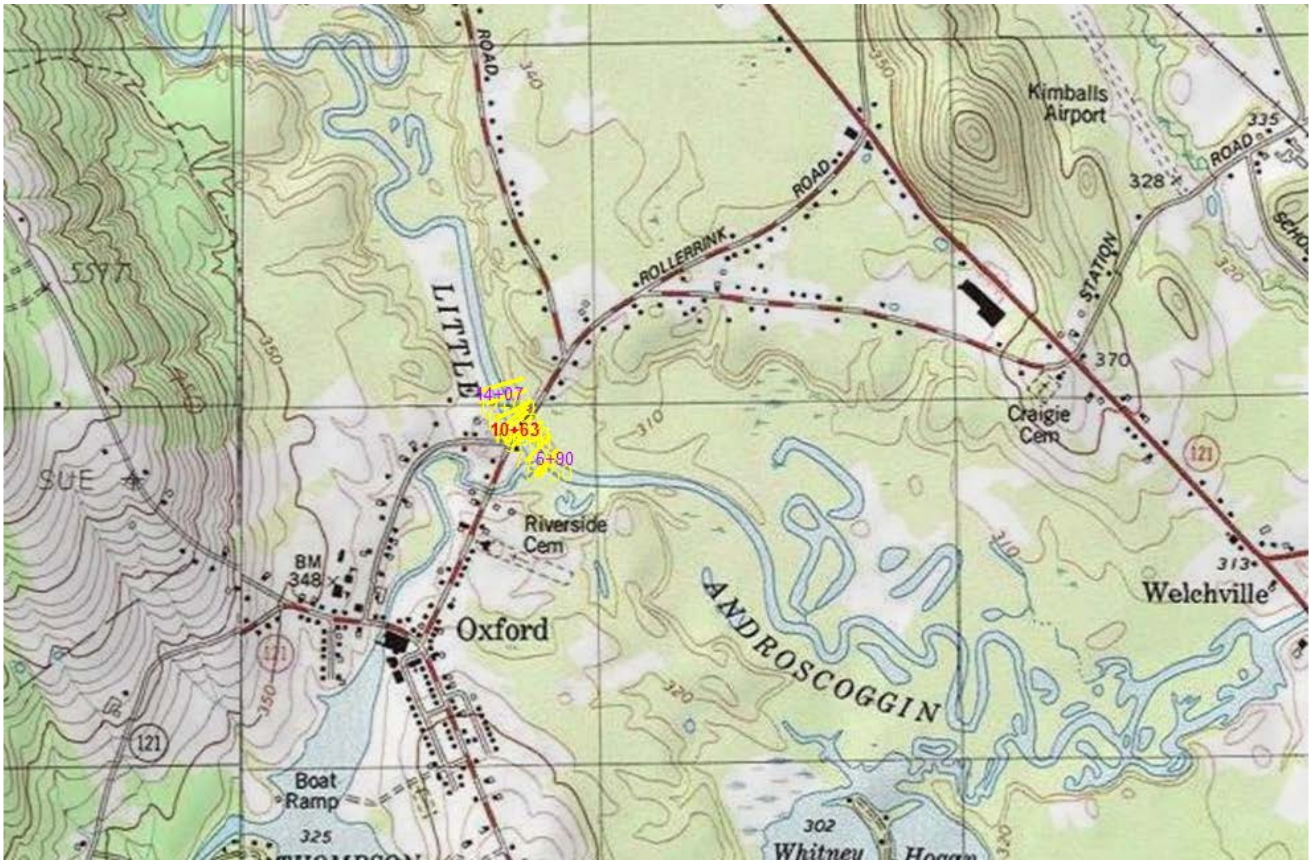
The proposed bridge will have the following impacts for improved hydraulic conditions:

- Lower headwater upstream of new bridge for Q50 and Q100
- Better clearance at high flows, better for potential ice impacts
- Decreased velocity through bridge opening
- Larger hydraulic opening (one pier and wider section) decreases velocity (less scour) and lowers flood levels, as well as improves conditions for potential ice impacts.

5.0 Scour

The scour POA report studied expected scour for the existing bridge, calculating potentially critical scour levels at both piers, but not at abutments. Abutments are protected by riprap in fair condition. Existing bridge scour plots are included in the appendix.

Existing bridge scour plots indicate possible aggradation in the streambed, based on comparing the 1940 bridge plans and measured sections at up- and down-stream faces of the existing bridge. Because the stream is apparently aggrading, no adjustments were made to scour calculations for aggradation/degradation. Stream geomorphology indicates potential meandering and channel migration approximately 2000’ upstream and 1800’ downstream of the bridge, but the bridge segment of channel appears to be well-incised and stable with vegetated banks and no recent bank scarring observed. The scour POA did not discuss potential for channel migration as an issue. The stable reach of river near the bridge and the up- and down-stream meanders are shown in the topographic map below.



Based on data gathered for the bridge replacement study, bed elevation at the left pier is 296.4-297.9 and at the right pier is 296.5-297.2. For the existing bridge, the following potential scour depths below stream bed level were computed in the scour POA:

	<u>50-year depth</u>	<u>500-year depth</u>
Left Abutment	0	0
Left Pier	17.3	21.3
Right Pier	17.0	21.0
Right Abutment	0	0

The report notes that “Abutment scour was not computed. Abutments are located near the top of slope, are supported on piles and slopes are protected by riprap in fair conditions. Pier scour governs critical scour condition for the bridge.”

Potential scour was computed for the proposed 170’ two-span bridge. Geotechnical data for the bridge indicates wet brown, fine to coarse sand, with a trace of silt. D50 and D95 were based on data from Boring number BB-OLAR-202, provided by MDOT. MDOT provided estimates of D50 and D95 of 0.7mm and 2.0 mm respectively, in an email to Becker Structural dated 9/17/13. Samples were collected for this boring at 0-2’, 10-12’, 15-17’ and 25-27’. Sieve analysis for the top three samples yielded D50 of 0.67 mm and 2.7 mm for D95. Values of 0.67 mm and 2 mm were used for scour analysis per recommendations of MDOT geotechnical engineers.

Abutment, contraction and pier scour were computed. The potential for abutment scour is low since abutments are set near top of bank, and bank protection is provided. Table 3 summarizes scour analysis results. Note that abutment and pier scour computations do not take scour protection into account, so these values are conservative. Abutments are assumed to be “spillthrough” and the pier is assumed to be “round nose” for purposes of scour computations.

Several key assumptions were assigned to the pier to calculate conservative scour values. Pier scour variables were assigned as follows:

- Pier geometry: 6 - 2.5’ diameter piles
- Pier alignment: 7.5 degrees to flow
- Projected pier width due to skew: approximately 6.6’
- Pier width with debris: 3.125’ (without skew)
- K2 coefficient used to account for skew
- K1 for round nosed pier
- K3: 1.1
- Length of Pier = 6 X 2.5 = 15’
- Y1, depth of flow upstream of pier from HECRAS
- V1, velocity just upstream of pier, used maximum velocity from flow distribution calculation from HECRAS

Pier Scour Equation 7.1 from FHWA HEC-18, 5th Edition, April, 2012

$$Ys = a \times 1 \times K1 \times K2 \times K3 \times (Y1/a)^{.35} \times Fr^{0.43}.$$

Scour Calculations	**Computed scour depth, ft** **50-year**	**100-year**	**500-year**	**Approx. Scour Elevation, ft** **50-year**	**100-year**	**500-year**
Contraction Scour	1.2	0.9	0.0			
Left Abutment[1] (306.0’)	5.8	7.1	11.0	300.2	298.9	295.0
Right Abutment[1] (309.3’)	6.0	2.2	5.2	303.3	307.1	304.2
Pier Scour (296.0’)	11.4	11.8	12.6			
Total Scour at Pier	12.6	12.7	12.6	283.4	283.3	283.4

1. Note that abutment scour is conservative, and does not account for scour protection such as riprap. Note also that abutments are near top of slope and set back within embankment.

Table 8. Scour Summary

5.1 Scour Protection at Abutments

Riprap scour protection was designed for the abutments according to design guidance provided in the MDOT Bridge Manual, and in FHWA publications HEC-23 and HEC-11. Riprap revetments at each abutment will use heavy riprap with a mounded toe as shown on the bridge section (appendix page 31). Design backup is included in the appendix, pages 62-71.

6.0 References

Federal Emergency Management Agency. Oxford County. July, 2009

U. S. Dept. of the Interior, Geological Survey, with Maine Dept. of Transportation. Estimating the Magnitude and Frequency of Peak Flows for Streams in Maine for Selected Recurrence Intervals. Water Resources Investigations Report 99-4008.

U.S. Army Corps of Engineers, Hydrologic Engineering Center. HEC-RAS River Analysis System. Version 4.1.0. January, 2010. Davis, CA

U.S. Department of Transportation. Federal Highway Administration. Evaluating Scour at Bridges, 4th edition. HEC-18. May, 2001

U.S. Department of Transportation. Federal Highway Administration. Bridge Scour and Stream Instability Countermeasures. HEC-23. Volume 2. September, 2009. FHWA-NHI-09-112 . DG 14, Rock Riprap at Bridge Abutments and DG 4, Riprap Revetment

Maine Dept. of Transportation. Scour Critical Bridge Plan of Action Report, Oxford, 3738, Covered Bridge. Not dated.

Maine Dept. of Transportation. Bridge Design Manual. August 2003

U.S. Dept. of Transportation. Design of Riprap Revetment. HEC No. 11. FHWA IP-89-016, March 1989

Appendix

Calculations and Background Material

Hydrology

Geotechnical

Hydraulics and Scour Existing Bridge

Hydraulics and Scour Proposed Bridge

The Floods of March, 1936

Table 15.-Flood crest stages--Continued

Stream and location	Miles above mouth	Date and time	Altitude in feet
Androscoggin River Basin--Continued			
Little Androscoggin River--Continued:			
South Paris, Maine, bend in river 2 miles below Bisco Falls, right bank	63.6	Mar.19	368.1
South Paris, Maine, 1.5 miles above village, mouth of brook, right bank	62.3	Mar.19	356.8
South Paris, Maine, concrete highway bridge, left bank	60.8	Mar.19	356.6
South Paris, Maine, concrete dam, headwater, left bank	60.2	Mar.19	ak349.6
South Paris, Maine, 275 feet below dam, left bank	60.1	Mar.19	342.5
South Paris, Maine, 0.5 mile below, Grand Trunk Ry. bridge, left bank	59.3	Mar.19	342.3
Norway, Maine, 0.1 mile above mouth of Pennesseewassee Lake outlet, right bank	58.5	Mar.19	342.2
Norway, Maine, mouth of Pennesseewassee Lake outlet, right bank	58.4	Mar.19	326.0
Norway, Maine, 1.5 miles below, highway bridge on Norway-Welchville road, left bank	56.9	Mar.19	324.2
Oxford, Maine, 3.3 miles above, field, left bank	55.3	Mar.19	318.3
Oxford, Maine, wooden highway bridge, right bank	52.0	Mar.19	312.9
Oxford, Maine, mouth of Thompson Lake outlet, right bank	51.9	Mar.19	311.5
Welchville, Maine, dam, headwater, left bank	49.6	Mar.19	am306.9
Welchville, Maine, dam, tailwater, right bank	49.6	Mar.19	305.0
Welchville, Maine, 800 feet below dam, left bank	49.4	Mar.19	304.9
Welchville, Maine, 1.4 miles below, near Coy's crossing, left bank	48.2	Mar.19	298.8
Mechanic Falls, Maine, 2.1 miles above, at highway bridge, left bank	45.4	Mar.19	286.5
Mechanic Falls, Maine, 0.7 mile above, Maine Central R.R. Co. bridge, left bank	44.0	Mar.20	283.5
Mechanic Falls, Maine, 0.6 mile above, concrete highway bridge	43.9	Mar.20	283.0
Mechanic Falls, Maine, Waterfalls Paper Co. dam, headwater, left bank	43.3	Mar.20 1-4am	an281.2
Mechanic Falls, Maine, dam, tailwater	43.3	Mar.20 1-4am	272.2
Mechanic Falls, Maine, 0.15 mile below dam, left bank	43.2	Mar.20	251.9
Mechanic Falls, Maine, mouth of Bog Brook, left bank	42.3	Mar.20	250.2
Mechanic Falls, Maine, 1.8 miles below, head of island, right bank	41.5	Mar.20	250.0
Hacketts Mills, Maine, highway bridge, left bank	39.0	Mar.20	244.6
Hacketts Mills, Maine, Rogers Fibre Co. dam, headwater, both banks (average)	38.9	Mar.20 12:40am	ao243.4
Hacketts Mills, Maine, dam, tailwater	38.9	Mar.20 12:40am	236.2
Minot Corner, Maine, highway bridge, upstream, left bank	38.2	Mar.20	235.1
Minot Corner, Maine, below highway bridge and rips, right bank	38.2	Mar.20	231.7
Minot Corner, Maine, 0.15 miles below, left bank	38.0	Mar.20	228.6
Littlefield, Maine, highway bridge, left bank	34.6	Mar.20	225.4
Littlefield, Maine, Central Maine Power Co. upper dam, headwater	34.0	Mar.20	ap225.0
Littlefield, Maine, Central Maine Power Co. lower dam, headwater, right bank	33.9	Mar.20	aq218.7
Littlefield, Maine, lower dam, tailwater, right bank	33.9	Mar.20	208.7
Rumford Junction, Maine, highway bridge, left bank	33.2	Mar.20	206.9
Auburn, Maine, Maine Central R.R. Co. bridge, left bank	32.1	Mar.20	204.1
Auburn, Maine, Central Maine Power Co. upper dam, headwater, left bank	30.8	Mar.20 noon	ar200.9
Auburn, Maine, upper dam, tailwater, left bank	30.8	Mar.20	176.3
Auburn, Maine, lower dam, headwater, left bank	30.6	Mar.20	as161.4
Auburn, Maine, lower dam, tailwater, left bank	30.6	Mar.20	141.8
Auburn, Maine, Main Street bridge, left bank	30.3	Mar.20	140.6
Auburn, Maine, confluence with Androscoggin River, left bank	30.1	Mar.20	139.6
Saco River Basin			
Saco River:			
Bartlett, N. H., steel highway bridge, right bank	110.8	--	576.3
Glen, N. H., 200 feet below R.R. bridge above Glen, left bank	105.8	--	554.8

151 sq.

ak Altitude of crest of dam, 343.0 feet.
am Altitude of crest of dam, 299.0 feet.
an Altitude of crest of dam, 271.3 feet.
ao Altitude of crest of dam, 234.4 feet.
ap Altitude of crest of dam, 211.0 feet.
aq Altitude of crest of dam, 204.0 feet.
ar Altitude of crest of dam, 188.9 feet.
as Altitude of crest of dam, 154.0 feet.

Q@S Paris = 6980 ≈ 100-yr
D.A. = 76.2 sq mi

Flood of April 1987 in Maine

Table 12.--Flood-crest stages for April 1987 flood in Maine--Continued

Stream and location	Miles upstream[a] from mouth	Elevation (in feet)
ANDROSCOGGIN RIVER BASIN--Continued		
Little Androscoggin River--Continued:		
West Paris, Maine, upstream side Hadley Pit Road, left bank	68.6	469.1
West Paris, Maine, downstream side Hadley Pit Road, left bank	68.6	464.7
West Paris, Maine, U.S. Geological Survey station 01057000, head of island 50 feet upstream from Snow Falls, right bank	66.9	459.2
West Paris, Maine, 30 feet upstream from Bisco Falls Dam at former site of U.S. Geological Survey station 01057000	65.6	407.5
Paris, Maine, upstream side Route 26 bridge, average of left and right bank elevations	60.8	353.5
Paris, Maine, downstream side Route 26 bridge, right bank	60.8	352.8
Paris, Maine, upstream side Park Street bridge, average of left and right bank elevations	60.5	351.5
Paris, Maine, downstream side Park Street bridge, average of left and right bank elevations	60.5	350.7
Paris, Maine, Billings Dam (headwater), average of left and right bank elevations	60.2	350.0[ai]
Paris, Maine, 50 feet downstream from Route 117 bridge, left bank	60.2	344.6
Paris, Maine, upstream side railroad bridge, right bank	59.3	334.5
Paris, Maine, downstream side railroad bridge, average of left and right bank elevations	59.3	333.6
Oxford, Maine, upstream side Route 26 bridge, right bank	56.9	325.4
Oxford, Maine, downstream side Route 26 bridge, average of left and right bank elevations	56.9	325.1
Oxford, Maine, upstream side Route 121 bridge, average of left and right bank elevations	52.0	311.8
Oxford, Maine, downstream side Route 121 bridge, average of left and right bank elevations	52.0	311.7
Oxford, Maine, upstream side Route 26 bridge near Welchville, average of left and right bank elevations	49.6	307.9

151 sq mi

Q @ S. Paris = 9340 cfs >100 yr

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[a] From Grover (1937, table 15).

[ai] Elevation of dam crest 342.7 feet (Federal Emergency Management Agency, 1991c).

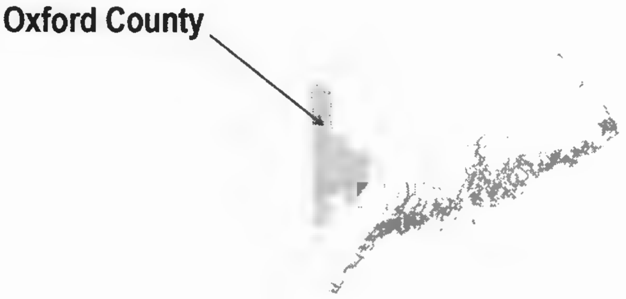
2

FLOOD INSURANCE STUDY

OXFORD COUNTY, MAINE

(ALL JURISDICTIONS)

VOLUME 1 OF 3



COMMUNITY NAME	COMMUNITY NUMBER
ADAMSTOWN T04 R02 WBKP, TOWNSHIP OF*	230688
ALBANY, TOWNSHIP OF*	230606
ANDOVER NORTH SURPLUS, TOWNSHIP OF*	230689
ANDOVER WEST SURPLUS, TOWNSHIP OF*	230690
ANDOVER, TOWN OF	230160
BATCHELDERS GRANT, TOWNSHIP OF*	230459
BETHEL, TOWN OF	230088
BOWMANTOWN T04 R06 WBKP, TOWNSHIP OF*	230691
BROWNFIELD, TOWN OF	230089
BUCKFIELD, TOWN OF	230090
BYRON, TOWN OF	230330
C SURPLUS, TOWNSHIP OF*	230692
CANTON, TOWN OF	230091
DENMARK, TOWN OF	230476
DIXFIELD, TOWN OF	230092
FRYEBURG, TOWN OF	230093
GILEAD, TOWN OF	230166
GRAFTON TA2, TOWNSHIP OF*	230607
GREENWOOD, TOWN OF	230332
HANOVER, TOWN OF	230333
HARTFORD, TOWN OF	230334
HEBRON, TOWN OF	230335
HIRAM, TOWN OF	230094
LINCOLN PLANTATION T5R2WBKP, TOWNSHIP OF*	230604
LOVELL, TOWN OF	230336
LOWER CUPSUPTIC T04 RO3 WBKP, TOWNSHIP OF*	230693
LYNCHTOWN T05 R04 WBKP, TOWNSHIP OF*	230694
MAGALLOWAY PLANTATION*	230605
MASON, TOWNSHIP OF*	230695
MEXICO, TOWN OF	230095
MILTON, TOWNSHIP OF	230460
NEWRY, TOWN OF	230337
NORWAY, TOWN OF	230096
OTISFIELD, TOWN OF	230203

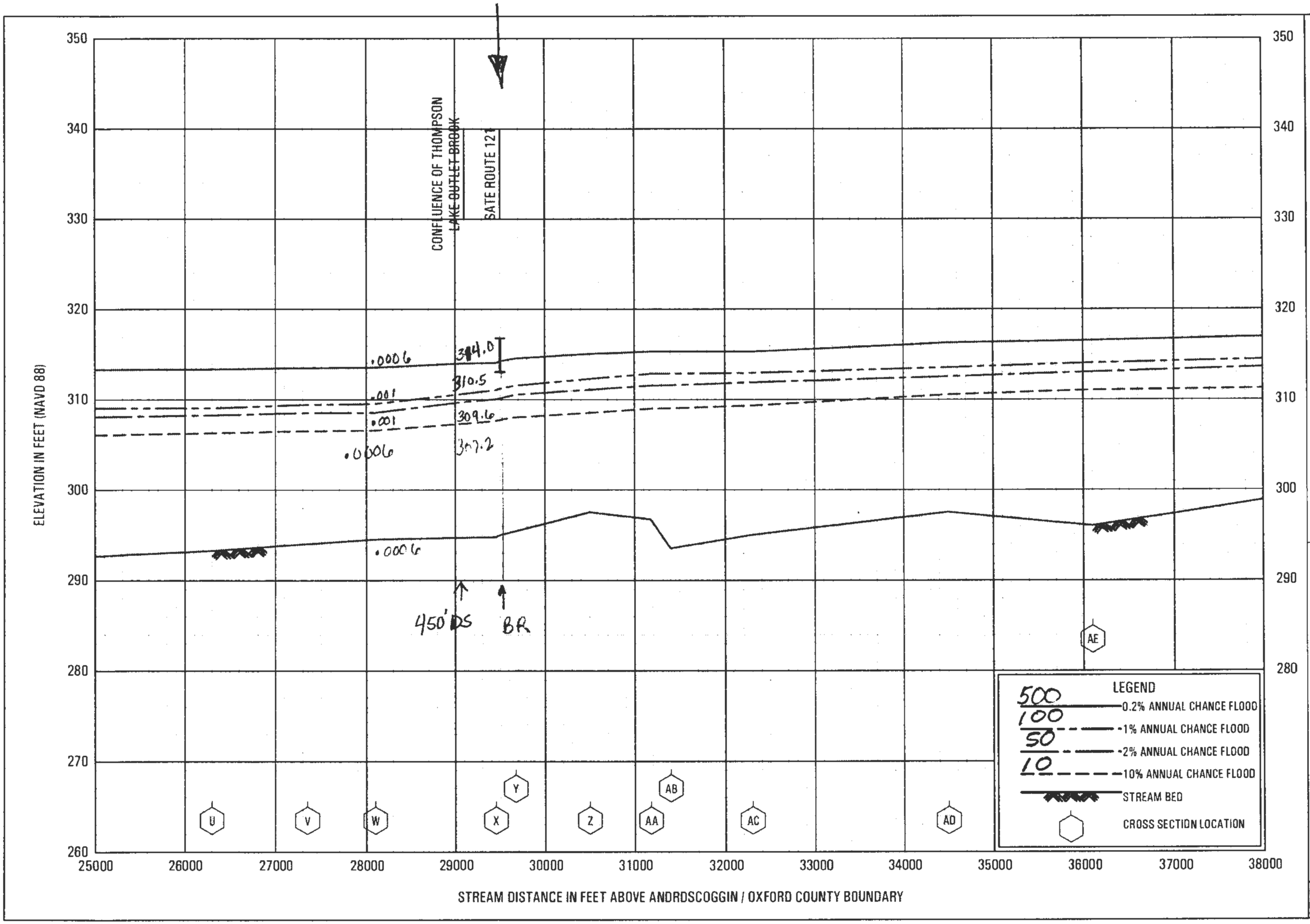
COMMUNITY NAME	COMMUNITY NUMBER
OXBOW T04 R05 WBKP, TOWNSHIP OF*	230696
OXFORD, TOWN OF	230869
PARIS, TOWN OF	230097
PARKERTOWN T05 R03 WBKP, TOWNSHIP OF*	230697
PARMACHENEE T05 R05 WBKP, TOWNSHIP OF*	230698
PERU, TOWN OF	230098
PORTER, TOWN OF	230338
RICHARDSONTOWN T04 R01 WBKP, TOWNSHIP OF*	230699
RILEY TA1, TOWNSHIP OF*	230700
ROXBURY, TOWN OF	230181
RUMFORD, TOWN OF	230099
STONEHAM, TOWN OF	230340
STOW, TOWN OF	230186
SUMNER, TOWN OF	230187
SWEDEN, TOWN OF	230341
TOWNSHIP C, TOWNSHIP OF*	230701
UPPER CUPSUPTIC T04 R04 WBKP TOWNSHIP OF*	230702
UPTON, TOWN OF	230342
WATERFORD, TOWN OF	230343
WEST PARIS, TOWN OF	230100
WOODSTOCK, TOWN OF	230344

*NO SPECIAL FLOOD HAZARD AREAS IDENTIFIED

July 7, 2009

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
23017CV001A



FLOOD PROFILES

LITTLE ANDROSCOGGIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

OXFORD COUNTY, ME

(ALL JURISDICTIONS)

53P

TABLE 7 – SUMMARY OF DISCHARGES (continued)

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND)			
		10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
Little Androscoggin River – continued					
Upstream of confluence of Waterhouse Brook	231.0	6,540	10,400	12,400	18,200
At State Route 26 Bridge (In Village of Welchville)	216.0	6,390	10,200	12,100	17,700
Upstream of confluence of Thompson Lake outlet	152.0	5,650	8,940	10,600	15,300
At State Route 26 Bridge (in Town of Oxford)	142.0	5,520	8,720	10,300	14,800
Upstream from State Route 26 in Oxford	142.0	5,520	8,720	10,300	14,800
Upstream from confluence of Pennesseewassee Brook	110.0	5,050	7,930	9,370	13,300
Upstream from confluence of Stony Brook	93.6	4,770	7,470	8,810	12,500
Upstream from confluence of Cole Brook	77.4	4,460	6,960	8,190	11,500
At West Paris-South Paris corporate Limits	75.8	*	*	6,540	*
At USGS gaging station at Snow Falls	73.5	*	*	6,540	*
Upstream of confluence of Moose Brook	57.5	*	*	5,370	*
Upstream of confluence of Andrews Brook	41.0	*	*	4,100	*
At West Paris-Greenwood corporate Limits	39.5	*	*	4,000	*
Mill Brook					
At U.S. Route 2	9.4	600	1,200	1,500	2,200
At State Route 5	9.0	600	1,200	1,500	2,100
At Confluence with Ossipee River	14.1	730	1,190	1,445	2,165

*Data not computed

Project Name:	Oxford	**PIN:**	19268.00
Stream Name:	Little Androscoggin	**Town:**	Oxford
Bridge Name:	Covered	**Bridge No.**	3738
Route No.	121	**USGS Quad:**	
Analysis by:	M. Lickus	**Date:**	12/1/2011

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km^2	mi^2	ac	*Enter data in [mi^2]*
A	394.45	152.30	97470.1	Watershed Area
W	27.53	10.63	6803.1	Wetlands area (by NWI)

P_c	375018.8	4905528	watershed centroid (E, N; UTM 19N; meters)
County	Oxford W		*choose county from drop-down menu*
pptA	45.2		mean annual precipitation (inches; by look-up)
SG	0.07		sand & gravel aquifer as decimal fraction of watershed A

Worksheet prepared by:
Charles S. Hebson, PE
Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

A (km^2)	394.45
W (%)	6.98

Conf Lvl 0.67

Ret Pd T (yr)	Peak Flow Estimate Lower	Q_T (m^3/s)	Upper
1.1		59.28	
2	80.01	111.47	155.29
5	118.22	165.26	231.03
10	144.81	204.24	288.05
25	178.20	254.65	363.88
50	203.22	293.60	424.19
100	228.91	334.50	488.82
500	288.57	434.77	655.02

Q_T (ft^3/s)
2093.2
3935.9
5835.5
7211.7
8991.6
10367.1
11811.3
15351.6

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$Q_T = b \times A^a \times 10^{-wW}$

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Covered Bridge #3738 carries Route 121 over Little Androscoggin River
Location: Oxford, Maine

Boring No.: BB-OLAR-102
WIN: 19268.00

Driller:	Northern Test Boring	**Elevation (ft.)**	295.8	**Auger ID/OD:**	N/A
Operator:	Mike, Adam	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	10/4/12; 07:30-17:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	15+82.8, 2.3 ft Rt.	**Casing ID/OD:**	HW	**Water Level*:**	Barge Boring
Hammer Efficiency Factor:	0.707	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample attempt
V = Insitu Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Insitu Vane Shear Test attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person
S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows				
0	1D	24/2	0.00 - 2.00	WOH/WOH/1/1	1	1	HP			Brown, wet, very loose, fine to coarse SAND, trace silt. (Glaciomarine Outwash Delta Deposit)	
							↓				
							9				
5	MD	24/0	5.00 - 7.00	1 2 2 2	4	5	8				
							17				
							22				
							40				
							44				
10	2D	24/13	10.00 - 12.00	1/1/4/4	5	6	14			Brown, wet, loose, fine to coarse SAND, trace silt. (Sample jar broke, lost sample).	
							42				
							73				
							68				
							106	281.80		14.00	
15	3D	24/17	15.00 - 17.00	2 2 4 4	6	7	25			Light brown-yellow, loose, fine to medium SAND, trace silt. (Glaciomarine Outwash Delta Deposits)	
							35				
							72				
							77				
	R1	72/48	19.40 - 25.40	RQD = 0%			NQ-2	276.40		19.40 R1: Granite boulders (upper 2'6") then nested sand and cobbles, followed by possibly top of metasedimentary bedrock inclusion (4"). R1:Core Times (min:sec) 19.4-20.4 ft (3:40) 20.4-*21.4 ft (4:00) 21.4-22.4 ft (3:35) 22.4-23.4 ft (2:10) 23.4-24.4 ft (2:15) 24.4-25.4 ft (3:22) 67% Recovery	
20											
25											

Remarks:

Auto Hammer #149
3.1 ft from Barge Deck to Ground.
HP = Hydraulic Push

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	**Project:** Covered Bridge #3738 carries Route 121 over Little Androscoggin River **Location:** Oxford, Maine	**Boring No.:** BB-OLAR-102 **WIN:** 19268.00

Driller:	Northern Test Boring	**Elevation (ft.)**	295.8	**Auger ID/OD:**	N/A
Operator:	Mike, Adam	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	10/4/12; 07:30-17:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	15+82.8, 2.3 ft Rt.	**Casing ID/OD:**	HW	**Water Level*:**	Barge Boring
Hammer Efficiency Factor:	0.707	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
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MU = Unsuccessful Thin Wall Tube Sample attempt
V = Insitu Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Insitu Vane Shear Test attempt

R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person

S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected

$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows				
25	R2	60/57	25.40 - 30.40	RQD = 100%				270.40		Top of Bedrock at Elev. 270.40 ft. R2: Metasedimentary bedrock inclusion. R2:Core Times (min:sec) 25.4-26.4 ft (4:32) 26.4-27.4 ft (3:28) 27.4-28.4 ft (3:56) 28.4-29.4 ft (3:59) 29.4-30.4 ft (3:10) 95% Recovery	
										25.40	
30								265.40		30.40 **Bottom of Exploration at 30.40 feet below ground surface.**	
35											
40											
45											
50											

Remarks:

Auto Hammer #149
3.1 ft from Barge Deck to Ground.
HP = Hydraulic Push

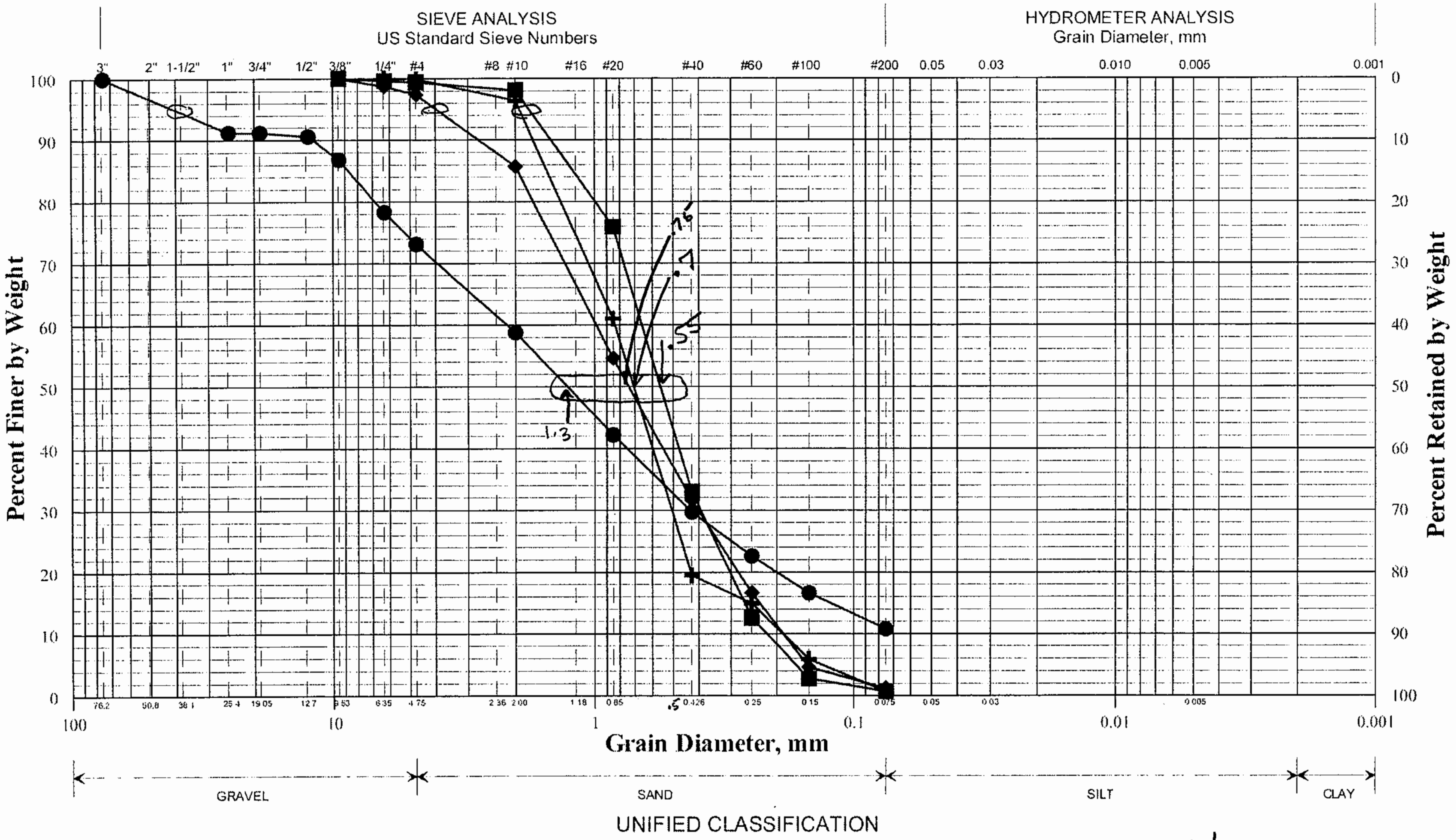
Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

Page 2 of 2

Boring No.: BB-OLAR-102

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



UNIFIED CLASSIFICATION

D50MM D95MM

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description Ave	W, %	LL	PL	PI
✚	BB-OLAR-202/1D	15+99.5	1.3 RT	0.0-2.0	SAND, trace silt, trace gravel.	26.5	.7	1.9	
◆	BB-OLAR-202/3D	15+99.5	1.3 RT	10.0-12.0	SAND, trace gravel, trace silt. .67	16.9	.75	4	2
■	BB-OLAR-202/4D	15+99.5	1.3 RT	15.0-17.0	SAND, trace gravel, trace silt.	23.3	.55	1.8	
●	BB-OLAR-202/6D	15+99.5	1.3 RT	25.0-27.0	SAND, some gravel, little silt.	10.0	1.3	40	
▲									
✕									

WIN	
019268.00	
Town	
Oxford	
Reported by/Date	
WHITE, TERRY A	6/11/2013

Ellen OBrien

From: Jack Burgess [Jack@beckerstructural.com]
Sent: Tuesday, September 17, 2013 4:27 PM
To: Ellen OBrien
Subject: FW: Oxford - 19268.00
Attachments: 01926800sh7.pdf

Hi Ellen

Below is updated D50 and D95 particle sizes based on the 5/29/2013 boring from Laura Krusinski. It appears that the new D95 particle size is smaller and the new D50 particle size is larger than the values we received last October. Could you please rerun the scour analyses based on these new particle sizes and forward us the results? Do you think it would be possible to have results by Wednesday of next week? If you need any additional information, please let me know.

Thanks for your assistance.

Jack Burgess, P.E.
Becker Structural Engineers, Inc, 75 York Street, Portland, ME 04101
Office: 207-879-1838 x108, Cell: 207-632-7145

From: Krusinski, Laura [mailto:Laura.Krusinski@maine.gov]
Sent: Tuesday, September 17, 2013 3:46 PM
To: Jack Burgess
Subject: Oxford - 19268.00

Hi Jack,

Based on Boring BB-OLAR-202 at Sta 15+99.5 (stationing we had as of 5/29/2013), samples 1D and 3D were obtained in the upper 13 feet of streambed and are classified as A-1-b and SP. This is an alluvial deposit.

Based on the laboratory grain size analyses I recommend a D95 of 2.0 mm (medium to coarse sand) and a D50 of 0.7 mm (medium sand). The gradation curves are attached.

Was the PDR signed and do you have a final design contract? If so, I can provide you with a draft, unchecked copy of the Text of the final geotechnical report – so that your office has H-pile and pipe pile geotechnical resistances. I could get that draft to you this week if you're in final design.

Laura

Piles 5-7
2'
spacing -

Laura Krusinski, P.E.
Senior Geotechnical Engineer
Maine Department of Transportation
16 State House Sta.
Augusta, ME 04333-016
Phone (207) 624-3441

Existing 10/30

HEC-RAS Plan: Plan 03 River: Little Androscog Reach: Reach 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	1407	1.1 yr	2093.00	295.50	302.25	300.29	302.61	0.001465	4.82	434.46	100.27	0.41
Reach 1	1407	10 yr	7212.00	295.50	309.00	303.36	309.56	0.000705	6.13	1521.84	376.03	0.33
Reach 1	1407	25 yr	8992.00	295.50	309.93	304.32	310.64	0.000817	6.97	1738.20	444.01	0.35
Reach 1	1407	50 yr	10367.00	295.50	310.07	304.98	310.98	0.001042	7.93	1771.47	453.35	0.40
Reach 1	1407	100 yr	11811.00	295.50	310.94	305.65	311.81	0.000952	7.94	2666.26	474.58	0.39
Reach 1	1407	500 yr	15352.00	295.50	313.55	307.12	314.35	0.000748	7.95	4066.08	569.33	0.35
Reach 1	1290	1.1 yr	2093.00	295.20	302.26		302.46	0.000595	3.52	595.10	116.33	0.27
Reach 1	1290	10 yr	7212.00	295.20	309.13		309.42	0.000374	4.36	1853.34	321.98	0.24
Reach 1	1290	25 yr	8992.00	295.20	310.11		310.47	0.000421	4.91	2224.95	420.58	0.26
Reach 1	1290	50 yr	10367.00	295.20	310.30		310.76	0.000526	5.55	2307.38	428.86	0.29
Reach 1	1290	100 yr	11811.00	295.20	311.11		311.62	0.000528	5.82	2669.86	462.33	0.30
Reach 1	1290	500 yr	15352.00	295.20	313.69		314.20	0.000427	5.96	3969.61	544.83	0.27
Reach 1	1150	1.1 yr	2093.00	294.00	302.21		302.37	0.000480	3.26	641.39	118.29	0.25
Reach 1	1150	10 yr	7212.00	294.00	309.03		309.36	0.000405	4.64	1768.00	342.40	0.25
Reach 1	1150	25 yr	8992.00	294.00	309.98		310.40	0.000463	5.26	2130.16	418.55	0.27
Reach 1	1150	50 yr	10367.00	294.00	310.14		310.68	0.000586	5.96	2196.02	423.80	0.31
Reach 1	1150	100 yr	11811.00	294.00	310.94		311.53	0.000594	6.28	2544.62	445.85	0.31
Reach 1	1150	500 yr	15352.00	294.00	313.53		314.13	0.000490	6.46	3791.09	516.88	0.29
Reach 1	1085	1.1 yr	2093.00	294.50	302.22		302.33	0.000289	2.73	765.38	127.15	0.20
Reach 1	1085	10 yr	7212.00	294.50	309.06		309.32	0.000272	4.15	1989.28	315.33	0.21
Reach 1	1085	25 yr	8992.00	294.50	310.01		310.35	0.000322	4.75	2293.55	344.65	0.23
Reach 1	1085	50 yr	10367.00	294.50	310.17		310.62	0.000409	5.40	2350.72	354.29	0.26
Reach 1	1085	100 yr	11811.00	294.50	310.97		311.47	0.000429	5.75	2651.73	401.22	0.27
Reach 1	1085	500 yr	15352.00	294.50	313.54		314.08	0.000382	6.09	3777.78	474.36	0.27
Reach 1	1043	1.1 yr	2093.00	294.00	302.16	297.79	302.32	0.000369	3.18	658.19	101.97	0.22
Reach 1	1043	10 yr	7212.00	294.00	308.93	301.03	309.30	0.000432	4.83	1521.15	266.23	0.26
Reach 1	1043	25 yr	8992.00	294.00	309.85	301.92	310.32	0.000511	5.55	1667.28	309.93	0.29
Reach 1	1043	50 yr	10367.00	294.00	309.96	302.57	310.58	0.000658	6.34	1685.12	315.15	0.32
Reach 1	1043	100 yr	11811.00	294.00	310.72	303.22	311.43	0.000693	6.78	1811.44	348.96	0.34
Reach 1	1043	500 yr	15352.00	294.00	313.35	304.80	314.05	0.000556	6.89	3335.41	465.55	0.31
Reach 1	1000		Bridge									
Reach 1	976	1.1 yr	2093.00	293.50	302.05		302.26	0.000532	3.72	562.80	93.11	0.27
Reach 1	976	10 yr	7212.00	293.50	308.68		309.20	0.000547	5.77	1291.84	212.83	0.30
Reach 1	976	25 yr	8992.00	293.50	309.49		310.19	0.000677	6.71	1399.54	274.03	0.34
Reach 1	976	50 yr	10367.00	293.50	309.46		310.39	0.000906	7.75	1395.70	272.20	0.39
Reach 1	976	100 yr	11811.00	293.50	310.12		311.21	0.000988	8.38	1492.11	320.96	0.41
Reach 1	976	500 yr	15352.00	293.50	312.45		313.71	0.000935	9.10	2213.14	435.76	0.41
Reach 1	900	1.1 yr	2093.00	292.00	302.04		302.20	0.000364	3.17	660.82	102.37	0.22
Reach 1	900	10 yr	7212.00	292.00	308.69		309.11	0.000441	5.26	1591.77	469.10	0.26
Reach 1	900	25 yr	8992.00	292.00	309.51		310.07	0.000544	6.06	2029.43	591.11	0.29
Reach 1	900	50 yr	10367.00	292.00	309.49		310.24	0.000727	7.00	2017.48	588.11	0.34
Reach 1	900	100 yr	11811.00	292.00	310.18		311.01	0.000775	7.45	2454.88	669.86	0.35
Reach 1	900	500 yr	15352.00	292.00	312.63		313.41	0.000643	7.55	4212.78	763.10	0.33
Reach 1	725	1.1 yr	2093.00	293.00	302.01		302.13	0.000308	2.79	749.18	123.55	0.20
Reach 1	725	10 yr	7212.00	293.00	308.73		309.01	0.000290	4.31	2533.05	756.36	0.21
Reach 1	725	25 yr	8992.00	293.00	309.59		309.93	0.000340	4.88	3259.36	934.87	0.24
Reach 1	725	50 yr	10367.00	293.00	309.60		310.05	0.000450	5.62	3266.72	936.50	0.27
Reach 1	725	100 yr	11811.00	293.00	310.32		310.80	0.000459	5.87	3991.34	1039.64	0.28
Reach 1	725	500 yr	15352.00	293.00	312.82		313.22	0.000346	5.69	6780.82	1192.13	0.25
Reach 1	590	1.1 yr	2093.00	292.40	302.04	295.84	302.09	0.000094	1.75	1196.75	169.50	0.12
Reach 1	590	10 yr	7212.00	292.40	308.82	298.45	308.94	0.000102	2.79	4175.19	823.84	0.13
Reach 1	590	25 yr	8992.00	292.40	309.71	299.16	309.85	0.000122	3.18	4919.71	866.79	0.15
Reach 1	590	50 yr	10367.00	292.40	309.75	299.65	309.94	0.000160	3.65	4960.19	869.06	0.17
Reach 1	590	100 yr	11811.00	292.40	310.48	300.14	310.69	0.000169	3.88	5604.85	904.52	0.18
Reach 1	590	500 yr	15352.00	292.40	312.92	301.26	313.13	0.000151	4.04	7958.63	1013.79	0.17
Reach 1	550	1.1 yr	2093.00	292.00	301.82	297.90	302.06	0.000601	3.93	532.02	83.64	0.27
Reach 1	550	10 yr	7212.00	292.00	308.36	301.54	308.89	0.000600	6.03	2161.57	715.28	0.30
Reach 1	550	25 yr	8992.00	292.00	309.15	302.59	309.79	0.000701	6.79	2781.53	861.54	0.33

POA

mDOT
7+10

DOT
8+50

EO
from
DOT
plan

DOT
+37

POA
17.6

DOT
+00

DOT
+75

OA

11
ia

HEC-RAS Plan: Plan 03 River: Little Androscog Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	550	50 yr	10367.00	292.00	308.95	303.30	309.85	0.001002	8.04	2612.71	824.29	0.39
Reach 1	550	100 yr	11811.00	292.00	309.66	304.05	310.60	0.001001	8.33	3250.99	957.54	0.40
Reach 1	550	500 yr	15352.00	292.00	312.49	306.35	313.09	0.000600	7.31	6317.01	1172.16	0.32

EXISTING

HEC-RAS Plan: Plan 03 River: Little Androscog Reach: Reach 1

Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Left	Q Channel	Q Right	Vel Chnl
			(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft/s)
Reach 1	1085	1.1 yr	302.33	302.22		0.01	0.00	127.15		2093.00		2.73
Reach 1	1085	10 yr	309.32	309.06		0.01	0.01	315.33	62.16	7132.12	17.72	4.15
Reach 1	1085	25 yr	310.35	310.01		0.02	0.01	344.65	137.44	8820.72	33.84	4.75
Reach 1	1085	50 yr	310.62	310.17		0.02	0.02	354.29	170.11	10155.46	41.43	5.40
Reach 1	1085	100 yr	311.47	310.97		0.02	0.02	401.22	267.19	11482.11	61.69	5.75
Reach 1	1085	500 yr	314.08	313.54		0.02	0.02	474.36	780.73	14417.71	153.57	6.09
Reach 1	1043	1.1 yr	302.32	302.16	297.79	0.01	0.00	101.97		2093.00		3.18
Reach 1	1043	10 yr	309.30	308.93	301.03	0.02	0.03	266.23	9.60	7200.33	2.07	4.83
Reach 1	1043	25 yr	310.32	309.85	301.92	0.02	0.05	309.93	18.23	8967.45	6.33	5.55
Reach 1	1043	50 yr	310.58	309.96	302.57	0.03	0.07	315.15	21.96	10337.10	7.94	6.34
Reach 1	1043	100 yr	311.43	310.72	303.22	0.03	0.08	348.96	32.95	11763.06	14.99	6.78
Reach 1	1043	500 yr	314.05	313.35	304.80	0.03	0.10	465.55	828.46	14467.48	56.05	6.89
Reach 1	1000 BR U	1.1 yr	302.30	302.13	296.51	0.02	0.00	88.81		2091.94	1.06	3.31
Reach 1	1000 BR U	10 yr	309.25	308.77	300.70	0.02	0.00	121.04	123.95	6896.32	191.73	5.61
Reach 1	1000 BR U	25 yr	310.26	309.62	301.75	0.03	0.01	124.29	202.09	8504.64	285.27	6.52
Reach 1	1000 BR U	50 yr	310.49	309.65	302.52	0.04	0.01	124.39	234.60	9801.96	330.44	7.50
Reach 1	1000 BR U	100 yr	311.32	310.35	303.28	0.04	0.01	129.58	302.27	11055.14	428.91	8.06
Reach 1	1000 BR U	500 yr	313.92	312.90	304.97	0.07	0.03	304.83	1017.33	13328.16	1006.51	8.46
Reach 1	1000 BR D	1.1 yr	302.28	302.11	296.70	0.01	0.01	89.78		2093.00	0.00	3.37
Reach 1	1000 BR D	10 yr	309.22	308.75	300.89	0.01	0.01	128.95	134.84	6930.94	146.22	5.58
Reach 1	1000 BR D	25 yr	310.22	309.60	301.95	0.01	0.02	133.40	222.84	8545.44	223.72	6.46
Reach 1	1000 BR D	50 yr	310.44	309.61	302.68	0.02	0.03	133.48	258.12	9850.05	258.83	7.44
Reach 1	1000 BR D	100 yr	311.26	310.32	303.41	0.02	0.04	137.21	358.26	11086.48	341.58	7.96
Reach 1	1000 BR D	500 yr	313.82	312.86	305.11	0.02	0.09	305.32	1213.15	13306.66	832.18	8.26
Reach 1	976	1.1 yr	302.26	302.05		0.03	0.03	93.11		2093.00		3.72
Reach 1	976	10 yr	309.20	308.68		0.04	0.04	212.83	17.47	7191.32	3.21	5.77
Reach 1	976	25 yr	310.19	309.49		0.05	0.07	274.03	31.60	8953.18	7.22	6.71
Reach 1	976	50 yr	310.39	309.46		0.06	0.09	272.20	36.01	10322.80	8.18	7.75
Reach 1	976	100 yr	311.21	310.12		0.07	0.13	320.96	47.43	11749.99	13.58	8.38
Reach 1	976	500 yr	313.71	312.45		0.06	0.24	435.76	272.56	15035.71	43.73	9.10
Reach 1	900	1.1 yr	302.20	302.04		0.06	0.01	102.37		2093.00		3.17
Reach 1	900	10 yr	309.11	308.69		0.06	0.05	469.10	43.84	7168.16		5.26
Reach 1	900	25 yr	310.07	309.51		0.07	0.06	591.11	187.78	8804.22		6.06
Reach 1	900	50 yr	310.24	309.49		0.10	0.09	588.11	211.90	10155.10		7.00
Reach 1	900	100 yr	311.01	310.18		0.10	0.10	669.86	450.05	11360.93	0.01	7.45
Reach 1	900	500 yr	313.41	312.63		0.08	0.11	763.10	1825.11	13511.25	15.64	7.55

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR U Profile: 50 yr Existing

E.G. Elev (ft)	310.49	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.84	Wt. n-Val.	0.030	0.030	0.030
W.S. Elev (ft)	309.65	Reach Len. (ft)	25.00	25.00	25.00
Crit W.S. (ft)	302.52	Flow Area (sq ft)	59.57	1307.26	75.34
E.G. Slope (ft/ft)	0.001278	Area (sq ft)	59.57	1307.26	75.34
Q Total (cfs)	10367.00	Flow (cfs)	234.60	9801.96	330.44
Top Width (ft)	124.39	Top Width (ft)	16.83	90.33	17.23
Vel Total (ft/s)	7.19	Avg. Vel. (ft/s)	3.94	7.50	4.39
Max Chl Dpth (ft)	18.05	Hydr. Depth (ft)	3.54	14.47	4.37
Conv. Total (cfs)	290008.4	Conv. (cfs)	6562.7	274201.8	9243.9
Length Wtd. (ft)	25.00	Wetted Per. (ft)	17.96	150.01	19.32
Min Ch El (ft)	291.60	Shear (lb/sq ft)	0.26	0.70	0.31
Alpha	1.05	Stream Power (lb/ft s)	421.32	0.00	0.00
Frctn Loss (ft)	0.04	Cum Volume (acre-ft)	8.24	18.23	4.69
C & E Loss (ft)	0.01	Cum SA (acres)	4.49	1.34	1.69

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR U Profile: 100 yr

E.G. Elev (ft)	311.32	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.97	Wt. n-Val.	0.030	0.030	0.030
W.S. Elev (ft)	310.35	Reach Len. (ft)	25.00	25.00	25.00
Crit W.S. (ft)	303.28	Flow Area (sq ft)	72.65	1371.23	88.03
E.G. Slope (ft/ft)	0.001427	Area (sq ft)	72.65	1371.23	88.03
Q Total (cfs)	11811.00	Flow (cfs)	302.27	11055.14	428.91
Top Width (ft)	129.58	Top Width (ft)	20.63	90.33	18.62
Vel Total (ft/s)	7.69	Avg. Vel. (ft/s)	4.16	8.06	4.87
Max Chl Dpth (ft)	18.75	Hydr. Depth (ft)	3.52	15.18	4.73
Conv. Total (cfs)	312643.7	Conv. (cfs)	8018.0	293248.3	11377.4
Length Wtd. (ft)	25.00	Wetted Per. (ft)	21.84	152.84	20.89
Min Ch El (ft)	291.60	Shear (lb/sq ft)	0.30	0.80	0.38
Alpha	1.05	Stream Power (lb/ft s)	421.32	0.00	0.00
Frctn Loss (ft)	0.04	Cum Volume (acre-ft)	11.69	19.18	5.98
C & E Loss (ft)	0.01	Cum SA (acres)	5.09	1.34	1.87

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR D Profile: 50 yr

E.G. Elev (ft)	310.44	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.83	Wt. n-Val.	0.040	0.040	0.040
W.S. Elev (ft)	309.61	Reach Len. (ft)	11.50	11.50	11.50
Crit W.S. (ft)	302.68	Flow Area (sq ft)	70.97	1324.80	64.76
E.G. Slope (ft/ft)	0.002095	Area (sq ft)	70.97	1324.80	64.76
Q Total (cfs)	10367.00	Flow (cfs)	258.12	9850.05	258.83
Top Width (ft)	133.48	Top Width (ft)	21.91	95.30	16.27
Vel Total (ft/s)	7.10	Avg. Vel. (ft/s)	3.64	7.44	4.00
Max Chl Dpth (ft)	19.51	Hydr. Depth (ft)	3.24	13.90	3.98
Conv. Total (cfs)	226485.0	Conv. (cfs)	5639.2	215191.3	5654.5
Length Wtd. (ft)	11.50	Wetted Per. (ft)	22.69	144.89	17.97
Min Ch El (ft)	290.10	Shear (lb/sq ft)	0.41	1.20	0.47
Alpha	1.06	Stream Power (lb/ft s)	359.50	0.00	0.00
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	8.21	17.47	4.65
C & E Loss (ft)	0.03	Cum SA (acres)	4.47	1.29	1.68

EXISTING

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR D Profile: 100 yr

E.G. Elev (ft)	311.26	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.94	Wt. n-Val.	0.040	0.040	0.040
W.S. Elev (ft)	310.32	Reach Len. (ft)	11.50	11.50	11.50
Crit W.S. (ft)	303.41	Flow Area (sq ft)	87.33	1392.51	76.79
E.G. Slope (ft/ft)	0.002317	Area (sq ft)	87.33	1392.51	76.79
Q Total (cfs)	11811.00	Flow (cfs)	358.26	11086.48	341.58
Top Width (ft)	137.21	Top Width (ft)	24.16	95.42	17.63
Vel Total (ft/s)	7.57	Avg. Vel. (ft/s)	4.10	7.96	4.45
Max Chl Dpth (ft)	20.22	Hydr. Depth (ft)	3.61	14.59	4.36
Conv. Total (cfs)	245395.2	Conv. (cfs)	7459.2	230824.2	7111.8
Length Wtd. (ft)	11.50	Wetted Per. (ft)	25.05	147.73	19.51
Min Ch El (ft)	290.10	Shear (lb/sq ft)	0.50	1.36	0.57
Alpha	1.06	Stream Power (lb/ft s)	359.50	0.00	0.00
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	11.64	18.39	5.93
C & E Loss (ft)	0.04	Cum SA (acres)	5.08	1.29	1.86

EXISTNG .

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR U Profile: 50 yr

	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	63.40	142.66	234.60	59.57	17.96	2.26	3.54	3.94	0.26	1.04
2	Chan	142.66	153.02	416.58	84.66	11.63	4.02	8.17	4.92	0.58	2.86
3	Chan	153.02	163.39	87.44	49.85	32.18	0.84	11.86	1.75	0.12	0.22
4	Chan	163.39	173.76	1308.29	161.42	10.49	12.62	15.57	8.11	1.23	9.95
5	Chan	173.76	184.12	1481.09	173.26	10.40	14.29	16.71	8.55	1.33	11.36
6	Chan	184.12	194.49	1508.39	175.23	10.41	14.55	16.90	8.61	1.34	11.56
7	Chan	194.49	204.86	1612.93	182.98	10.49	15.56	17.65	8.81	1.39	12.27
8	Chan	204.86	215.22	1425.44	169.83	10.48	13.75	16.38	8.39	1.29	10.86
9	Chan	215.22	225.59	1245.49	156.36	10.43	12.01	15.08	7.97	1.20	9.52
10	Chan	225.59	235.96	81.01	47.94	32.73	0.78	11.59	1.69	0.12	0.20
11	Chan	235.96	246.32	635.30	105.73	10.77	6.13	10.20	6.01	0.78	4.71
12	ROB	246.32	281.32	330.44	75.34	19.32	3.19	4.37	4.39	0.31	1.36

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR U Profile: 100 yr

	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	63.40	142.66	302.27	72.65	21.84	2.56	3.52	4.16	0.30	1.23
2	Chan	142.66	153.02	500.23	92.00	11.63	4.24	8.88	5.44	0.70	3.83
3	Chan	153.02	163.39	96.73	52.47	33.60	0.82	12.48	1.84	0.14	0.26
4	Chan	163.39	173.76	1472.90	168.76	10.49	12.50	16.28	8.73	1.43	12.51
5	Chan	173.76	184.12	1659.18	180.60	10.40	14.08	17.42	9.19	1.55	14.22
6	Chan	184.12	194.49	1688.47	182.58	10.41	14.33	17.61	9.25	1.56	14.45
7	Chan	194.49	204.86	1800.38	190.32	10.49	15.28	18.36	9.46	1.32	15.30
8	Chan	204.86	215.22	1599.03	177.17	10.48	13.57	17.09	9.03	1.51	13.60
9	Chan	215.22	225.59	1405.48	163.70	10.43	11.92	15.79	8.59	1.40	12.00
10	Chan	225.59	235.96	89.96	50.55	34.14	0.76	12.23	1.78	0.13	0.23
11	Chan	235.96	246.32	742.76	113.07	10.77	6.30	10.91	6.57	0.94	6.15
12	ROB	246.32	281.32	428.91	88.03	20.89	3.64	4.73	4.87	0.38	1.83

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR D Profile: 50 yr

	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	58.49	116.03	258.12	70.97	22.69	2.49	3.24	3.64	0.41	1.49
2	Chan	116.03	126.49	410.92	85.28	12.46	3.96	8.15	4.82	0.90	4.31
3	Chan	126.49	136.95	156.25	66.92	28.98	1.51	11.43	2.33	0.30	0.71
4	Chan	136.95	147.41	1265.61	158.11	10.79	12.21	15.11	8.00	1.92	15.35
5	Chan	147.41	157.88	1460.43	170.32	10.48	14.09	16.28	8.57	2.13	18.23
6	Chan	157.88	168.34	1593.57	180.50	10.63	15.37	17.25	8.83	2.22	19.61
7	Chan	168.34	178.80	1791.97	195.79	10.92	17.29	18.72	9.15	2.34	21.46
8	Chan	178.80	189.26	1394.44	167.95	10.85	13.45	16.05	8.30	2.03	16.82
9	Chan	189.26	199.72	1102.62	144.59	10.61	10.64	13.82	7.63	1.78	13.60
10	Chan	199.72	210.18	131.92	59.87	28.28	1.27	10.40	2.20	0.28	0.61
11	Chan	210.18	220.65	542.32	95.45	10.89	5.23	9.12	5.68	1.15	6.51
12	ROB	220.65	248.46	258.83	64.76	17.97	2.50	3.98	4.00	0.47	1.88

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR D Profile: 100 yr

	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	58.49	116.03	358.26	87.33	25.05	3.04	3.61	4.10	0.50	2.07
2	Chan	116.03	126.49	492.13	92.71	12.46	4.18	8.86	5.31	1.08	5.71
3	Chan	126.49	136.95	174.44	71.10	30.40	1.48	12.03	2.45	0.34	0.83
4	Chan	136.95	147.41	1423.64	165.54	10.79	12.08	15.82	8.60	2.22	19.09
5	Chan	147.41	157.88	1633.98	177.75	10.48	13.86	16.99	9.19	2.45	22.55

EXISTING

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 BR D Profile: 100 yr (Continued)

	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)
6	Chan	157.88	168.34	1775.95	187.93	10.63	15.07	17.96	9.45	2.56	24.16
7	Chan	168.34	178.80	1986.79	203.22	10.92	16.86	19.43	9.78	2.69	26.30
8	Chan	178.80	189.26	1561.69	175.38	10.85	13.25	16.76	8.90	2.34	20.82
9	Chan	189.26	199.72	1248.98	152.02	10.61	10.60	14.53	8.22	2.07	17.03
10	Chan	199.72	210.18	148.60	63.98	29.71	1.26	11.00	2.32	0.31	0.72
11	Chan	210.18	220.65	640.27	102.88	10.89	5.43	9.83	6.22	1.37	8.50
12	ROB	220.65	248.46	341.58	76.79	19.51	2.90	4.36	4.45	0.57	2.53

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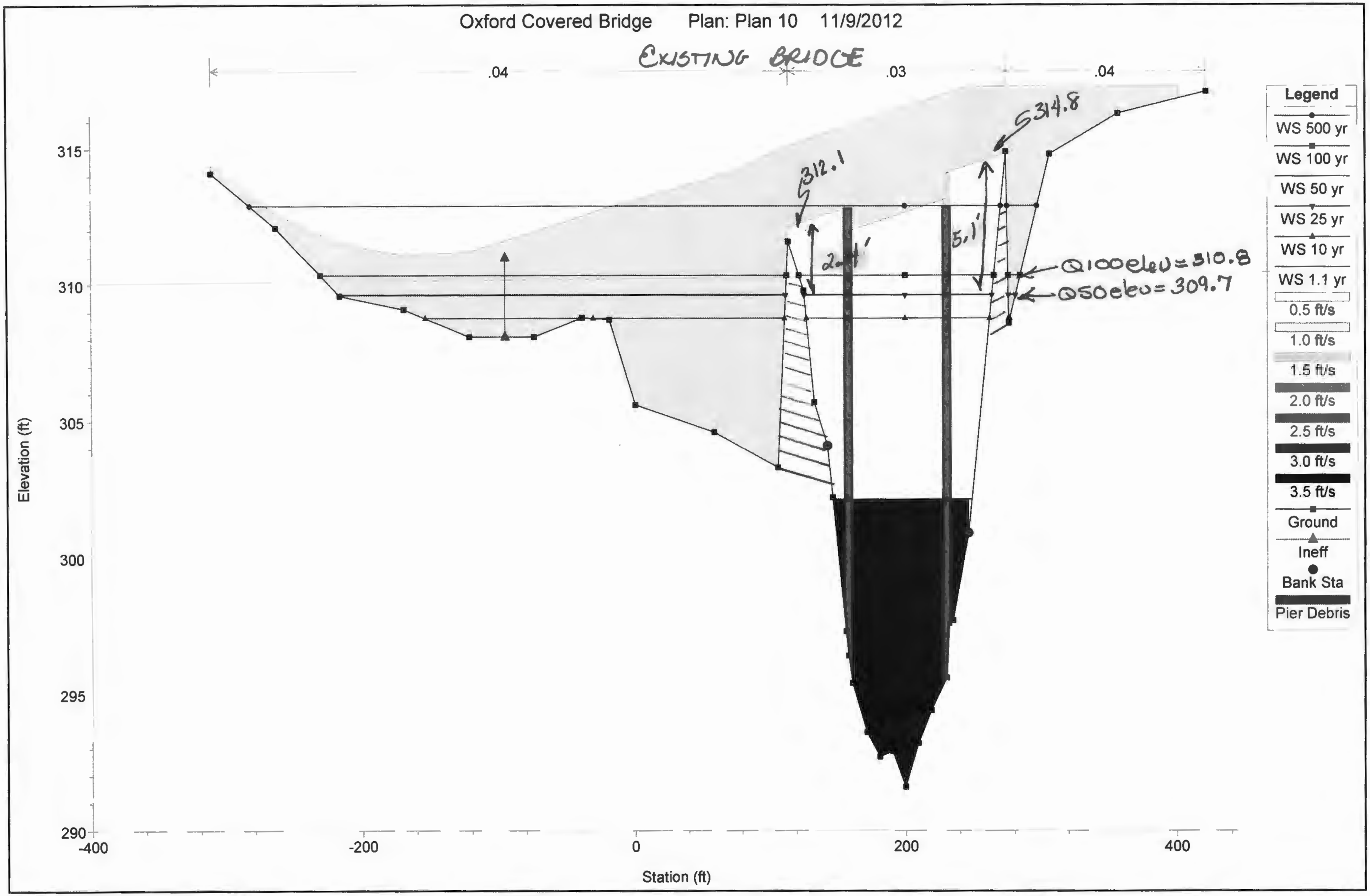
EXISTING

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 Profile: 50 yr

E.G. US. (ft)	310.58	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	309.96	E.G. Elev (ft)	310.49	310.44
Q Total (cfs)	10367.00	W.S. Elev (ft)	309.65	309.61
Q Bridge (cfs)	10367.00	Crit W.S. (ft)	302.52	302.68
Q Weir (cfs)		Max Chl Dpth (ft)	18.05	19.51
Weir Sta Lft (ft)		Vel Total (ft/s)	7.19	7.10
Weir Sta Rgt (ft)		Flow Area (sq ft)	1442.17	1460.53
Weir Submerg		Froude # Chl	0.35	0.35
Weir Max Depth (ft)		Specif Force (cu ft)	12632.63	12520.83
Min El Weir Flow (ft)	311.11	Hydr Depth (ft)	11.59	10.94
Min El Prs (ft)	314.82	W.P. Total (ft)	187.29	185.55
Delta EG (ft)	0.19	Conv. Total (cfs)	290008.4	226485.0
Delta WS (ft)	0.49	Top Width (ft)	124.39	133.48
BR Open Area (sq ft)	1903.68	Frctn Loss (ft)	0.04	0.02
BR Open Vel (ft/s)	7.19	C & E Loss (ft)	0.01	0.03
Coef of Q		Shear Total (lb/sq ft)	0.61	1.03
Br Sel Method	Energy only	Power Total (lb/ft s)	-311.95	-340.48

Plan: Plan 03 Little Androscog Reach 1 RS: 1000 Profile: 100 yr

E.G. US. (ft)	311.43	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	310.72	E.G. Elev (ft)	311.32	311.26
Q Total (cfs)	11811.00	W.S. Elev (ft)	310.35	310.32
Q Bridge (cfs)	11786.32	Crit W.S. (ft)	303.28	303.41
Q Weir (cfs)	24.68	Max Chl Dpth (ft)	18.75	20.22
Weir Sta Lft (ft)	-205.73	Vel Total (ft/s)	7.69	7.57
Weir Sta Rgt (ft)	-108.71	Flow Area (sq ft)	1531.91	1556.64
Weir Submerg	0.00	Froude # Chl	0.36	0.37
Weir Max Depth (ft)	0.34	Specif Force (cu ft)	14201.34	14090.16
Min El Weir Flow (ft)	311.11	Hydr Depth (ft)	11.82	11.34
Min El Prs (ft)	314.82	W.P. Total (ft)	195.57	192.29
Delta EG (ft)	0.22	Conv. Total (cfs)	312643.7	245395.2
Delta WS (ft)	0.60	Top Width (ft)	129.58	137.21
BR Open Area (sq ft)	1903.68	Frctn Loss (ft)	0.04	0.02
BR Open Vel (ft/s)	7.69	C & E Loss (ft)	0.01	0.04
Coef of Q		Shear Total (lb/sq ft)	0.70	1.17
Br Sel Method	Energy/Weir	Power Total (lb/ft s)	-311.95	-340.48



1 in Horiz. = 100 ft 1 in Vert. = 5 ft

Covered Bridge #3738
Oxford, Maine
10-02-2012

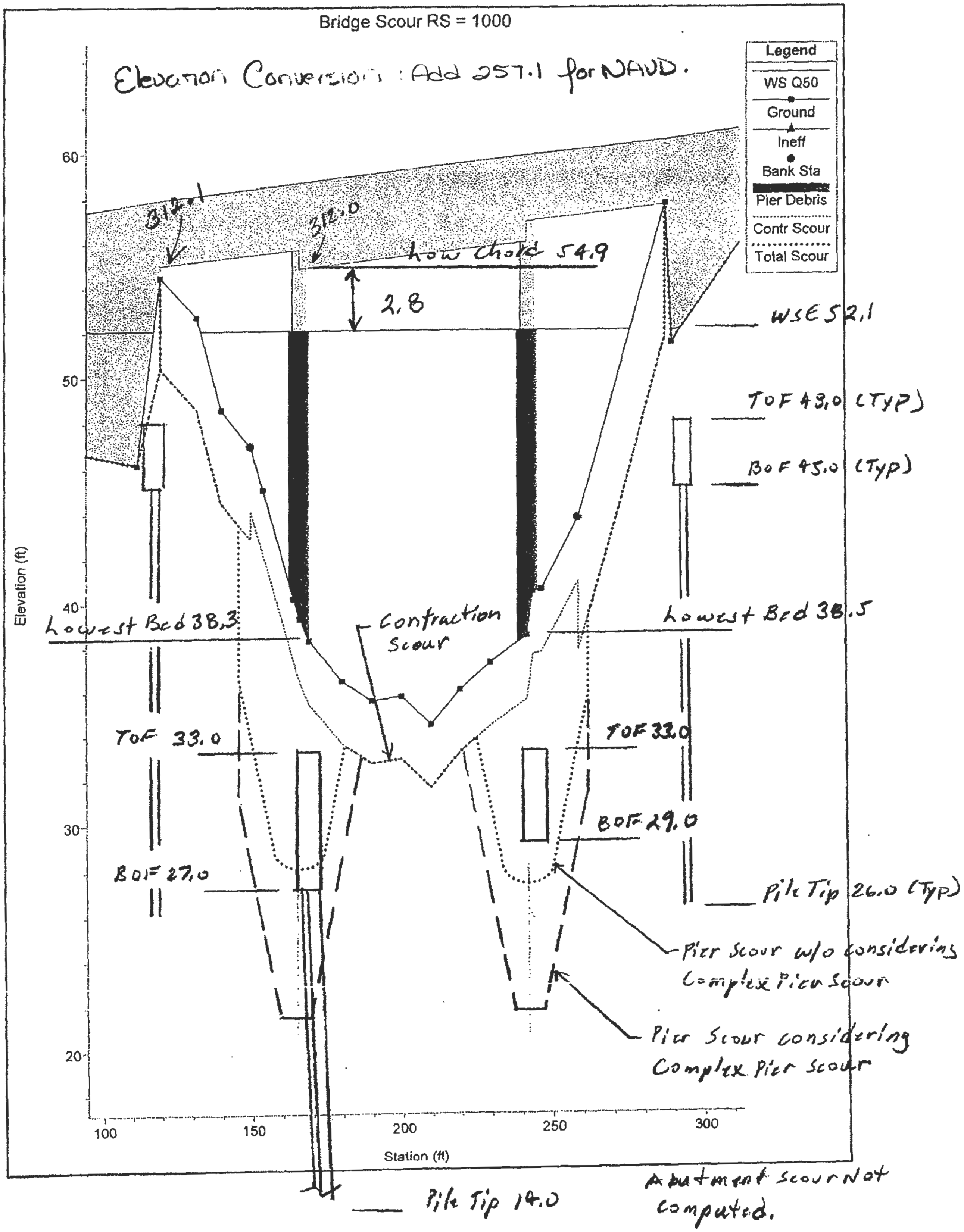
Summary of Water Elevations from Hydraulic Analyses

Event / Location	Existing Plan Datum	1988 NAVD (+257.1')	Comments
Scour Monitoring Event (Q10 - POA Study)	49.90'	307.00'	Low Mark on Scour POA Placard
June 2012 High Water Event	52.00'	309.10'	Don McKenna, Bridge Maintenance Supervisor, observed water within 1" of the Bridge Closure Level on the Scour POA Placard. Steve Brown, Oxford Road Foreman noted the highest water level he has observed in his twenty years of service.
Close Bridge Event (Q50 - POA Study)	52.10'	309.20'	High Mark on Scour POA Placard
Q50 (HECRAS Model of Existing Bridge)	52.50'	309.60'	
Q100 (HECRAS Model of Existing Bridge)	53.40'	310.30'	
Existing Roadway is Breached and Mobile Home is Flooded	53.90'	311.00'	
1987 Flood - Downstream of Bridge (Between 100 and 500 yr)	53.90'	311.00'	
1987 Flood - Upstream of Bridge (Between 100 and 500 yr)	54.00'	311.10'	
• *1 foot of freeboard above Q100*	*54.40'*	*311.30'*	
• *2 feet of freeboard above Q50 (Other Riverine Bridge)*	*54.50'*	*311.60'*	
Low Chord on Existing Bridge	54.90'	312.00'	
• *1 foot of freeboard above Record Flood (1987)*	*55.00'*	*312.10'*	
Q500 (HECRAS Model of Existing Bridge)	55.50'	312.60'	
• *4 feet of freeboard above Q50 (Major River Crossing)*	*56.50'*	*313.60'*	

FROM SCOUR POA, [illegible] E

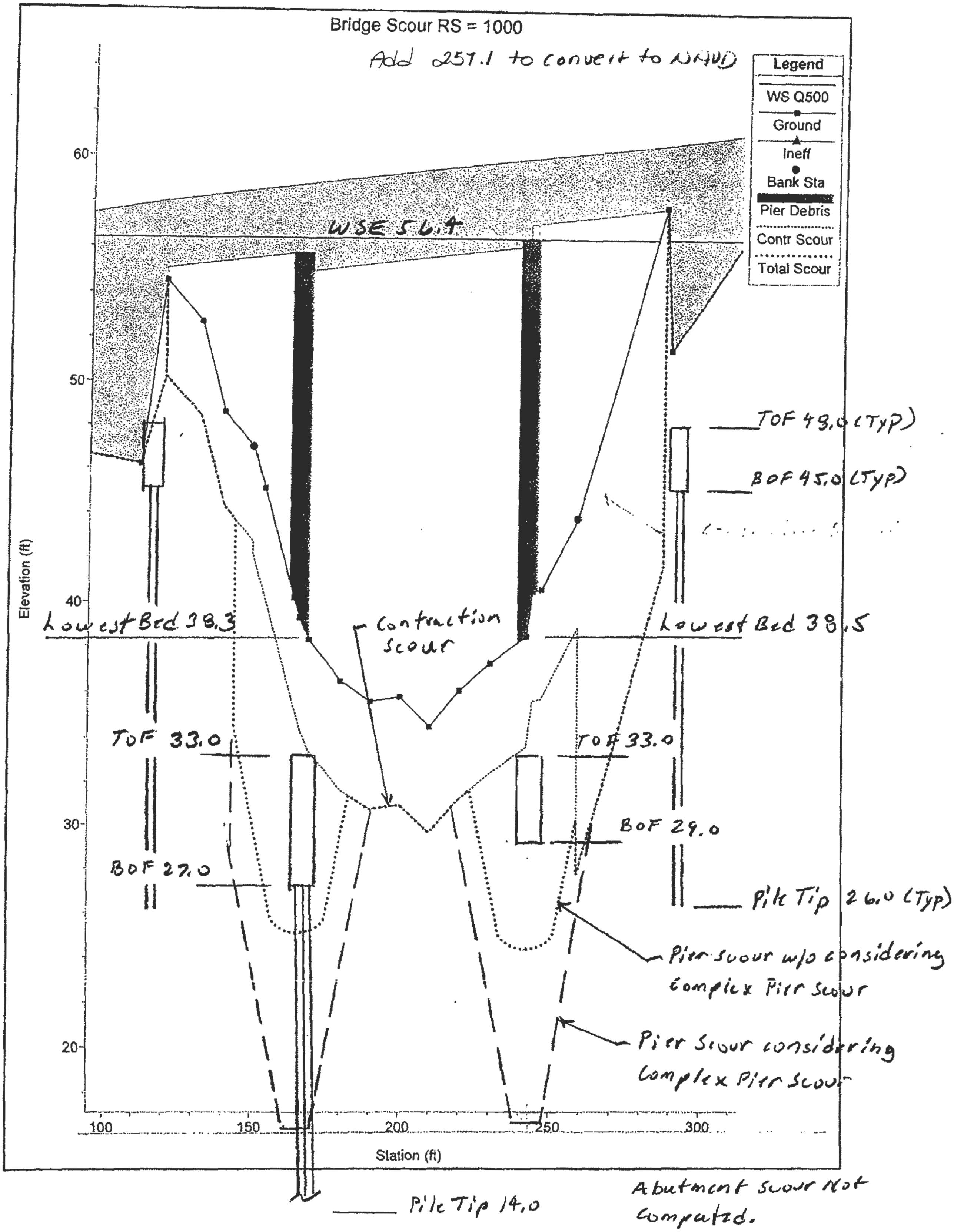
50-YR Event

Ox ford # 3738



Abutment scour Not computed.

FROM SCOUR FOR, EXISTING BRIDGE
500-YR Event
Oxford # 3738



HEC-RAS Plan:

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Reach 1	1407	1.1 yr	2093.00	295.50	302.80	300.29	303.09	0.000994	4.27	490.17	100.50	0.34
Reach 1	1407	10 yr	7212.00	295.50	309.43	303.36	309.94	0.000614	5.87	1619.63	409.83	0.31
Reach 1	1407	25 yr	8992.00	295.50	309.99	304.32	310.69	0.000804	6.93	1751.65	447.80	0.35
Reach 1	1407	50 yr	10367.00	295.50	310.21	304.98	311.01	0.000933	7.56	2323.10	462.50	0.38
Reach 1	1407	100 yr	11811.00	295.50	311.02	305.65	311.87	0.000928	7.87	2703.67	475.88	0.38
Reach 1	1407	500 yr	15352.00	295.50	313.50	307.12	314.32	0.000758	7.98	4039.97	568.57	0.36
Reach 1	1290	1.1 yr	2093.00	295.20	302.82		302.97	0.000465	3.16	662.25	126.14	0.24
Reach 1	1290	10 yr	7212.00	295.20	309.55		309.81	0.000326	4.17	1997.67	396.87	0.23
Reach 1	1290	25 yr	8992.00	295.20	310.16		310.52	0.000414	4.88	2247.70	422.89	0.26
Reach 1	1290	50 yr	10367.00	295.20	310.37		310.83	0.000513	5.50	2339.09	432.01	0.29
Reach 1	1290	100 yr	11811.00	295.20	311.19		311.69	0.000516	5.78	2704.69	464.73	0.29
Reach 1	1290	500 yr	15352.00	295.20	313.65		314.16	0.000432	5.98	3945.83	543.43	0.28
Reach 1	1150	1.1 yr	2093.00	294.00	302.77		302.91	0.000354	2.95	709.11	120.57	0.21
Reach 1	1150	10 yr	7212.00	294.00	309.46		309.76	0.000352	4.44	1923.15	376.91	0.24
Reach 1	1150	25 yr	8992.00	294.00	310.04		310.45	0.000455	5.23	2153.63	421.04	0.27
Reach 1	1150	50 yr	10367.00	294.00	310.22		310.75	0.000572	5.92	2228.83	425.92	0.30
Reach 1	1150	100 yr	11811.00	294.00	311.02		311.60	0.000581	6.23	2579.75	448.01	0.31
Reach 1	1150	500 yr	15352.00	294.00	313.48		314.09	0.000496	6.48	3767.64	515.79	0.29
Reach 1	1085	1.1 yr	2093.00	294.50	302.78	297.89	302.88	0.000232	2.57	815.93	126.02	0.18
Reach 1	1085	10 yr	7212.00	294.50	309.47	300.82	309.73	0.000254	4.10	2067.37	309.70	0.21
Reach 1	1085	25 yr	8992.00	294.50	310.05	301.61	310.41	0.000336	4.86	2248.59	338.17	0.24
Reach 1	1085	50 yr	10367.00	294.50	310.23	302.21	310.69	0.000425	5.51	2310.40	348.50	0.27
Reach 1	1085	100 yr	11811.00	294.50	311.03	302.76	311.55	0.000446	5.87	2605.99	393.34	0.28
Reach 1	1085	500 yr	15352.00	294.50	313.47	304.09	314.05	0.000410	6.28	3649.76	460.35	0.27
Reach 1	1063		Bridge									
Reach 1	1043	1.1 yr	2093.00	294.00	302.14		302.28	0.000354	3.10	675.06	106.47	0.22
Reach 1	1043	10 yr	7212.00	294.00	308.93		309.24	0.000398	4.50	1810.67	288.21	0.25
Reach 1	1043	25 yr	8992.00	294.00	309.84		310.24	0.000457	5.11	2094.95	332.36	0.27
Reach 1	1043	50 yr	10367.00	294.00	309.95		310.47	0.000588	5.82	2131.03	337.55	0.31
Reach 1	1043	100 yr	11811.00	294.00	310.71		311.29	0.000604	6.17	2399.69	370.48	0.32
Reach 1	1043	500 yr	15352.00	294.00	313.16		313.78	0.000516	6.46	3434.07	472.04	0.30
Reach 1	976	1.1 yr	2093.00	293.50	302.05		302.24	0.000479	3.54	591.86	97.91	0.25
Reach 1	976	10 yr	7212.00	293.50	308.70		309.16	0.000491	5.48	1359.28	204.50	0.28
Reach 1	976	25 yr	8992.00	293.50	309.51		310.14	0.000606	6.37	1485.39	254.25	0.32
Reach 1	976	50 yr	10367.00	293.50	309.49		310.33	0.000811	7.36	1482.08	253.01	0.37
Reach 1	976	100 yr	11811.00	293.50	310.14		311.12	0.000883	7.95	1588.32	291.48	0.39
Reach 1	976	500 yr	15352.00	293.50	312.44		313.58	0.000842	8.65	2261.53	418.39	0.39
Reach 1	900	1.1 yr	2093.00	292.00	302.04		302.20	0.000364	3.17	660.82	102.37	0.22
Reach 1	900	10 yr	7212.00	292.00	308.69		309.11	0.000441	5.26	1591.77	469.10	0.26
Reach 1	900	25 yr	8992.00	292.00	309.51		310.07	0.000544	6.06	2029.45	591.11	0.29
Reach 1	900	50 yr	10367.00	292.00	309.49		310.24	0.000727	7.00	2017.48	588.11	0.34
Reach 1	900	100 yr	11811.00	292.00	310.18		311.01	0.000775	7.45	2454.88	669.86	0.35
Reach 1	900	500 yr	15352.00	292.00	312.63		313.41	0.000643	7.55	4212.78	763.10	0.33
Reach 1	725	1.1 yr	2093.00	293.00	302.01		302.13	0.000308	2.79	749.18	123.55	0.20
Reach 1	725	10 yr	7212.00	293.00	308.73		309.01	0.000290	4.31	2533.05	756.36	0.21
Reach 1	725	25 yr	8992.00	293.00	309.59		309.93	0.000340	4.88	3259.39	934.87	0.24
Reach 1	725	50 yr	10367.00	293.00	309.60		310.05	0.000450	5.62	3266.72	936.50	0.27
Reach 1	725	100 yr	11811.00	293.00	310.32		310.80	0.000459	5.87	3991.34	1039.64	0.28
Reach 1	725	500 yr	15352.00	293.00	312.82		313.22	0.000346	5.69	6780.82	1192.13	0.25
Reach 1	590	1.1 yr	2093.00	292.40	302.04	295.84	302.09	0.000094	1.75	1196.75	169.50	0.12
Reach 1	590	10 yr	7212.00	292.40	308.82	298.45	308.94	0.000102	2.79	4175.19	823.84	0.13
Reach 1	590	25 yr	8992.00	292.40	309.71	299.16	309.85	0.000122	3.18	4919.74	866.79	0.15
Reach 1	590	50 yr	10367.00	292.40	309.75	299.65	309.94	0.000160	3.65	4960.19	869.06	0.17
Reach 1	590	100 yr	11811.00	292.40	310.48	300.14	310.69	0.000169	3.88	5604.85	904.52	0.18
Reach 1	590	500 yr	15352.00	292.40	312.92	301.26	313.13	0.000151	4.04	7958.63	1013.79	0.17
Reach 1	550	1.1 yr	2093.00	292.00	301.82	297.90	302.06	0.000601	3.93	532.02	83.64	0.27
Reach 1	550	10 yr	7212.00	292.00	308.36	301.54	308.89	0.000600	6.03	2161.57	715.28	0.30
Reach 1	550	25 yr	8992.00	292.00	309.15	302.58	309.79	0.000701	6.79	2781.56	861.55	0.33

HEC-RAS Plan: (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	550	50 yr	10367.00	292.00	308.95	303.32	309.85	0.001002	8.04	2612.71	824.29	0.39
Reach 1	550	100 yr	11811.00	292.00	309.66	304.05	310.60	0.001001	8.33	3250.99	957.54	0.40
Reach 1	550	500 yr	15352.00	292.00	312.49	306.35	313.09	0.000600	7.31	6317.01	1172.16	0.32

HEC-RAS Plan:

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Reach 1	1150	1.1 yr	302.91	302.77		0.02	0.01	120.57		2093.00		2.95
Reach 1	1150	10 yr	309.76	309.46		0.02	0.01	376.91	92.28	7119.60	0.12	4.44
Reach 1	1150	25 yr	310.45	310.04		0.03	0.02	421.04	175.35	8815.43	1.22	5.23
Reach 1	1150	50 yr	310.75	310.22		0.03	0.02	425.92	229.64	10135.27	2.09	5.92
Reach 1	1150	100 yr	311.60	311.02		0.03	0.02	448.01	408.52	11394.35	8.13	6.23
Reach 1	1150	500 yr	314.09	313.48		0.03	0.01	515.79	1115.52	14173.42	63.06	6.48
Reach 1	1085	1.1 yr	302.88	302.78	297.89			126.02		2093.00		2.57
Reach 1	1085	10 yr	309.73	309.47	300.82			309.70	87.36	7102.99	21.65	4.10
Reach 1	1085	25 yr	310.41	310.05	301.61	0.00	0.06	338.17	140.07	8817.55	34.38	4.86
Reach 1	1085	50 yr	310.69	310.23	302.21	0.00	0.08	348.50	174.52	10150.17	42.31	5.51
Reach 1	1085	100 yr	311.55	311.03	302.76	0.00	0.09	393.34	273.88	11474.30	62.82	5.87
Reach 1	1085	500 yr	314.05	313.47	304.09	0.00	0.09	460.35	769.96	14430.52	151.51	6.28
Reach 1	1063 BR U	1.1 yr	302.88	302.71	298.44			103.78		2093.00		3.35
Reach 1	1063 BR U	10 yr	309.75	309.36	301.94			141.03	4.29	7207.71	0.00	5.01
Reach 1	1063 BR U	25 yr	310.35	309.79	302.84	0.03	0.02	142.57	6.95	8985.03	0.03	6.00
Reach 1	1063 BR U	50 yr	310.61	309.88	303.49	0.03	0.03	142.89	8.42	10358.53	0.05	6.86
Reach 1	1063 BR U	100 yr	311.45	310.62	304.22	0.04	0.03	146.28	13.68	11786.53	0.48	7.32
Reach 1	1063 BR U	500 yr	313.96	313.08	305.63	0.04	0.04	106.99	16.11	14531.04	6.85	7.54
Reach 1	1063 BR D	1.1 yr	302.29	302.11	297.84			101.76		2093.00		3.41
Reach 1	1063 BR D	10 yr	309.25	308.86	301.33			139.25		7212.00		5.05
Reach 1	1063 BR D	25 yr	310.30	309.79	302.33	0.00	0.06	142.55		8992.00		5.76
Reach 1	1063 BR D	50 yr	310.55	309.88	302.99	0.00	0.08	142.87		10367.00		6.59
Reach 1	1063 BR D	100 yr	311.38	310.62	303.73	0.00	0.10	146.27	0.30	11800.39		7.02
Reach 1	1063 BR D	500 yr	313.88	313.07	305.19	0.00	0.09	107.14	0.83	14553.15	0.01	7.20
Reach 1	1043	1.1 yr	302.28	302.14		0.03	0.01	106.47		2093.00		3.10
Reach 1	1043	10 yr	309.24	308.93		0.03	0.05	288.21	77.63	7132.35	2.02	4.50
Reach 1	1043	25 yr	310.24	309.84		0.04	0.07	332.36	152.44	8833.44	6.11	5.11
Reach 1	1043	50 yr	310.47	309.95		0.05	0.10	337.55	184.34	10175.00	7.65	5.82
Reach 1	1043	100 yr	311.29	310.71		0.05	0.12	370.48	287.31	11509.42	14.28	6.17
Reach 1	1043	500 yr	313.78	313.16		0.04	0.16	472.04	759.75	14541.15	51.10	6.46
Reach 1	976	1.1 yr	302.24	302.05		0.03	0.01	97.91		2093.00		3.54
Reach 1	976	10 yr	309.16	308.70		0.04	0.01	204.50	12.03	7196.71	3.27	5.48
Reach 1	976	25 yr	310.14	309.51		0.04	0.02	254.25	29.41	8955.26	7.33	6.37
Reach 1	976	50 yr	310.33	309.49		0.06	0.03	253.01	33.43	10325.23	8.34	7.36
Reach 1	976	100 yr	311.12	310.14		0.06	0.04	291.48	57.14	11740.09	13.76	7.95
Reach 1	976	500 yr	313.58	312.44		0.06	0.11	418.39	289.63	15018.72	43.65	8.65

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Plan: Plan 25   Little Androscog   Reach 1  RS: 1063   BR U   Profile: 50 yr
 E.G. Elev (ft)            310.61   Element                  Left OB     Channel    Right OB
 Vel Head (ft)               0.73   Wt. n-Val.                 0.120       0.030       0.090
 W.S. Elev (ft)            309.88   Reach Len. (ft)            33.30       33.30       33.30
 Crit W.S. (ft)            303.49   Flow Area (sq ft)          14.68     1510.06        0.24
 E.G. Slope (ft/ft)      0.001036   Area (sq ft)               14.68     1510.06        0.24
 Q Total (cfs)           10367.00   Flow (cfs)                  8.42    10358.53        0.05
 Top Width (ft)            142.89   Top Width (ft)              7.57      134.45        0.87
 Vel Total (ft/s)            6.80   Avg. Vel. (ft/s)            0.57        6.86        0.20
 Max Chl Dpth (ft)          15.17   Hydr. Depth (ft)            1.94       11.23        0.27
 Conv. Total (cfs)       322127.4   Conv. (cfs)                261.7    321864.2         1.5
 Length Wtd. (ft)           33.30   Wetted Per. (ft)            8.50      169.16        1.03
 Min Ch El (ft)            294.71   Shear (lb/sq ft)            0.11        0.58        0.01
 Alpha                       1.02   Stream Power (lb/ft s)    152.00        0.00        0.00
 Frctn Loss (ft)             0.03   Cum Volume (acre-ft)        8.58       21.00        4.66
 C & E Loss (ft)             0.03   Cum SA (acres)              4.68        1.60        1.69

Plan: Plan 25   Little Androscog   Reach 1  RS: 1063   BR U   Profile: 100 yr
 E.G. Elev (ft)            311.45   Element                  Left OB     Channel    Right OB
 Vel Head (ft)               0.83   Wt. n-Val.                 0.120       0.030       0.090
 W.S. Elev (ft)            310.62   Reach Len. (ft)            33.30       33.30       33.30
 Crit W.S. (ft)            304.22   Flow Area (sq ft)          21.66     1609.48        1.32
 E.G. Slope (ft/ft)      0.001099   Area (sq ft)               21.66     1609.48        1.32
 Q Total (cfs)           11811.00   Flow (cfs)                 13.68    11786.53        0.48
 Top Width (ft)            146.28   Top Width (ft)              9.77      134.45        2.05
 Vel Total (ft/s)            7.23   Avg. Vel. (ft/s)            0.63        7.32        0.36
 Max Chl Dpth (ft)          15.91   Hydr. Depth (ft)            2.22       11.97        0.64
 Conv. Total (cfs)       356307.2   Conv. (cfs)                412.9    355879.8        14.5
 Length Wtd. (ft)           33.30   Wetted Per. (ft)           11.33      170.64        2.42
 Min Ch El (ft)            294.71   Shear (lb/sq ft)            0.13        0.65        0.04
 Alpha                       1.03   Stream Power (lb/ft s)    152.00        0.00        0.00
 Frctn Loss (ft)             0.04   Cum Volume (acre-ft)       12.18       22.14        5.95
 C & E Loss (ft)             0.03   Cum SA (acres)              5.32        1.60        1.87

Plan: Plan 25   Little Androscog   Reach 1  RS: 1063   BR D   Profile: 50 yr
 E.G. Elev (ft)            310.55   Element                  Left OB     Channel    Right OB
 Vel Head (ft)               0.67   Wt. n-Val.                             0.030
 W.S. Elev (ft)            309.88   Reach Len. (ft)             5.70        5.70        5.70
 Crit W.S. (ft)            302.99   Flow Area (sq ft)                    1573.37
 E.G. Slope (ft/ft)      0.000984   Area (sq ft)                         1573.37
 Q Total (cfs)           10367.00   Flow (cfs)                          10367.00
 Top Width (ft)            142.87   Top Width (ft)                        142.87
 Vel Total (ft/s)            6.59   Avg. Vel. (ft/s)                        6.59
 Max Chl Dpth (ft)          15.88   Hydr. Depth (ft)                       11.01
 Conv. Total (cfs)       330518.4   Conv. (cfs)                         330518.4
 Length Wtd. (ft)            5.70   Wetted Per. (ft)                      180.13
 Min Ch El (ft)            294.00   Shear (lb/sq ft)                        0.54
 Alpha                       1.00   Stream Power (lb/ft s)    136.41        0.00        0.00
 Frctn Loss (ft)             0.00   Cum Volume (acre-ft)        8.58       19.82        4.66
 C & E Loss (ft)             0.08   Cum SA (acres)              4.67        1.49        1.69
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Plan: Plan 25   Little Androscog   Reach 1  RS: 1063   BR D   Profile: 100 yr
 E.G. Elev (ft)           311.38  Element                    Left OB    Channel    Right OB
 Vel Head (ft)              0.77  Wt. n-Val.                   0.120      0.030
 W.S. Elev (ft)           310.62  Reach Len. (ft)               5.70       5.70        5.70
 Crit W.S. (ft)           303.73  Flow Area (sq ft)             1.21    1680.02
 E.G. Slope (ft/ft)     0.001050  Area (sq ft)                  1.21    1680.02
 Q Total (cfs)          11811.00  Flow (cfs)                    0.30   11800.39
 Top Width (ft)           146.27  Top Width (ft)                1.98     144.29
 Vel Total (ft/s)           7.02  Avg. Vel. (ft/s)              0.24       7.02
 Max Chl Dpth (ft)         16.62  Hydr. Depth (ft)              0.61      11.64
 Conv. Total (cfs)      364463.6  Conv. (cfs)                    9.1   364454.5
 Length Wtd. (ft)           5.70  Wetted Per. (ft)              2.57     183.29
 Min Ch El (ft)           294.00  Shear (lb/sq ft)              0.03       0.60
 Alpha                      1.00  Stream Power (lb/ft s)      136.41       0.00        0.00
 Frctn Loss (ft)            0.00  Cum Volume (acre-ft)         12.17      20.89        5.95
 C & E Loss (ft)            0.10  Cum SA (acres)                5.32       1.49        1.87
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Plan: Plan 25    Little Androscog    Reach 1  RS: 1063      Profile: 50 yr
 E.G. US. (ft)                 310.69   Element                Inside BR US    Inside BR DS
 W.S. US. (ft)                 310.23   E.G. Elev (ft)               310.61          310.55
 Q Total (cfs)               10367.00   W.S. Elev (ft)               309.88          309.88
 Q Bridge (cfs)              10367.00   Crit W.S. (ft)               303.49          302.99
 Q Weir (cfs)                           Max Chl Dpth (ft)             15.17           15.88
 Weir Sta Lft (ft)                      Vel Total (ft/s)               6.80            6.59
 Weir Sta Rgt (ft)                      Flow Area (sq ft)           1524.98         1573.37
 Weir Submerg                           Froude # Chl                   0.36            0.35
 Weir Max Depth (ft)                    Specif Force (cu ft)       11844.22        12473.87
 Min El Weir Flow (ft)         311.01   Hydr Depth (ft)               10.67           11.01
 Min El Prs (ft)               315.00   W.P. Total (ft)              178.69          180.13
 Delta EG (ft)                   0.23   Conv. Total (cfs)          322127.4        330518.4
 Delta WS (ft)                   0.28   Top Width (ft)               142.89          142.87
 BR Open Area (sq ft)         2084.65   Frctn Loss (ft)                0.03            0.00
 BR Open Vel (ft/s)              6.80   C & E Loss (ft)                0.03            0.08
 Coef of Q                              Shear Total (lb/sq ft)         0.55            0.54
 Br Sel Method            Energy only   Power Total (lb/ft s)       -487.19         -487.19
```

```
Plan: Plan 25    Little Androscog    Reach 1  RS: 1063      Profile: 100 yr
 E.G. US. (ft)                 311.55   Element                Inside BR US    Inside BR DS
 W.S. US. (ft)                 311.03   E.G. Elev (ft)               311.45          311.38
 Q Total (cfs)               11811.00   W.S. Elev (ft)               310.62          310.62
 Q Bridge (cfs)              11800.69   Crit W.S. (ft)               304.22          303.73
 Q Weir (cfs)                   10.31   Max Chl Dpth (ft)             15.91           16.62
 Weir Sta Lft (ft)            -304.19   Vel Total (ft/s)               7.23            7.02
 Weir Sta Rgt (ft)            -276.59   Flow Area (sq ft)           1632.45         1681.23
 Weir Submerg                    0.00   Froude # Chl                   0.37            0.36
 Weir Max Depth (ft)             0.55   Specif Force (cu ft)       13485.41        14134.30
 Min El Weir Flow (ft)         311.01   Hydr Depth (ft)               11.16           11.49
 Min El Prs (ft)               315.00   W.P. Total (ft)              184.39          185.85
 Delta EG (ft)                   0.26   Conv. Total (cfs)          356307.2        364463.6
 Delta WS (ft)                   0.32   Top Width (ft)               146.28          146.27
 BR Open Area (sq ft)         2084.65   Frctn Loss (ft)                0.04            0.00
 BR Open Vel (ft/s)              7.23   C & E Loss (ft)                0.03            0.10
 Coef of Q                              Shear Total (lb/sq ft)         0.61            0.59
 Br Sel Method            Energy/Weir   Power Total (lb/ft s)       -487.19         -487.19
```

Plan: Plan 25 Little Androscog Reach 1 RS: 1063 BR U Profile: 50 yr

	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	-487.19	-71.13	8.42	14.68	8.50	0.08	1.94	0.57	0.11	0.06
2	Chan	-71.13	-57.00	226.22	60.74	14.56	2.18	4.30	3.72	0.27	1.00
3	Chan	-57.00	-42.87	630.26	115.50	15.61	6.08	8.18	5.46	0.48	2.61
4	Chan	-42.87	-28.74	1622.04	201.50	15.20	15.65	14.26	8.05	0.86	6.90
5	Chan	-28.74	-14.62	1719.02	202.71	14.14	16.58	14.35	8.48	0.93	7.86
6	Chan	-14.62	-0.49	755.63	155.68	25.09	7.29	13.90	4.85	0.40	1.95
7	Chan	-0.49	13.64	665.32	141.96	24.11	6.42	13.88	4.69	0.38	1.78
8	Chan	13.64	27.77	1646.43	197.50	14.14	15.88	13.98	8.34	0.90	7.53
9	Chan	27.77	41.90	1767.33	206.21	14.16	17.05	14.60	8.57	0.94	8.07
10	Chan	41.90	56.03	1064.39	158.67	15.73	10.27	11.23	6.71	0.65	4.37
11	Chan	56.03	70.16	261.91	69.57	16.41	2.53	4.92	3.76	0.27	1.03
12	ROB	70.16	152.00	0.05	0.24	1.03	0.00	0.27	0.20	0.01	0.00

Plan: Plan 25 Little Androscog Reach 1 RS: 1063 BR U Profile: 100 yr

	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	-487.19	-71.13	13.68	21.66	11.33	0.12	2.22	0.63	0.13	0.08
2	Chan	-71.13	-57.00	304.61	71.19	14.56	2.58	5.04	4.28	0.34	1.43
3	Chan	-57.00	-42.87	752.58	125.95	15.61	6.38	8.91	5.98	0.55	3.31
4	Chan	-42.87	-28.74	1823.93	211.95	15.20	15.46	15.00	8.61	0.96	8.23
5	Chan	-28.74	-14.62	1932.03	213.16	14.14	16.37	15.09	9.06	1.03	9.37
6	Chan	-14.62	-0.49	835.16	163.97	25.83	7.08	14.64	5.09	0.44	2.22
7	Chan	-0.49	13.64	734.87	149.53	24.85	6.23	14.62	4.91	0.41	2.03
8	Chan	13.64	27.77	1854.44	207.95	14.14	15.71	14.72	8.92	1.01	9.00
9	Chan	27.77	41.90	1983.57	216.66	14.16	16.81	15.33	9.16	1.05	9.61
10	Chan	41.90	56.03	1223.54	169.11	15.73	10.37	11.97	7.24	0.74	5.33
11	Chan	56.03	70.16	341.80	80.02	16.41	2.90	5.66	4.27	0.33	1.43
12	ROB	70.16	152.00	0.48	1.32	2.42	0.00	0.64	0.36	0.04	0.01

Plan: Plan 25 Little Androscog Reach 1 RS: 1063 BR D Profile: 50 yr

	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	-78.92	-63.24	122.09	45.24	16.38	1.18	2.93	2.70	0.17	0.46
2	Chan	-63.24	-47.55	423.19	96.59	16.91	4.08	6.16	4.38	0.35	1.54
3	Chan	-47.55	-31.86	1450.53	202.96	17.06	13.99	12.94	7.15	0.73	5.22
4	Chan	-31.86	-16.17	2079.23	244.02	15.76	20.06	15.56	8.52	0.95	8.11
5	Chan	-16.17	-0.49	953.27	190.56	27.35	9.20	14.93	5.00	0.43	2.14
6	Chan	-0.49	15.20	778.96	165.44	26.00	7.51	14.04	4.71	0.39	1.84
7	Chan	15.20	30.89	1886.16	229.92	15.71	18.19	14.66	8.20	0.90	7.37
8	Chan	30.89	46.58	1851.91	234.70	17.01	17.86	14.96	7.89	0.85	6.69
9	Chan	46.58	62.26	763.90	139.93	17.62	7.37	8.92	5.46	0.49	2.66
10	Chan	62.26	77.95	57.75	24.00	10.33	0.56	2.74	2.41	0.14	0.34

Plan: Plan 25 Little Androscog Reach 1 RS: 1063 BR D Profile: 100 yr

	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	-487.19	-78.92	0.30	1.21	2.57	0.00	0.61	0.24	0.03	0.01
2	Chan	-78.92	-63.24	183.28	56.87	16.65	1.55	3.62	3.22	0.22	0.72
3	Chan	-63.24	-47.55	530.25	108.23	16.91	4.49	6.90	4.90	0.42	2.06
4	Chan	-47.55	-31.86	1649.92	214.61	17.06	13.98	13.68	7.69	0.82	6.34
5	Chan	-31.86	-16.17	2329.17	255.67	15.76	19.74	16.30	9.11	1.06	9.69
6	Chan	-16.17	-0.49	1052.27	200.03	28.09	8.92	15.68	5.26	0.47	2.46
7	Chan	-0.49	15.20	863.42	174.19	26.75	7.32	14.78	4.96	0.43	2.12

Plan: Plan 25 Little Androscog Reach 1 RS: 1063 BR D Profile: 100 yr (Continued)

	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)
8	Chan	15.20	30.89	2122.74	241.57	15.71	17.99	15.40	8.79	1.01	8.86
9	Chan	30.89	46.58	2080.78	246.35	17.01	17.63	15.70	8.45	0.95	8.02
10	Chan	46.58	62.26	904.59	151.57	17.62	7.67	9.66	5.97	0.56	3.37
11	Chan	62.26	77.95	83.97	30.94	11.73	0.71	3.11	2.71	0.17	0.47

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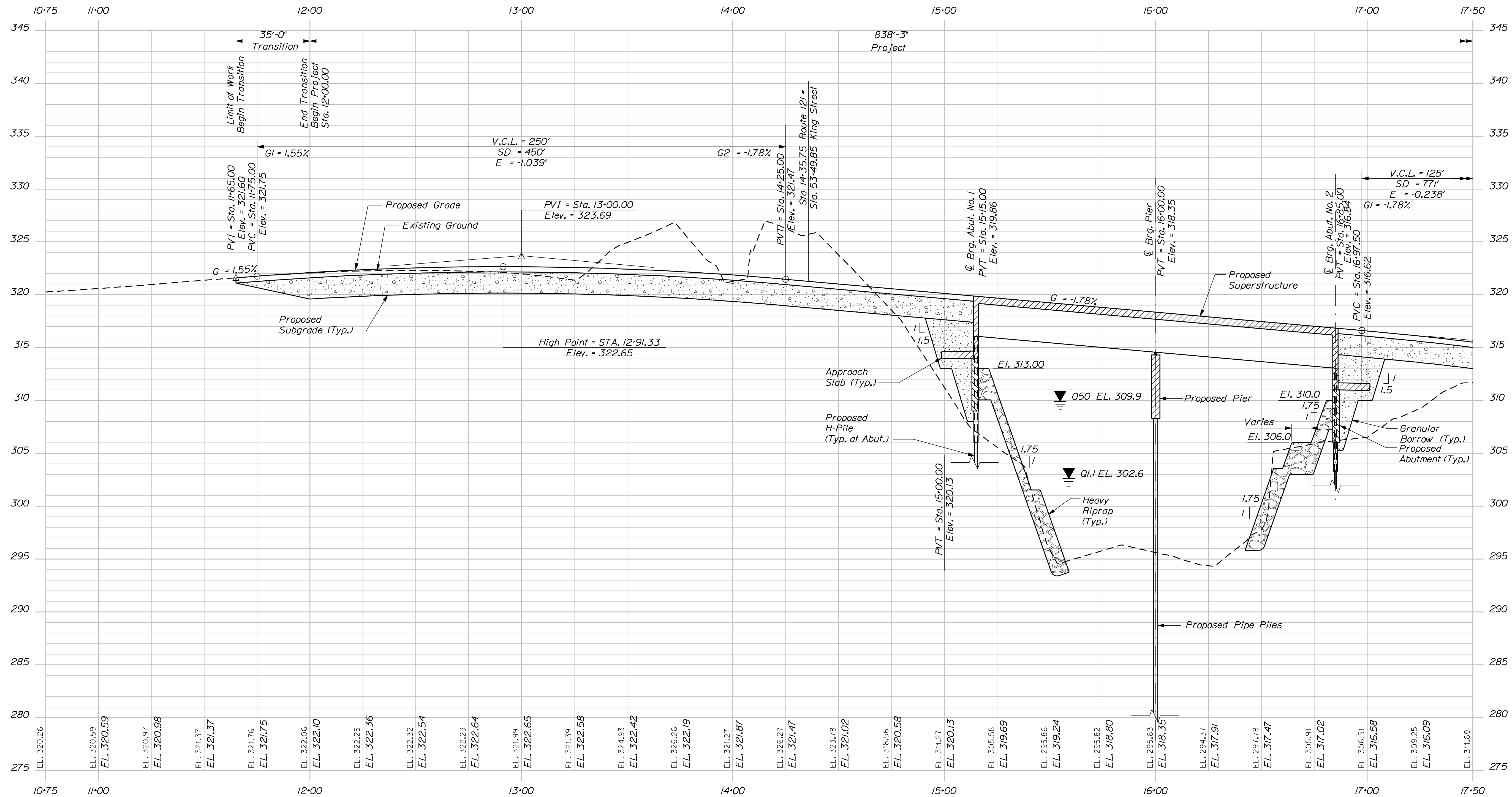
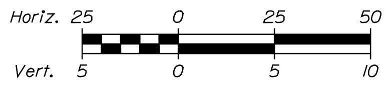
Division: BRIDGE

Username: CADD

Date:2/19/2014



PROFILE



Scale of Feet

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

AC-BH-1926(800)X

BRIDGE NO. 3738

WIN
19268.00

BRIDGE PLANS

		BY	DATE
PROJ. MANAGER	STEPHEN BODGE		
DESIGN-DETAILED	L.MEEK	L. NEWHOUSE	01-23-14
CHECKED-REVIEWED	D. ETTINGER	-	01-23-14
DESIGN2-DETAILED2	-	-	-
DESIGN3-DETAILED3	-	-	-
REVISIONS 1	-		-
REVISIONS 2	-		-
REVISIONS 3	-		-
REVISIONS 4	-		-
FIELD CHANGES	-		-

SIGNATURE

P.E. NUMBER

DATE

COVERED BRIDGE
OVER LITTLE ANDROSCOGGIN RIVER
OXFORD OXFORD COUNTY

PROFILE (1 of 2)

SHEET NUMBER

6

OF 59

Oxford Bridge Number 3738
Pier Scour

Flood	flood depth, y1	Velocity, fps	FR	a	a*1.25 (debris)	K1	L = 6 * a	L/a	K2	K3	Ys, pier	Contrac-tion Scour	Ys, Total Scour	HECRAS total		HECRAS average	Total projected width = a*debris*K2	Ysmax for projected width	projected width w/ debris by plot	Ysmax
														CSU equa	Froelich					
Q50	13.9	8.6	0.4065	2.5	3.125	1	15	6	1.45	1.1	11.4	1.18	12.6	12.61	12.96	12.79	4.53125	10.875	8.25	19.8
Q100	14.7	9.1	0.4183	2.5	3.125	1	15	6	1.45	1.1	11.8	0.93	12.7	13.26	13.39	13.33	4.53125	10.875	8.25	19.8
Q500	17.1	10.1	0.4304	2.5	3.125	1	15	6	1.45	1.1	12.6	0	12.6	12.36	12.29	12.33	4.53125	10.875	8.25	19.8

*"a" - pier width in feet X 1.25 for debris
** assumed NO riprap protection at piers or abutments

Ys = a X 2.0 X K1 X K2 x K3 X (y1/a)^0.35 * Fr ^.43
Pier Scour Equation 7.1 from HEC-18, 5th Edition, April, 2012

Pier Scour

Oxford "Covered Bridge" # 378.

9/24 + 9/30 EO

1 of 4

a = pier diameter or width in direction of flow

V = approach velocity

y_1 = flow depth

y_s = depth of scour

y_s/a Max = 2.4

if y_s = 24" ; y_{max} = 4.8
= 36" ; y_{max} = 7.2 } for $F < 0.8$ } Adjust for debris x1.25

For Round Nosed piers aligned w/flow.

Adjust for skew via K2 or projected width (see excel).

Evaluate skew –

Piles are aligned approximately 7.5° to flow

$$\frac{y_s}{y_1} = 2.0\, K_1 K_2 K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr_1^{0.43}$$

$$= a \times 2.0 \times K_1 \times K_2 \times K_3 \times (y_1/a)^{.35}\, Fr_1^{.43}$$

y_s = scour depth

y_1 = flow depth just upstream of pier

$y_1(100)$ = 14.7 ✓ $y_1(50)$ = 13.9)

$y_1(500)$ = 17.1'

K_1 (Round Nose) = 1.0 ✓ (Table 7.1) (Sharp Nose = 0.9)
(Group of Cylinders) = 1.0

K_2 = Correction for angle of attack (Table 7.2) OR Equa 7.4

∠ = 7.5°

Length of pier = # of piers × a = 5×3 OR 6×2
15 OR 12
6×2.5 = 15

L/a = 15/3 = 5 OR 12/2 = 6 OR 15/2.5 = 6
= 5 OR 6

7.4: $K_2 = \left(\cos\theta + \frac{L}{a}\sin\theta\right)^{0.65}$

$= \left(.99 + \overset{}{\underset{6}{5}}(.13)\right)^{.65} = 1.4 –$
$= 1.45$

K_2 for 6 piles @ 2.5'
$= .99 + 6(.13)^{.65} = 1.45$

K_3 = correction factor for bed conditions (Table 7.3)

= 1.1

a = Pier width = 2 ~~OR~~ $\overset{2.5}{}$ 3 $\overset{9/30}{}$, a debris = $2\times1.25 = 2.5$

$3\times1.25 = 3.75$

$2.5\times1.25 = 3.125$

L = length of pier = 15 OR 12

Fr₁ = Froude # just upstream of pier

$= V_1 / \sqrt{g\,y_1}$

$V_1(50) =$ 8.6

$V_1(100) =$ ~~5.0 → 8.5~~ 9.1

$V_1(500) =$ ~~5.6 – 10.1~~ 10.1

$y_1(50) = 13.9$

$y_1(100) = 14.7$

$y_1(500) = 17.1$

$$Fr_{100} = \frac{(\overset{9.1}{\cancel{5 - 8.5}})}{(32.2\times14.7)^{0.5}} = \frac{(\overset{9.1}{\cancel{5 - 8.5}})}{21.8} = \cancel{0.23 \rightarrow 0.39}\ \overset{.42}{}$$

$$Fr_{500} = \frac{(\overset{10.1}{\cancel{5.6 - 10.1}})}{(32.2\times17.1)^{0.5}} = \frac{(\cancel{5.6 - 10.1})}{(23.5)} = \cancel{0.24 \rightarrow 0.43}\ \overset{.43}{}$$

$$F_1(50) = \left(8.6/32.2\times13.9\right)^{0.5} = 0.41$$

$$y_{100} = a\times2.0\times K_1\,K_2\,K_3\left(\frac{y_1}{a}\right)^{.35} Fr_1^{\,0.43}$$

$$\left(\underset{3.125}{\cancel{2\ 3.75}}\right)\times2.0\times1.0\times\left(\underset{1.45}{\cancel{1.4 - 1.45}}\right)\times\left(\frac{14.7}{\underset{3.125}{\cancel{2 - 3.75}}}\right)^{.35}\left(\underset{.42}{\cancel{.23 - .39}}\right)^{.43}$$

See spreadsheet.

y_{100} ~~Range~~ ~~7.1 – 12.2~~ (no debris → max velocity w/debris)

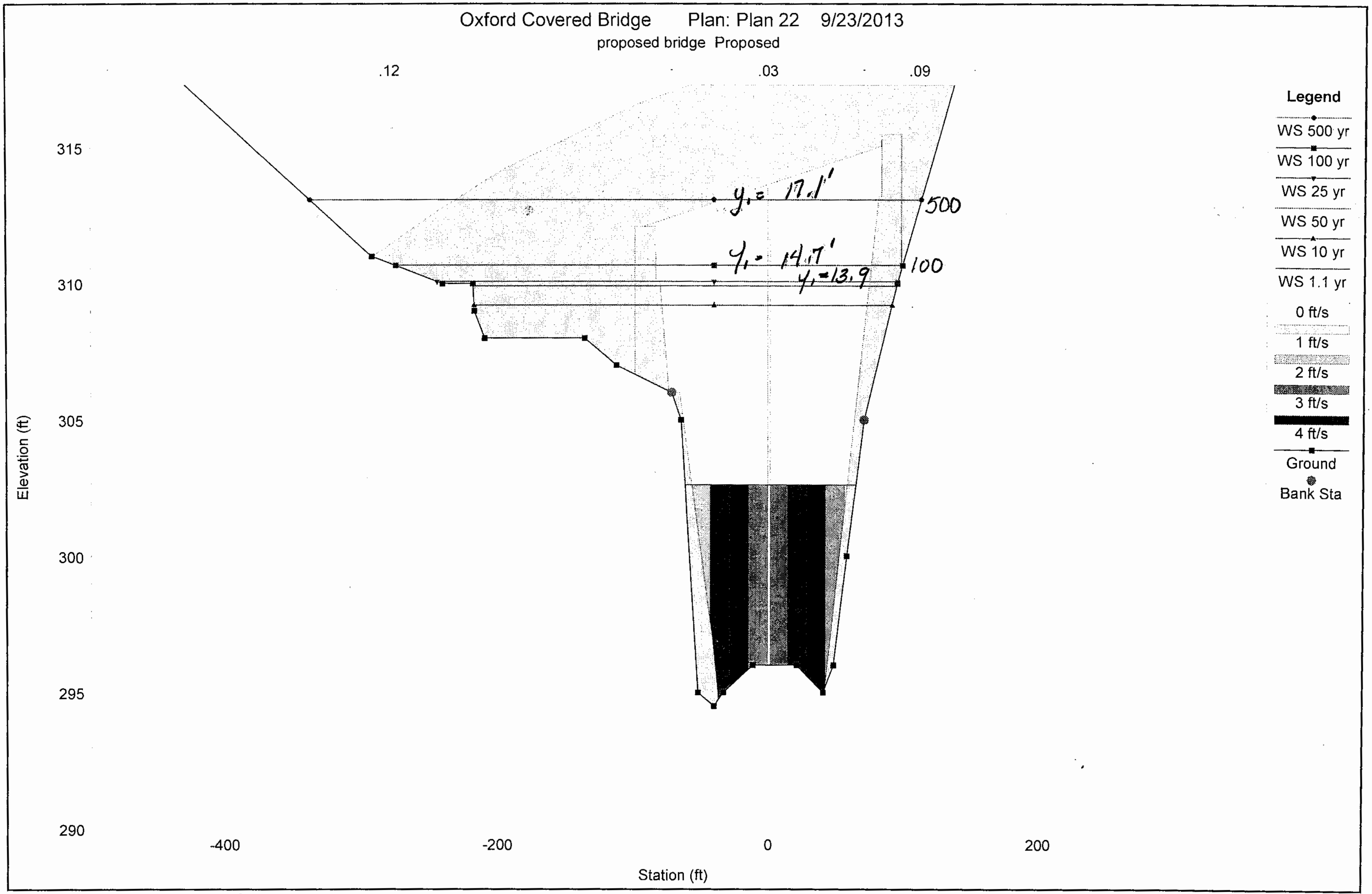
y_s Max = $a\times2.4$

a proj (w debris + skew)

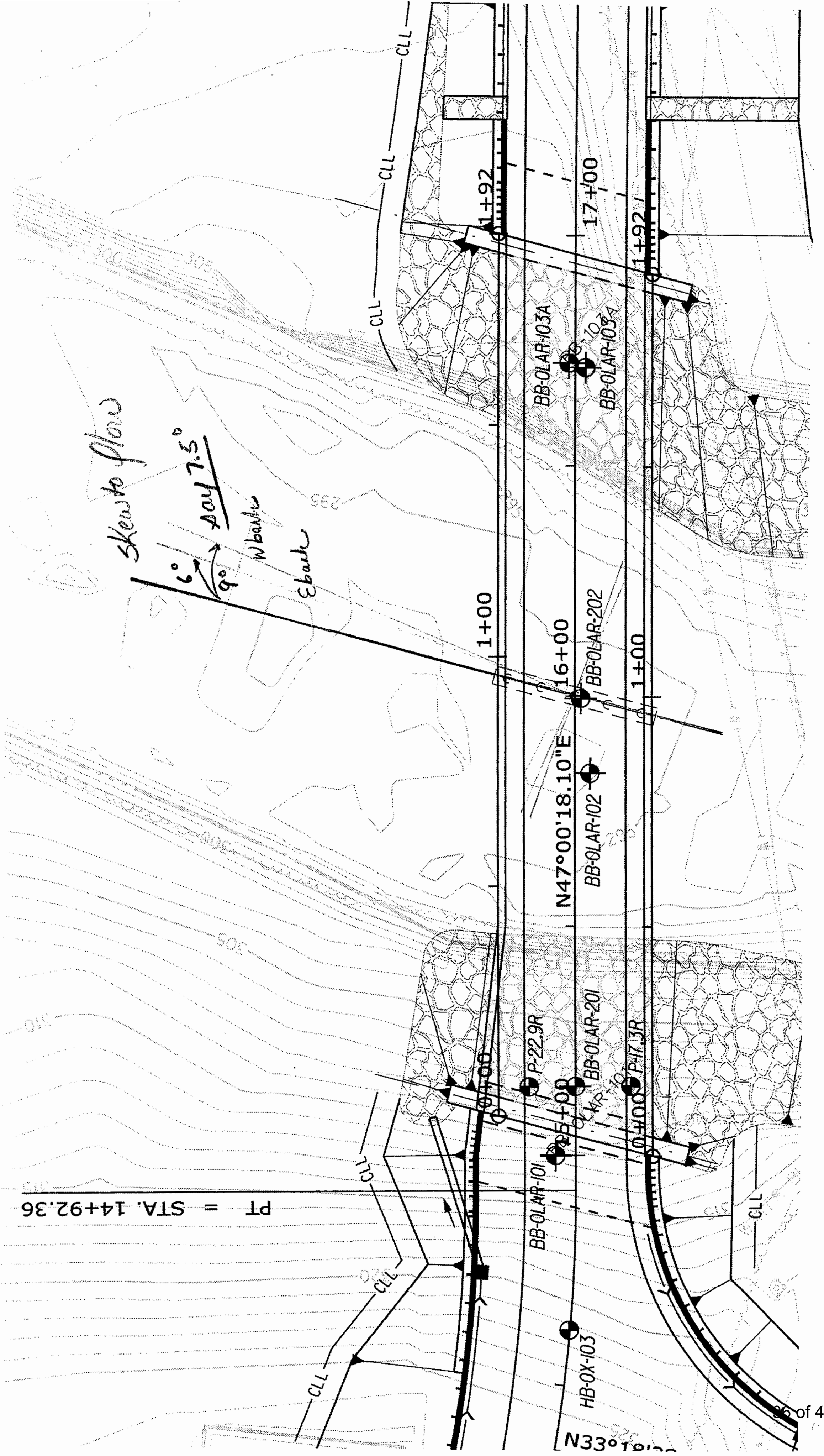
$= (2\times1.25\times1.45)\times2.4 = 8.6'$

$= (3\times1.25\times1.4)\times2.4 = 12.6'$

$(2.5\times1.25\times1.45)\times2.4 = 10.9'$ OR $(6.83\times1.25)\times2.4 = 20.5$

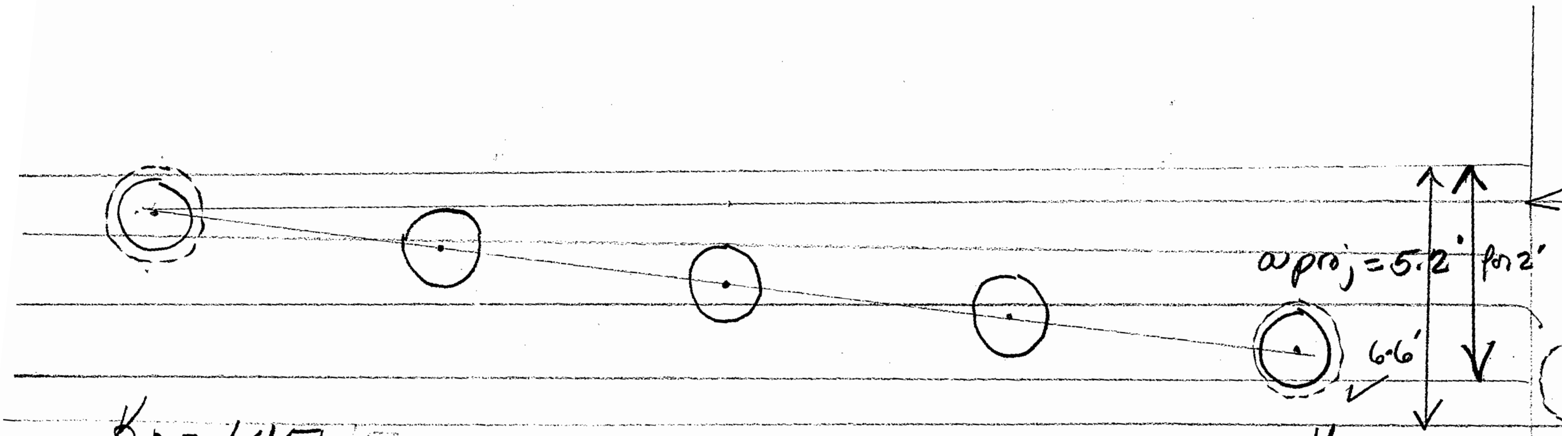


1 in Horiz. = 100 ft 1 in Vert. = 5 ft


CLL
CLL
CLL
1+92
17+00
1+92
BB-OLAR-103A
B-103
BB-OLAR-103A
Skew to flow
6°
90°
say 7.5°
W bank
E bank
295
300
305
1+00
16+00
BB-OLAR-202
1+00
N47°00'18.10"E
BB-OLAR-102
295
300
305
310
P-22.9R
BB-OLAR-201
P-17.3R
0+00
15+00
OLAR-101
0+00
BB-OLAR-101
PT = STA. 14+92.36
CLL
CLL
CLL
CLL
HB-OX-103
N33°18'2

project width of pile group to skewed flow. 4 of 4

$a^*_{pq} = a_{proj} \times K_{sp} \times K_m$
$= 5.2 \times$



$K_2 = 1.45$ $1.45 \times 2 \boxed{= 2.9'}$

$K_m = 1$

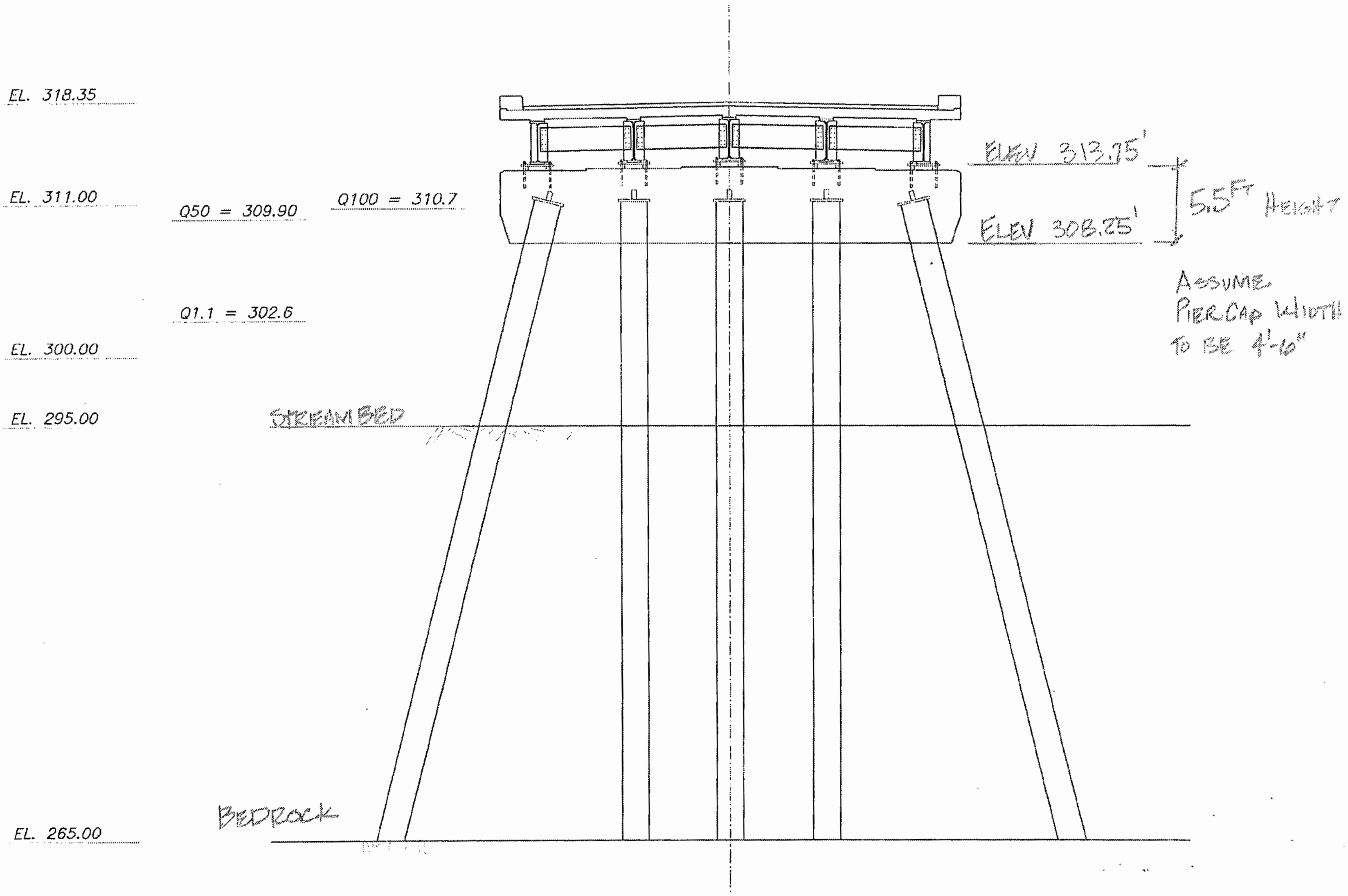
$\frac{S}{a} = 7.5/2 = 3.75$

$\frac{a_{proj}}{a} = \frac{5.2}{2} = 2.6$

$K_{sp} \simeq 0.52$

$a^*_{pg} = 5.2 \times 0.52 \times 1$
$\boxed{= 2.7}$

Use K_2 - very similar to using projected width


EL. 318.35
EL. 311.00
Q50 = 309.90
Q100 = 310.7
Q1.1 = 302.6
EL. 300.00
EL. 295.00
STREAMBED
EL. 265.00
BEDROCK
ELEV 313.75'
ELEV 308.25'
5.5FT HEIGHT
ASSUME
PIERCAP WIDTH
TO BE 4'-10"

50-year

Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	1.87	11.79	0.60
	Approach Velocity (ft/s):	0.45	5.93	0.28
	Br Average Depth (ft):	2.39	11.42	0.79
	BR Opening Flow (cfs):	12.80	10353.07	1.12
	BR Top WD (ft):	8.43	134.45	3.46
	Grain Size D50 (mm):	0.67	0.67	0.67
	Approach Flow (cfs):	225.88	10139.14	1.98
	Approach Top WD (ft):	268.35	145.00	11.91
	K1 Coefficient:	0.640	0.640	0.590
Results				
	Scour Depth Ys (ft):	0.00	1.18	0.00
	Critical Velocity (ft/s):	1.62	2.20	1.34
	Equation:	Clear	Live	Clear

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Round nose
	Pier Width (ft):	6.83
	Grain Size D50 (mm):	0.67000
	Depth Upstream (ft):	15.39
	Velocity Upstream (ft/s):	6.09
	K1 Nose Shape:	1.00
	Pier Angle:	0.00
	Pier Length (ft):	33.30
	K2 Angle Coef:	1.00
	K3 Bed Cond Coef:	1.10
	Grain Size D90 (mm):	2.00000
	K4 Armouring Coef:	1.00
Results		
	Scour Depth Ys (ft):	11.44
	Froude #:	0.27
	Equation:	CSU equation

Abutment Scour

		Left	Right
Input Data			
	Station at Toe (ft):	-73.16	97.61
	Toe Sta at appr (ft):	-62.03	112.46
	Abutment Length (ft):	250	40
	Depth at Toe (ft):	4.1	4.2
	K1 Shape Coef:	0.55 - Spill-through abutment	
	Degree of Skew (degrees):	90.00	90.00
	K2 Skew Coef:	1.00	1.00
	Projected Length L' (ft):	250	40
	Avg Depth Obstructed Ya (ft):	4.1	4.2
	Flow Obstructed Qe (cfs):	150	5
	Area Obstructed Ae (sq ft):	300	12
Results			
	Scour Depth Ys (ft):	5.79	6.01
	Qe/Ae = Ve:	0.00	0.42

Froude #:	0.04	0.04
Equation:	HIRE	Froehlich

Combined Scour Depths

Pier Scour + Contraction Scour (ft):		
	Channel:	12.61
Left abutment scour + contraction scour (ft):	5.79	
Right abutment scour + contraction scour (ft):	6.01	

100-year

Contraction Scour

Input Data

	Left	Channel	Right
Average Depth (ft):	2.56	12.59	1.00
Approach Velocity (ft/s):	0.56	6.24	0.40
Br Average Depth (ft):	2.40	12.16	1.14
BR Opening Flow (cfs):	18.39	11789.38	3.23
BR Top WD (ft):	11.72	134.45	5.16
Grain Size D50 (mm):	0.67	0.67	0.67
Approach Flow (cfs):	403.94	11399.17	7.89
Approach Top WD (ft):	282.39	145.00	19.94
K1 Coefficient:	0.640	0.640	0.590

Results

	Left	Channel	Right
Scour Depth Ys (ft):	0.00	1.44	0.00
Critical Velocity (ft/s):	1.70	2.22	1.46
Equation:	Clear	Live	Clear

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Round nose
Pier Width (ft):	6.83
Grain Size D50 (mm):	0.67000
Depth Upstream (ft):	16.18
Velocity Upstream (ft/s):	6.47
K1 Nose Shape:	1.00
Pier Angle:	0.00
Pier Length (ft):	33.30
K2 Angle Coef:	1.00
K3 Bed Cond Coef:	1.10
Grain Size D90 (mm):	2.00000
K4 Armouring Coef:	1.00

Results

Scour Depth Ys (ft):	11.82
Froude #:	0.28
Equation:	CSU equation

Abutment Scour

Input Data

	Left	Right
Station at Toe (ft):	-73.16	97.61
Toe Sta at appr (ft):	-62.03	112.46
Abutment Length (ft):	250	40
Depth at Toe (ft):	4.95	5
K1 Shape Coef:	0.55 - Spill-through abutment	
Degree of Skew (degrees):	90.00	90.00
K2 Skew Coef:	1.00	1.00
Projected Length L' (ft):	250	40
Avg Depth Obstructed Ya (ft):	1.6	1.00
Flow Obstructed Qe (cfs):	181	6
Area Obstructed Ae (sq ft):	344	16

Results

	Left	Right
Scour Depth Ys (ft):	7.08	2.16
Qe/Ae = Ve:	0.00	0.38

Froude #:	0.04	0.07
Equation:	HIRE	Froehlich

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

	Channel:	13.26

Left abutment scour + contraction scour (ft):	7.08
Right abutment scour + contraction scour (ft):	2.16

500-year

Contraction Scour

Input Data

	Left	Channel	Right
Average Depth (ft):	4.52	15.05	2.23
Approach Velocity (ft/s):	0.75	6.50	0.63
Br Average Depth (ft):		20.23	2.39
BR Opening Flow (cfs):	22.26	14523.02	23.60
BR Top WD (ft):		96.56	10.47
Grain Size D50 (mm):	0.67	0.67	0.67
Approach Flow (cfs):	1109.84	14179.84	62.32
Approach Top WD (ft):	325.52	145.00	44.58
K1 Coefficient:	0.640	0.640	0.640

Results

	Left	Channel	Right
Scour Depth Ys (ft):		0.00	0.00
Critical Velocity (ft/s):		2.29	1.66
Equation:		Live	Clear

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Round nose
Pier Width (ft):	6.83
Grain Size D50 (mm):	0.67000
Depth Upstream (ft):	18.63
Velocity Upstream (ft/s):	6.87
K1 Nose Shape:	1.00
Pier Angle:	0.00
Pier Length (ft):	33.30
K2 Angle Coef:	1.00
K3 Bed Cond Coef:	1.10
Grain Size D90 (mm):	2.00000
K4 Armouring Coef:	1.00

Results

Scour Depth Ys (ft):	12.36
Froude #:	0.28
Equation:	CSU equation

Abutment Scour

Input Data

	Left	Right
Station at Toe (ft):	-73.16	97.61
Toe Sta at appr (ft):	-62.03	112.46
Abutment Length (ft):	250	40
Depth at Toe (ft):	7.4	7.4
K1 Shape Coef:	0.55 - Spill-through abutment	
Degree of Skew (degrees):	90.00	90.00
K2 Skew Coef:	1.00	1.00
Projected Length L' (ft):	250	40
Avg Depth Obstructed Ya (ft):	3.7	2.23
Flow Obstructed Qe (cfs):	641	52
Area Obstructed Ae (sq ft):	858	43

Results

	Left	Right
Scour Depth Ys (ft):	11.01	5.17
Qe/Ae = Ve:	0.00	1.21

Froude #:	0.05	0.14
Equation:	HIRE	Froehlich

OXFORD COVERED BRIDGE

2-13-14
E OBRIEN
Northstar Hydro, Inc.

Rip Rap Protection for Abutments
Ref: Email E Brownell 2-12 per MDOT 2-6 email
— Rip Rap Size ?
— Toe trench rather than HEC-23 DG 14

1.) D50 Recommendation
see Comps dated 1-3-2014.

D50 = 1.3'

2.) Per MDOT Standard Specifications, Section 7, Materials
pgs 7'20-21 Attached.

Plain Rip Rap = 10-200 lb.
Stone Blanket = 300-3000 lb
Heavy Riprap = > 500 lb.

3.) PER HEC-23, DG4

D50 = 1.3' = 15-16"

Class IV Riprap = 14.5 — 17.5 d50
Class IV Riprap = 300 lb., 240 → 420 = d50.

∴ Stone Blanket Size

4.) Size of Toe
References -
a) MDOT 610(03); 610(04)
3' thick plain rip rap, toe depth = 3'
4' thick heavy rip rap, toe depth = 4'
b) HEC-11 pg 42
either Excavate + construct riprap slope to scour depth OR add mound at base of riprap slope to fill scour hole.

c) HEC-23 DG 4.

Either toe rip rap slope to projected scour depth
OR place mound of stone to fill potential
scour hole

see attached page DG 4.10.

Left (East) Abutment Scour depth = 7.1'

West Abutment Scour depth = 6.0'

MEDOT Standard Specifications. Materials -

Crushed or uncrushed material for Underdrain Type C shall conform to the following table:

Sieve Designation Metric	US Customary	Percentage by Weight Passing Square Mesh Sieves
25.0 mm	1 in	100
19.0 mm	¾ in	90-100
9.5 mm	⅜ in	0-75
4.75 mm	No. 4	0-25
2.00 mm	No. 10	0-5

703.24 Stone for French Drains Stones for French drains shall consist of hard, durable rock and shall conform to the following table:

Sieve Designation Metric	US Customary	Percentage by Weight Passing Square Mesh Sieves
150 mm	6 in	90-100
37.5 mm	1½ in	0-40
4.75 mm	No. 4	0-5

Gradation test shall conform to AASHTO T27 except that the total sample shall be sieved and the minimum weight of the sample will be 55 kg [120 lb].

703.25 Stone Fill Stones for stone fill shall consist of sound durable rock that will not disintegrate by exposure to water or weather. Either field stone or rough, unhewn quarry stone may be used. Stones shall weigh from 5 kg [10 lb] to a maximum of 225 kg [500 lb] or larger if approved by the Resident. 50 percent by weight of the stones shall be approximately 100 kg [200 lb].

703.26 Plain and Hand Laid Riprap Stones shall consist of sound durable rock which will not disintegrate by exposure to water or weather. Either field stone or rough, unhewn quarry stone may be used. Exposed stones shall be angular and as nearly rectangular in cross-section as practicable. Rounded boulders or cobbles will not be permitted. Stones shall weigh from 5 kg [10 lb] to 100 kg [200 lb] except that when available suitable stones weighing more than 90 kg [200 lb] may be used. Approximately 50% of the stones by volume, shall exceed a mass of 25 kg [50 lb] each.

703.27 Stone Blanket Stones shall consist of sound durable rock that will not disintegrate by exposure to water or wind. Either field stone or rough, unhewn quarry stone may be used. Stones shall weigh from 150 kg [300 lb] to 1500 kg [3,000 lb]. Approximately 50% of the stones, by volume, shall exceed a ~~mass of~~ 450 kg [1,000 lb] each.

703.28 Heavy Riprap Stones shall consist of sound, durable rock, resistant to the action of air and water. Either field stone or rough, unhewn quarry stone may be used. The exposed stones shall be angular. Round or thin, flat stones will not be permitted. Stones shall have a minimum weight of 225 kg [500 lb] each and at least 50% of the stones, by volume, shall exceed 450 kg [1,000 lb] each.

703.29 Stone Ditch Protection Rock used for ditch protection shall consist of sound, durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarry stone, blasted ledge rock or tailings may be used. The rock shall be graded within the following limits or as otherwise approved.

Sieve Designation		Percentage by Weight Passing Square Mesh Sieves
Metric	US Customary	
300 mm	12 in	90-100
100 mm	4 in	0-15

The size of any stone shall not exceed 450 mm [18 in] when measured along its longest axis.

703.31 Crushed Stone Crushed stone shall be obtained from rock of uniform quality and shall consist of clean, angular fragments of quarried rock, free from soft disintegrated pieces or other objectionable matter.

The stone, which shall be similar to railroad ballast, shall meet the following gradation requirements in the stockpile at the source.

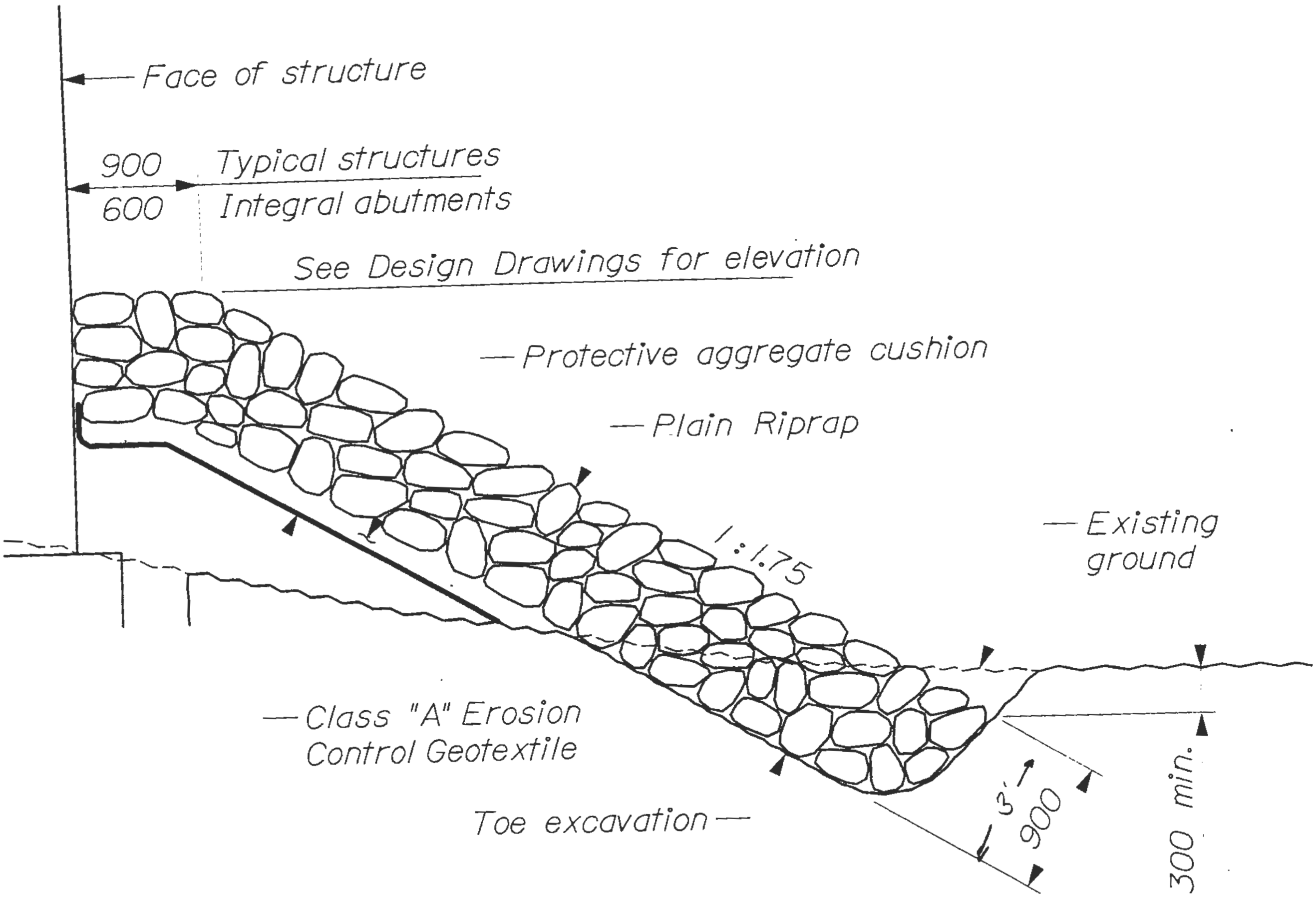
Sieve Designation		Percentage by Weight Passing Square Mesh Sieves
Metric	US Customary	
63 mm	2½ in	100
50 mm	2 in	95-100
25 mm	1 in	0-30
19 mm	¾ in	0-5

SECTION 704 - MASONRY UNITS

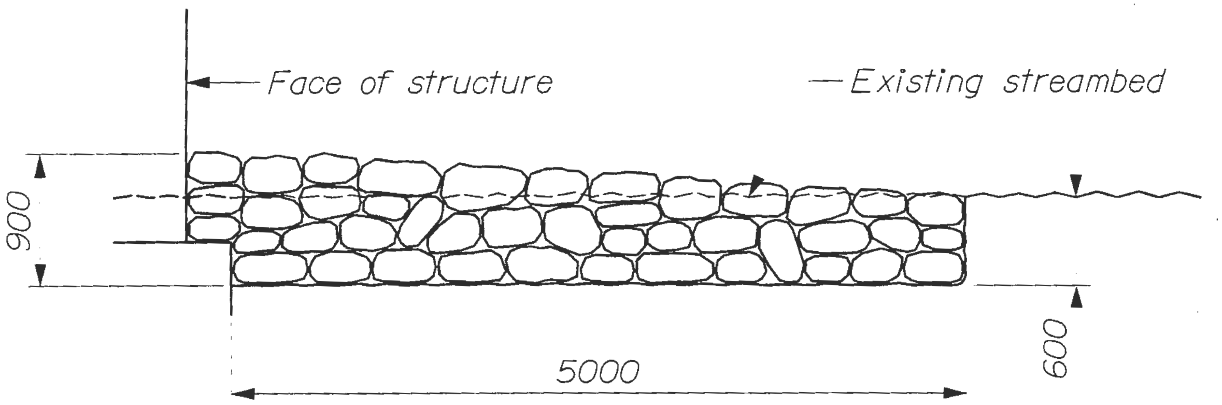
704.01 Clay or Shale Brick Except as modified below, brick shall conform to the requirements of one of the following specifications:

Type of Brick	Specification
Sewer and Manhole	AASHTO M91, Grade MS or SM
Building	AASHTO M114, Grade SW

MEDOT Standard Details



-- PLAIN RIPRAP SLOPE AT STRUCTURES --
Refer to Page 620(05) for specific
details on geotextile placement

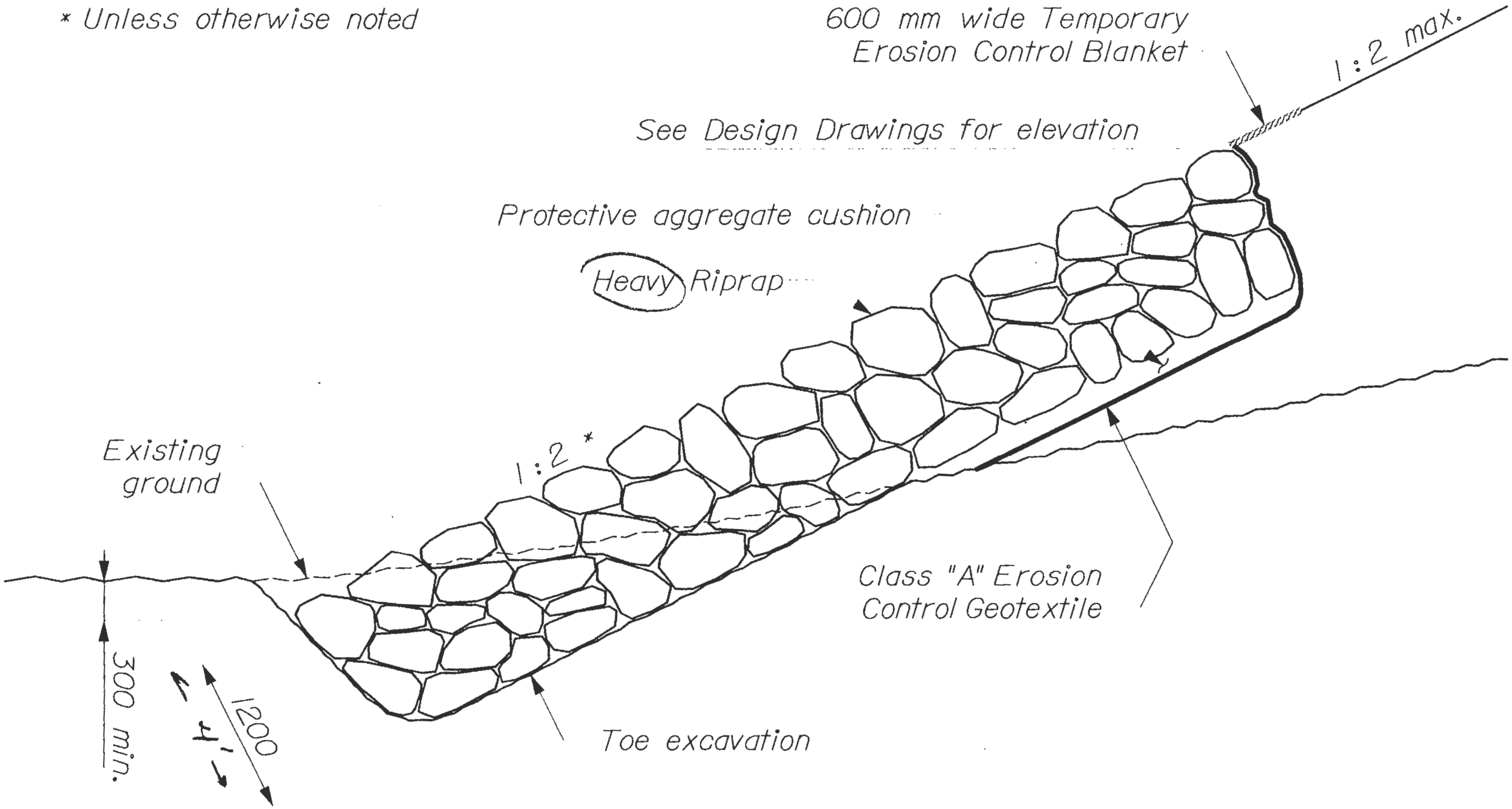


-- STONE BLANKET --

STONE SCOUR PROTECTION

610(03)

* Unless otherwise noted



-- HEAVY RIPRAP SIDE SLOPE --
(Refer to Page 620(05) for specific details on geotextile placement)

HEC-23 DG4

$$S_g = \frac{\gamma_s}{\gamma_w} \tag{4.4}$$

Typically, a minimum allowable specific gravity of 2.5 is required for riprap applications. Where quarry sources uniformly produce rock with a specific gravity significantly greater than 2.5 (such as dolomite, S_g = 2.7 to 2.8), the equivalent stone size can be substantially reduced and still achieve the same particle weight gradation.

Size and weight: Based on field studies, the recommended relationship between size and weight is given by:

$$W = 0.85(\gamma_s d^3) \tag{4.5}$$

where:

W = Weight of stone, lb (kg)
γ_s = Density of stone, lb/ft^3 (kg/m^3)
d = Size of intermediate ("B") axis, ft (m)

Table 4.1 provides recommended gradations for ten standard classes of riprap based on the median particle diameter d_{50} as determined by the dimension of the intermediate ("B") axis. These gradations conform to those recommended in NCHRP Report 568 (Lagasse et al. 2006). The proposed gradation criteria are based on a nominal or "target" d_{50} and a uniformity ratio d_{85}/d_{15} that results in riprap that is well graded. The target uniformity ratio d_{85}/d_{15} is 2.0 and the allowable range is from 1.5 to 2.5.

Table 4.1. Minimum and Maximum Allowable Particle Size in Inches.

Nominal Riprap Class by Median Particle Diameter		d_{15}		d_{50}		d_{85}		d_{100}
Class	Size	Min	Max	Min	Max	Min	Max	Max
I	6 in	3.7	5.2	5.7	6.9	7.8	9.2	12.0
II	9 in	5.5	7.8	8.5	10.5	11.5	14.0	18.0
III	12 in	7.3	10.5	11.5	14.0	15.5	18.5	24.0
IV	15 in	9.2	13.0	14.5	17.5	19.5	23.0	30.0
V	~~18 in~~	11.0	15.5	17.0	20.5	23.5	27.5	36.0
VI	21 in	13.0	18.5	20.0	24.0	27.5	32.5	42.0
VII	24 in	14.5	21.0	23.0	27.5	31.0	37.0	48.0
VIII	30 in	18.5	26.0	28.5	34.5	39.0	46.0	60.0
IX	36 in	22.0	31.5	34.0	41.5	47.0	55.5	72.0
X	42 in	25.5	36.5	40.0	48.5	54.5	64.5	84.0

Note: Particle size d corresponds to the intermediate ("B") axis of the particle.

Based on Equation 4.5, which assumes the volume of the stone is 85% of a cube, Table 4.2 provides the equivalent particle weights for the same ten classes, using a specific gravity of 2.65 for the particle density.

HEC 23 DG 4

Table 4.2. Minimum and Maximum Allowable Particle Weight in Pounds.

Nominal Riprap Class by Median Particle Weight		W_{15}		W_{50}		W_{85}		W_{100}
Class	Weight	Min	Max	Min	Max	Min	Max	Max
I	20 lb	4	12	15	27	39	64	140
II	60 lb	13	39	51	90	130	220	470
III	150 lb	32	93	120	210	310	510	1100
IV	300 lb	62	180	240	420	600	1,000	2,200
V	1/4 ton	110	310	410	720	1,050	1,750	3,800
VI	3/8 ton	170	500	650	1,150	1,650	2,800	6,000
VII	1/2 ton	260	740	950	1,700	2,500	4,100	9,000
VIII	1 ton	500	1,450	1,900	3,300	4,800	8,000	1,7600
IX	2 ton	860	2,500	3,300	5,800	8,300	13,900	30,400
X	3 ton	1,350	4,000	5,200	9,200	13,200	22,000	48,200

Note: Weight limits for each class are estimated from particle size by: $W = 0.85(\gamma_s d^3)$ where d corresponds to the intermediate ("B") axis of the particle, and particle specific gravity is taken as 2.65.

4.2.5 Recommended Tests for Rock Quality

Standard test methods relating to material type, characteristics, and testing of rock and aggregates typically associated with riprap installations (e.g., filter stone and bedding layers) are provided in this section and are recommended for specifying the quality of the riprap stone. In general, the test methods recommended in this section are intended to ensure that the stone is dense and durable, and will not degrade significantly over time.

Rocks used for riprap should only break with difficulty, have no earthy odor, no closely spaced discontinuities (joints or bedding planes), and should not absorb water easily. Rocks comprised of appreciable amounts of clay, such as shales, mudstones, and claystones, are ***never*** acceptable for use as fill for gabion mattresses. Table 4.3 summarizes the recommended tests and allowable values for rock and aggregate.

4.2.6 Filter Requirements

The importance of the filter component of revetment riprap installation should not be underestimated. Geotextile filters and granular filters may be used in conjunction with riprap bank protection. When using a granular stone filter, the layer should have a minimum thickness of 4 times the d_{50} of the filter stone or 6 inches, whichever is greater. When placing a granular filter under water, its thickness should be increased by 50%.

The filter must retain the coarser particles of the subgrade while remaining permeable enough to allow infiltration and exfiltration to occur freely. It is not necessary to retain all the particle sizes in the subgrade; in fact, it is beneficial to allow the smaller particles to pass through the filter, leaving a coarser substrate behind. Detailed aspects of filter design are presented in Design Guideline 16 of this document.

Some situations call for a composite filter consisting of both a granular layer and a geotextile. The specific characteristics of the base soil determine the need for, and design considerations of the filter layer. ***In cases where dune-type bedforms may be present at the toe of a bank slope protected with riprap, and where adequate toe down extent cannot be ensured, it is strongly recommended that only a geotextile filter be considered.***

HEC-23 DG 4

4.2.7 Edge Treatment and Termination Details

Riprap revetment should be toed down below the toe of the bank slope to a depth at least as great as the depth of anticipated long-term bed degradation plus toe scour (see Volume 1, Section 4.3.5). Installations in the vicinity of bridges must also consider the potential for contraction scour.

Recommended freeboard allowance calls for the riprap to be placed on the bank to an elevation at least 2.0 feet greater than the design high water level. Upstream and downstream terminations should utilize a key trench that is dimensioned in relation to the d_{50} size of the riprap. Where the design water level is near or above the top of bank, the riprap should be carried to the top of the bank. Figures 4.2, 4.3, and 4.4 are schematic diagrams that summarize these recommendations. If toe down cannot be placed below the anticipated contraction scour and degradation depth (Figure 4.2), a mounded toe approach (Figure 4.3) is suggested.

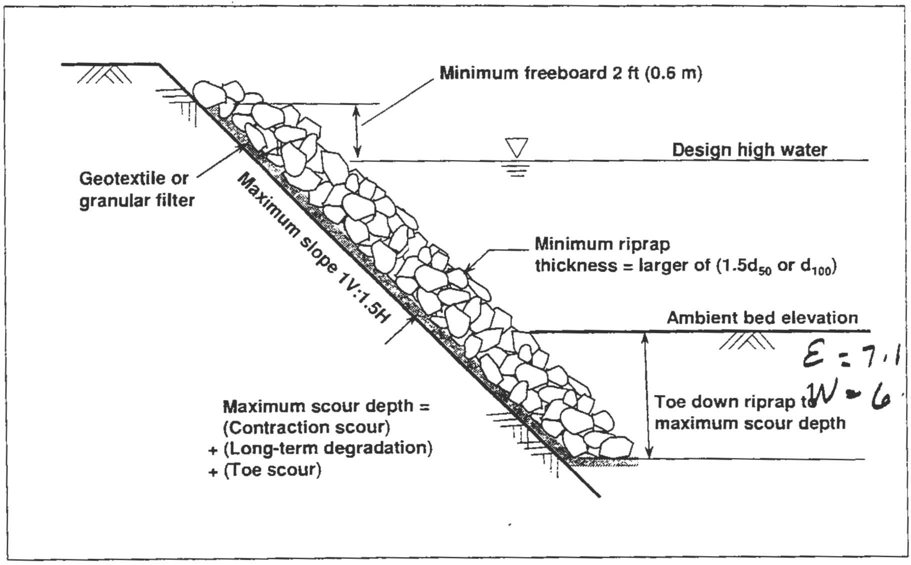


Figure 4.2. Riprap revetment with buried toe.

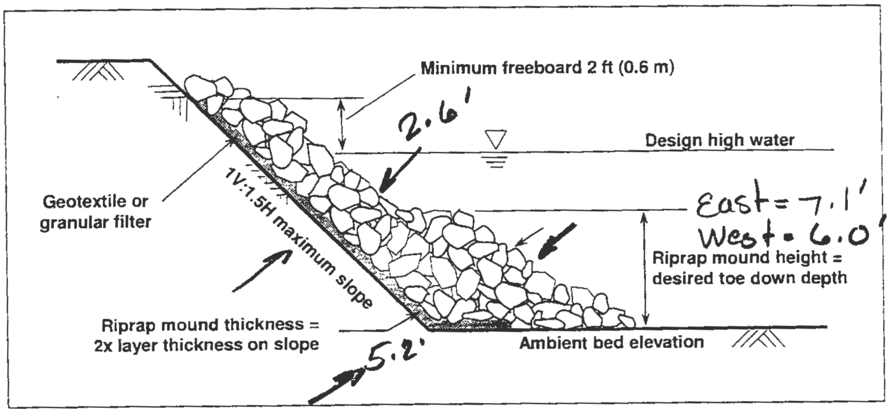


Figure 4.3. Riprap revetment with mounded toe.

HEC-11 Toe Extent

4.6 EDGE TREATMENT

The edges of riprap revetments (head, toe, and flanks) require special treatment to prevent undermining.

Flanks: The flanks of the revetment should be designed as illustrated in figure 20. The upstream flank is illustrated in part (b) and the downstream flank in part (c) of figure 20. An alternative to the upstream flank section illustrated in part (b) is to fill the compacted fill area with riprap.

Toe: Undermining of the revetment toe is one of the primary mechanisms of riprap failure. The toe of the riprap should be designed as illustrated in figure 21. The toe material should be placed in a toe trench along the entire length of the riprap blanket as illustrated in figure 21. Where a toe trench cannot be dug, the riprap blanket should terminate in a thick, narrow stone toe at the level of the streambed (see alternate design in figure 21). Care must be taken during the placement of the stone to ensure that the toe material does not mound and form a low dike; a low dike along the toe could result in flow concentration along the revetment face which could stress the revetment to failure. In addition, care must be exercised to ensure that the channel's design capability is not impaired by placement of too much riprap in a toe mound.

The size of the toe trench or the alternate stone toe is controlled by the anticipated depth of scour along the revetment. As scour occurs (and in most cases it will) the stone in the toe will launch into the eroded area as illustrated in figure 22. Observation of the performance of these types of rock toe designs indicates that the riprap will launch to a final slope of approximately 2:1. The volume of rock required for the toe must be equal to or exceed one and one-half times the volume of rock required to extend the riprap blanket (at its design thickness and on a slope of 2:1) to the anticipated depth of scour. Establishing a design scour depth is covered in section 3.6.2.2.

4.7 CONSTRUCTION

Additional considerations related to the construction of riprap revetments include bank slope or angle, bank preparation, and riprap placement.

Bank slope: A primary consideration in the design of stable riprap bank protection schemes is the slope of the channel bank. For riprap installations, the maximum recommended face slope is 2:1.

Bank Preparation: The bank should be prepared by first clearing all trees and debris from the bank, and grading the bank surface to the desired slope. In general, the graded surface should not deviate from the specified slope line by more than 6 in (15 cm). However, local depressions larger than this can be accommodated since initial placement of filter material and/or rock for the revetment will fill these depressions. In addition, any large boulders or debris found buried near the edges of the revetment should be removed.

Riprap Placement: The common methods of riprap placement are hand placing; machine placing, such as from a skip, dragline, or some form of bucket; and dumping from trucks and spreading by bulldozer. Hand placement produces the best riprap revetment, but it is the most expensive method except when labor is unusually