Indirect Measurement Summary

Blaylock Creek near Langley, Arkansas
Ouchita River Basin
Miscellaneous Site

Q= 14,200 ft^3/s

Flood of June 11, 2010

Type of measurement: Slope Area

Location of site: A miscellaneous site on Blaylock Creek approximately 2,500 feet upstream from Little Missouri River at Lat N 34˚22'02", Long W 93˚54'21". This site was selected because it was the best available straight reach that was as far downstream as possible without getting into the backwater from the Little Missouri. The reach runs southeast.

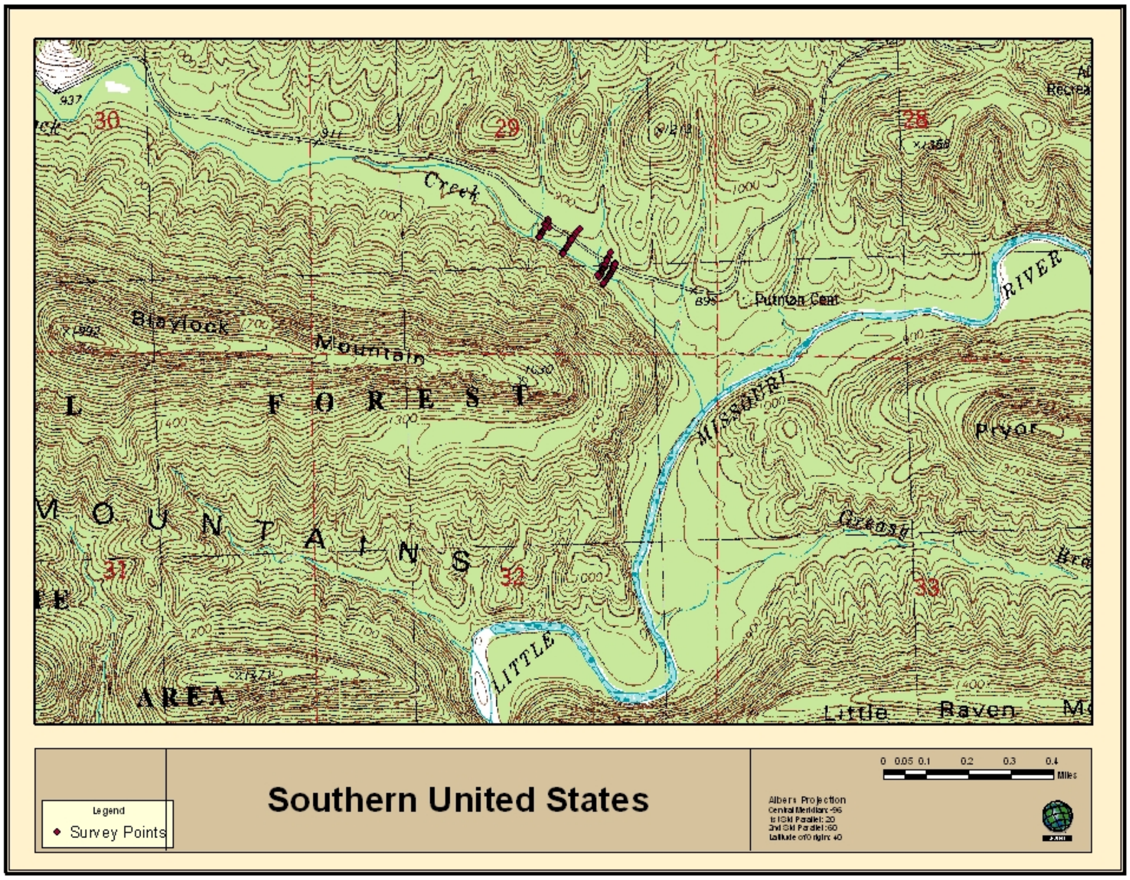
The site is Approximately 5.29 miles northwest of Langley, Arkansas, 14.17 miles southwest of Norman, Arkansas, and 29.27 miles southeast of Cove, Arkansas.

Survey of site: On Sunday, June 13, 2010, the original site for the survey for the indirect was selected. High water marks were obtained and a survey was begun on Wednesday June 16, 2010 by Paul Rydlund and Larry Buschman. It was realized through the survey of the intial reach, which was 1000 feet upstream from the Little Missouri, that although the trees were pushed over and leaning in the downstream direction, the high water marks indicated no fall for much of the reach. As such, it is speculated that given the orientation of the bent trees and saplings, Blaylock Creek had peaked prior to the Little Missouri and that the high water marks being surveyed were the result of the backwater from the Little Missouri. In the afternoon of June 16, 2010, a second reach was identified about 1500 feet upstream that was well out the the backwater from the Little Missouri. High water marks were obtained and the reach surveyed by Paul Rydlund and Larry Buschman on June 16, 2010.

The initial occupation point (OC-1) was a rebar driven into the ground on the west end of the gravel parking lot for the "Winding Staircase". An arbitrary Northing/Easting of 5000/5000 was assumed with an elevation of 100. The azimuth was established with a compass bearing of magnetic north. After the point was vacated by the total station survey, a Trimble GPS unit was setup to occupy the point for several hours to establish the true horizontal and vertical position of each survey point. UTM Zone 16 NAD83 horizontal position and NAVD88 vertical elevation for OC-1 are as follows:

Elevation NAVD88	Northing (UTM Feet)	Easting (UTM Feet)
883.10	12477429.62	1368160.50

The Survey of the indirect measurement site was made using a Nikon DTM-450 2-second total station, serial number 111304.



Map of Surveyed Indirect Reach and Cross Sections

Discharge and Gage Height: 14,200 cfs. No Gage Height as this is a miscellaneous site.

Drainage area: 10.7 mi^2 . This was determined by subtracting 0.192 mi^2 (determined by Robert Holmes using GIS) from the value for mouth of Blaylock Creek (10.89 mi^2 (at Little Missouri River) as determined by Albert Rea of the USGS using NHD Plus.

Unit Discharge: 1,327 cfs/mi^2. Crippen and Bue (1977) envelope curve for this region (Region 8) is below, with this flood approximately plotted.

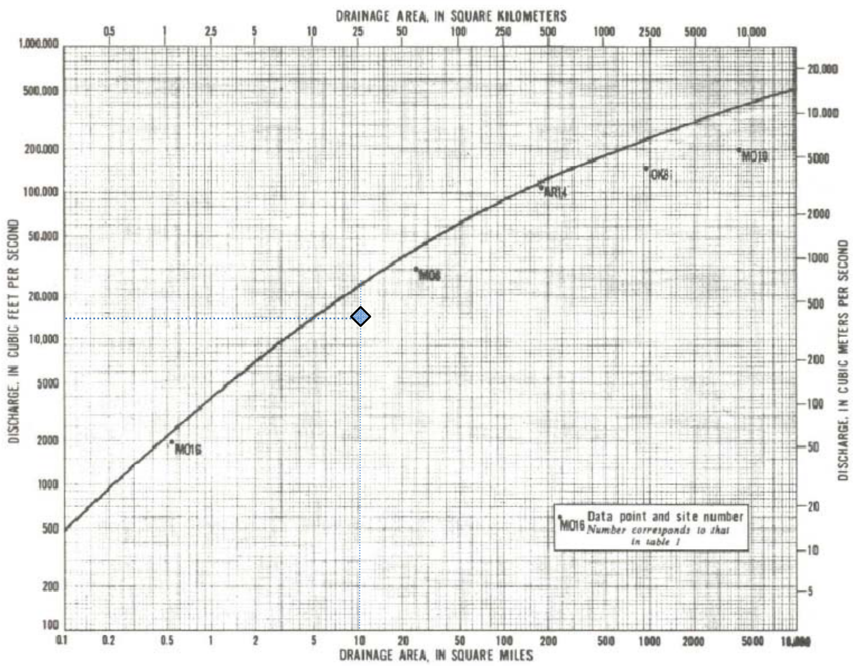


FIGURE 10.—Peak discharge versus drainage area, and envelope curve for region 8.

Nature of flood: This flood was a flash flood of extreme nature. As much as 7 inches of rain fell in a very short period of time starting just before or at midnight on June 10. Rates of rise at the USGS streamgage on the Little Missouri River 10 miles downstream were as much as 8 ft/hour. Anecdotal accounts of the rates of rise on the Little Missouri River from survivors in the Albert Pike Campground indicate as much as 3 feet in a few minutes. It is fully conceivable that the rates of rise on Blaylock Creek would be even faster. The Ouachita mountains are a known “flood hotspot” in the United States due to their steep topography and proximity to the Gulf of Mexico (GOM) moisture source. Moisture-laden air masses travel north from the GOM over the Coastal plain with Orographic lifting occurring as the mass meets the Ouachita mountains of southwestern Arkansas. The orographic lifting can produce intense rainfall. The intense rainfall on steep slopes results in large peak streamflows.

Field conditions: The indirect reach is in a fairly straight reach of Blaylock Creek. There is an expansion of the overall cross section immediately upstream of the X2. Each of the four cross sections was subdivided into 2 subsections, the left overbank and the main channel. In the lowest two cross sections the main channel has a small island in the middle and the left overbank is wooded. The right bank goes into the bluff. In the upper two cross sections the main channel has a few large boulders, but no island dividing the channel. The left overbank is wooded, but less dense than the lower part of the indirect reach.

Videos documenting the Field Conditions are:

M4H01821.MP4---Blaylock Creek: Left overbank of downstream XS for the indirect. Standing in roadway looking into the left overbank. Panned.

M4H01829.MP4—Blaylock Creek: main channel of downstream XS for indirect. Note the island of trees in middle of channel.

M4H01830.MP4—Blaylock Creek: left overbank at middle XS for indirect.

M4H01831.MP4---Blaylock Creek: tributary stream coming into the indirect reach

M4H01832.MP4---Blaylock Creek: XS3 which is third from DS end of indirect reach

M4H01845.MP4—Blaylock Creek: XS3 Main channel standing on left bank. Panning to the left overbank.

M4H01850.MP4---Blaylock Creek: USXS4 left overbank. USXS4 is most upstream xsecction

M4H01851.MP4---Blaylock Creek: Calling in the owl.

M4H01852.MP4---Blaylock Creek: USX4 (most upstream). From left bank showing main channel. Shows rock on right bank bluff

M4H01853.MP4---Blaylock Creek: USX4 looking downstream at main channel.

Left overbank area of X1 which is the most downstream cross section

Main channel of X1 (most downstream cross section)

Left overbank of X3 (upstream of USXS1)

Main Channel of X3

Left overbank of X4

Main channel of X4 (most upstream)

The high water marks were of generally fair to poor condition on both the right and left bank due to high velocities through this reach.

Right Bank High Water Marks

Mark Name	Station	Elevation	MSL Elevation
RH-8-P	140.1	100.60	883.70
RH-6-P	498.9	98.23	881.33
RH-7-P	503.3	98.27	881.37
RH-5-G	1009.6	91.56	874.66
RH-4-F	1009.8	91.35	874.45
RH-3-F	1049.9	91.32	874.42
RH-2-F	1139.0	91.06	874.16
RH-1-F	1142.1	91.32	874.42

Left Bank High Water Marks

Mark Name	Station	Elevation	MSL Elevation
LH-15-P	113.9	101.76	884.86
LH-13-F	134.9	101.66	884.76
LH-14-P	153.1	101.35	884.45
LH-16-P	183.3	101.00	884.10
LH-10-G	488.9	96.94	880.04
LH-11-P	502.0	97.47	880.57
LH-12-F	504.3	97.95	881.05
LH-9-P	1013.5	92.09	875.19
LH-5-P	1033.7	92.26	875.36
LH-6-P	1041.7	91.45	874.55
LH-7-P	1051.5	91.96	875.06
LH-8-P	1054.2	92.03	875.13
LH-4-P	1141.0	90.92	874.02
LH-1-P	1151.7	90.87	873.97
LH-3-P	1153.8	90.68	873.78

Computations:

SAM 2.1 was used to process the Total Station Survey data and ready it for input into the SAC program (Slope Area Computation). The discharge computed for this measurement was 14,200 cfs. Although not shown in the computations there was a slight expansion between X2 and X3 because of the small tributary coming in on the left valley wall. Following are the output diagnostics from SAC.

Reach	dH,fall (ft)	length (ft)	Discharge (cfs)	Spread (%)	HF (ft)	CX	RC	RX	ER
X4 - X3	4.20	398.	13919.	9	4.594	0.952	0.000	-0.172	
X3 - X2	5.25	495.	14144.	1	5.346	0.991	0.000	-0.036	
X2 - X1	1.25	123.	15910.	12	1.393	0.941	0.000	-0.205	#
X4 - X2	9.45	893.	14043.	5	9.946	0.973	0.000	-0.100	
X3 - X1	6.50	618.	14439.	3	6.718	0.983	0.000	-0.065	
X4 - X1	10.70	1016.	14228.	6	11.324	0.970	0.000	-0.110	

Definitions:

Spread: the percent difference between discharge computed with no expansion loss (k=0) and discharge computed with full expansion loss (k=1.0), divided by the discharge computed with full expansion loss

HF: friction head which is the sum of Q*Q*L/(K1*K2) over subreaches

L: reach length; K1, upstream section conveyance;

K2: downstream section conveyance

CX: the computed discharge divided by the discharge computed with no expansion loss (k=0)

RC: velocity head change in contracting section divided by friction head

RX: velocity head change in expanding section divided by friction head

Sensitivity Analysis

Sensitivity analysis was conducted on the n values for the reach, by changing the n values +/- 10%. The discharge changed by -9.1 % and +25.8% respectively, showing large sensitivity when the n values are lowered.

Evaluation:

Use 14,200 cfs and consider it fair reliability. The indirect is graded at fair based on the following:

1. The high water marks were flagged and surveyed within 4 days of the flood. Only a few good marks were found on the left bank, with the majority of marks were either fair or poor, with no marks considered excellent.
2. There was an expansion between X2 and X3. However, the reach for this indirect was the best available.
3. The computation diagnostics are fair with the largest spread at 12% for X2 to X1 reach and CX near 1,) however, given the expansion section between X2 and X3, had another cross section been inserted between XS2 and XS3, this would have increased the values of CX and the spread.
4. The velocity head change from one cross section to another in the reach (RX and RC values) has a maximum value of 20% from X2 to X1, with most of the change in velocity head being much smaller in the other reaches. The lower this ratio the more accurate the measurement per Kirby (1987).
5. There is little evidence that the reach cross section main channel has changed much during the flood. The channel is remarkably stable.

6. There is no evidence that this flood was a debris flow based on evidence left behind such as scouring and deposition.

Previous computations:

None

Remarks:

Response to selected review comments of Rodney Southard. Southard comments as numbered item, Holmes response in *italics*:

1. GPS equipment was used to establish vertical and horizontal control at the point of origin for the indirect survey. Suggest documenting the coordinates of this point in the indirect report and water surface elevations used in the analyses. It would be beneficial to translate all points to real world coordinates for future reference.

   UTM Zone 15 NAD83 horizontal position and NAVD88 vertical elevation for OC-1 have been noted in the summary. The real world coordinates for all the points had already been listed in the file "Blaylock.xlsx".

2. Reference was made to an initial reach being selected downstream on Blaylock but backwater from the Little Missouri River was noted and the reach was moved upstream. Further inspection of the upstream reach indicates that cross sections 1 and 2 may also be influenced by backwater conditions. Left overbank photographs at each cross section indicates that at the lower 2 cross sections low streamflow velocities was experienced with minimal disturbance compared to the upper overbank cross sections where scour, debris movement, and vegetation disturbance was observable. A plot of the water surface profiles of the two reaches shows the lower reach with minimal water surface slope, indicating back water conditions, and the water surface slope in the vicinity of the two lower cross sections of the upper reach is much less than the slope of the upper two cross sections of the upper reach. Backwater conditions will reduce the accuracy of the indirect measurement. Indirect initially rated fair. Perhaps the rating may be fair to poor with suspected backwater conditions at cross sections 1 and 2.

   I reviewed the profile plot that you supplied showing the change in slope of the water surface and the assertion the change in slope is due to backwater from the Little Missouri. At first blush I tended to agree with you, however, upon further analysis and review of the photographs, I don't believe your assertion to be true. It was noted in my original analysis that the roughness increases toward cross section 1 and 2 because of the island that appears in the middle of the channel. I think the presence of the island is the cause of the lower water slope in the lower reach of this indirect. Furthermore, on site reconnaissance in the immediate aftermath of the flood revealed that in the lower reaches of Blaylock Creek, where the backwater from the Little Missouri was evident, the trees were pushed over in the downstream direction. This suggests that the velocities were quite large in the lower reaches of Blaylock and that the peak flow for Blaylock Creek occurred before the Little Missouri River peaked. Thus the Blaylock high water marks above the reach that had flatwater during the Little Missouri peak, would have had little influence from the Little Missouri. As such, I do not plan to downgrade the quality of the measurement because of the change in water slope.

3. Suggest doing a 2 section slope area computation to remove the furthest downstream cross section and minimize backwater effects for this indirect by using cross sections 4, 3, and 2.

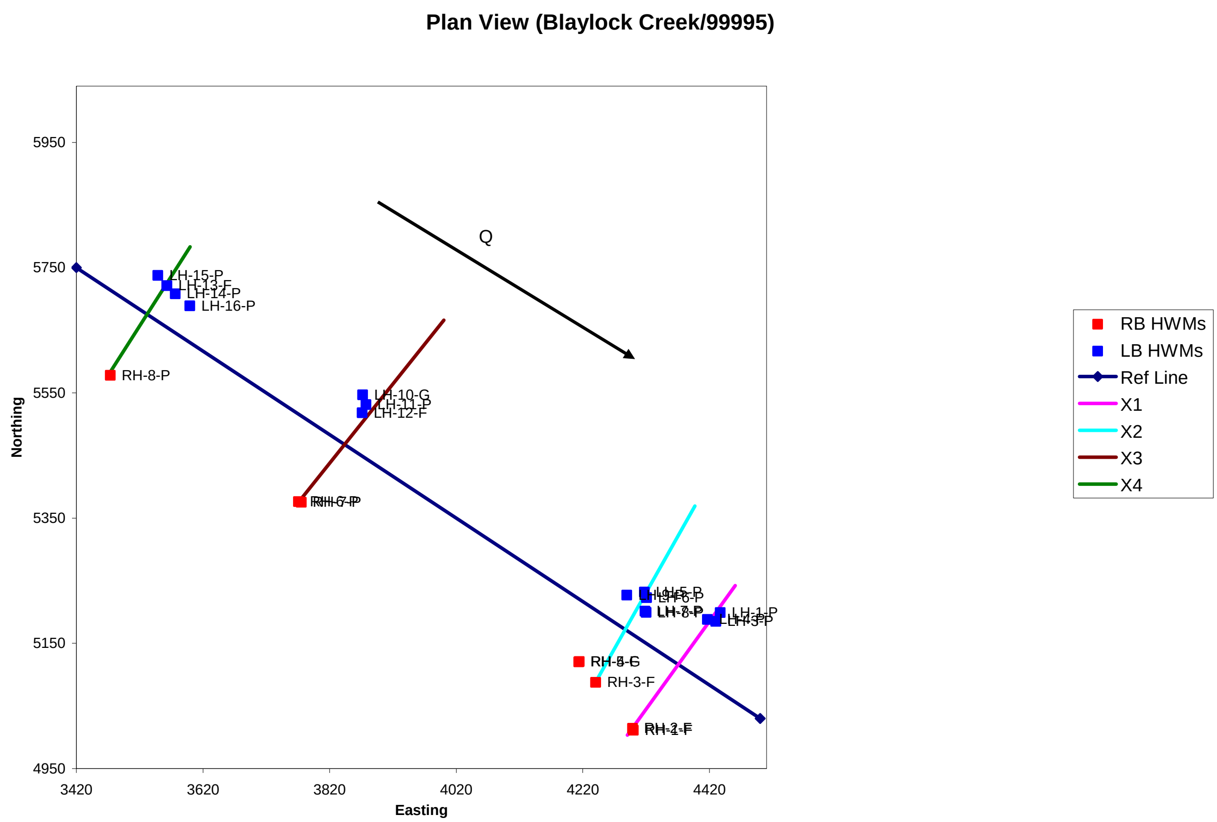
   See response to item 2.

Computed By: Robert R. Holmes, Jr. PhD, P.E., D.WRE
National Flood Specialist
Date: August 2, 2010

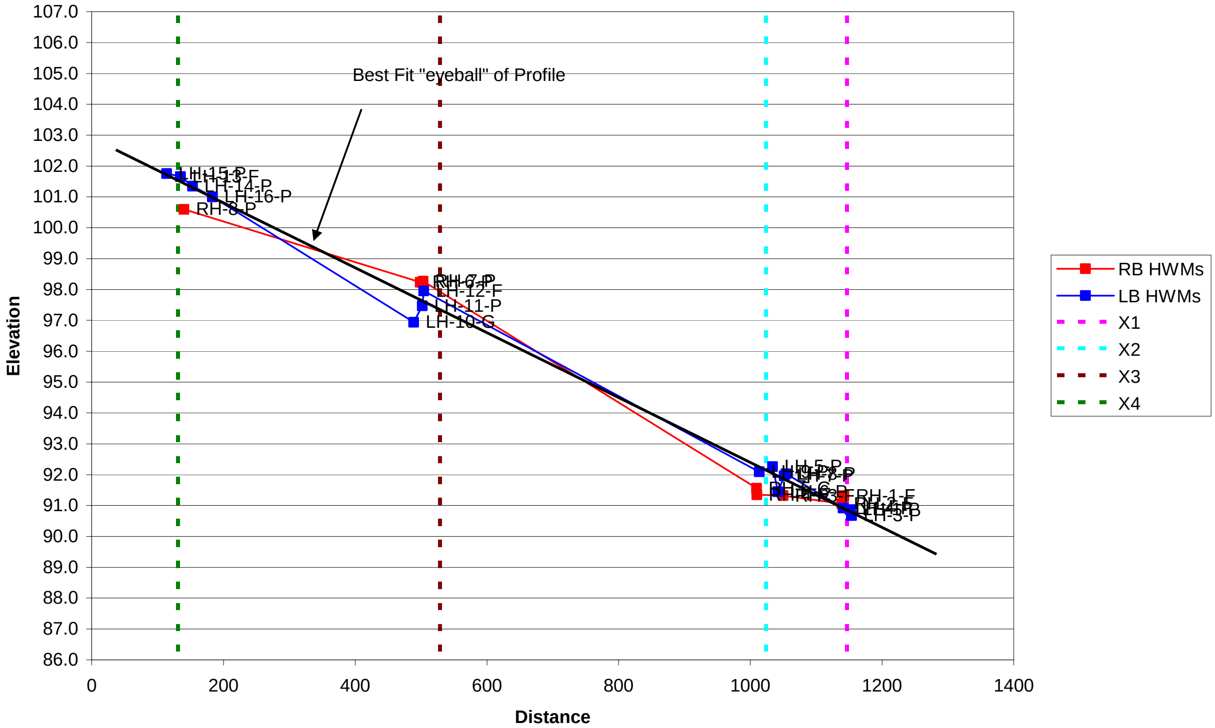
Check/Review By: Rodney Southard
Missouri WSC Surface Water Specialist
Date: August 26, 2010

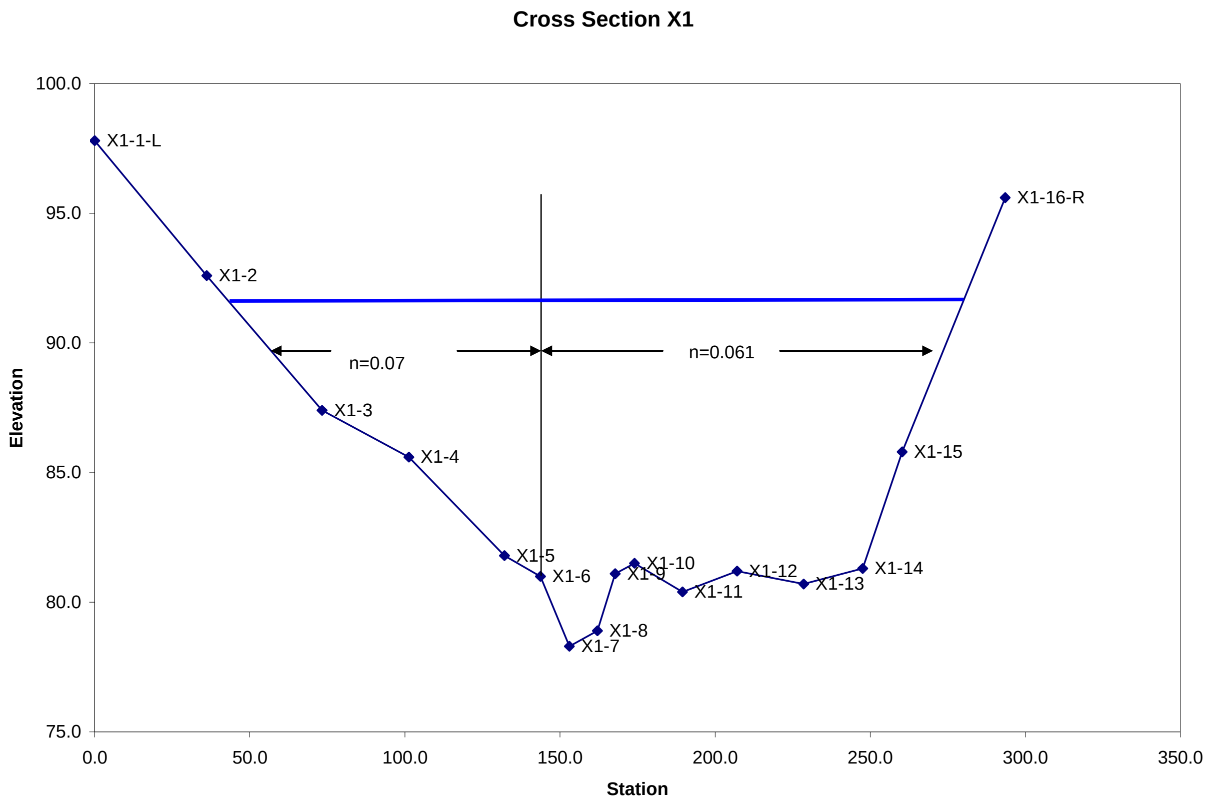
Approval: Mark E. Smith
Surface Water Specialist,
Central Water Science Field Team
Date: January 21, 2011

Graphs from SAM

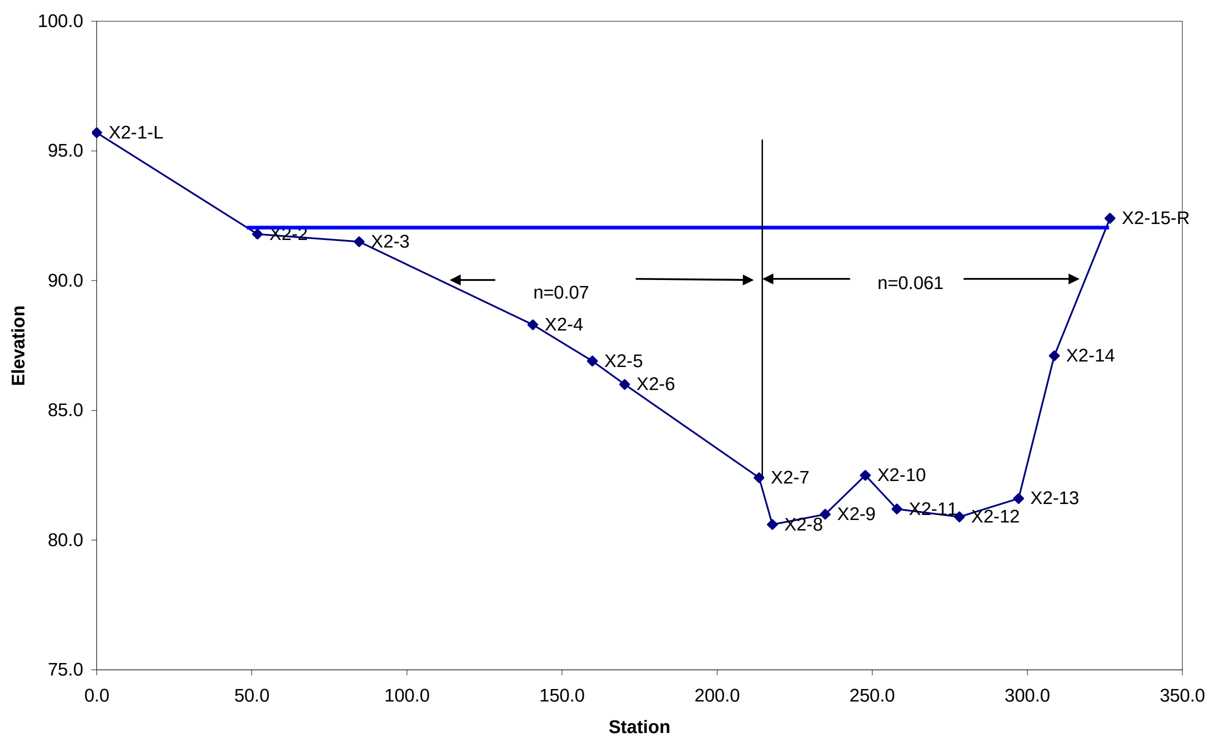


High Water Marks Profile (Blaylock Creek/99995)

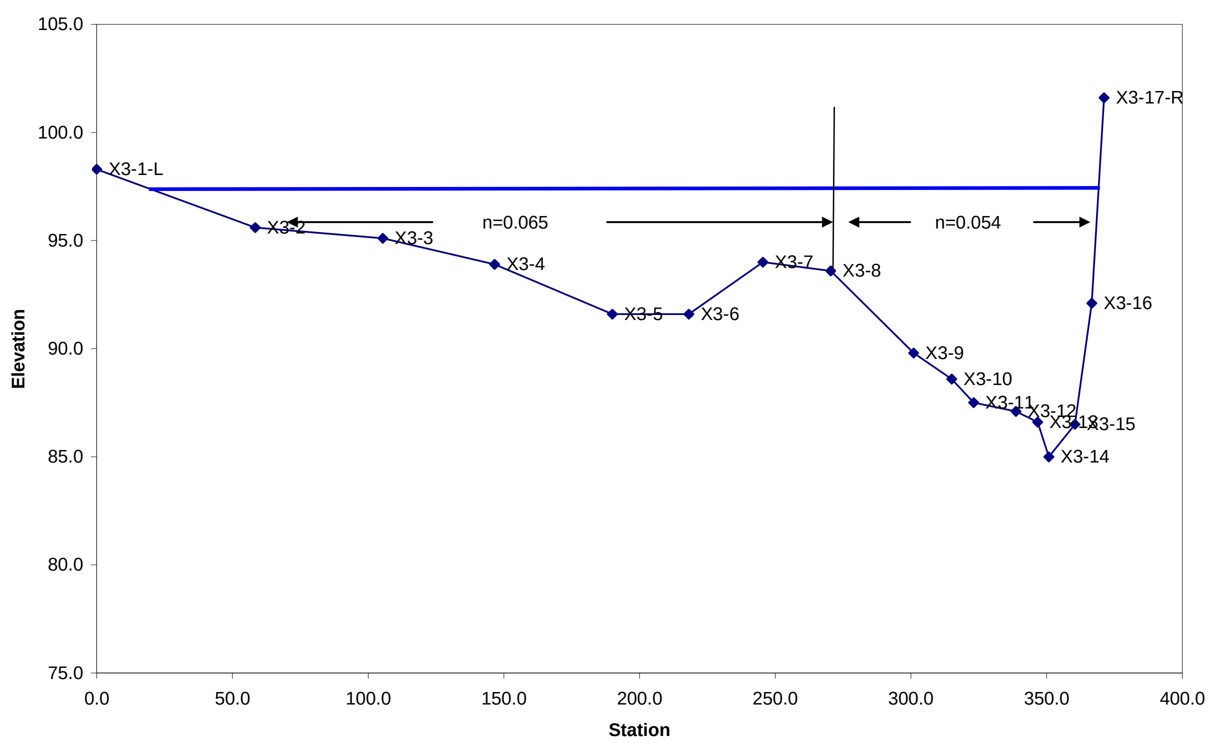


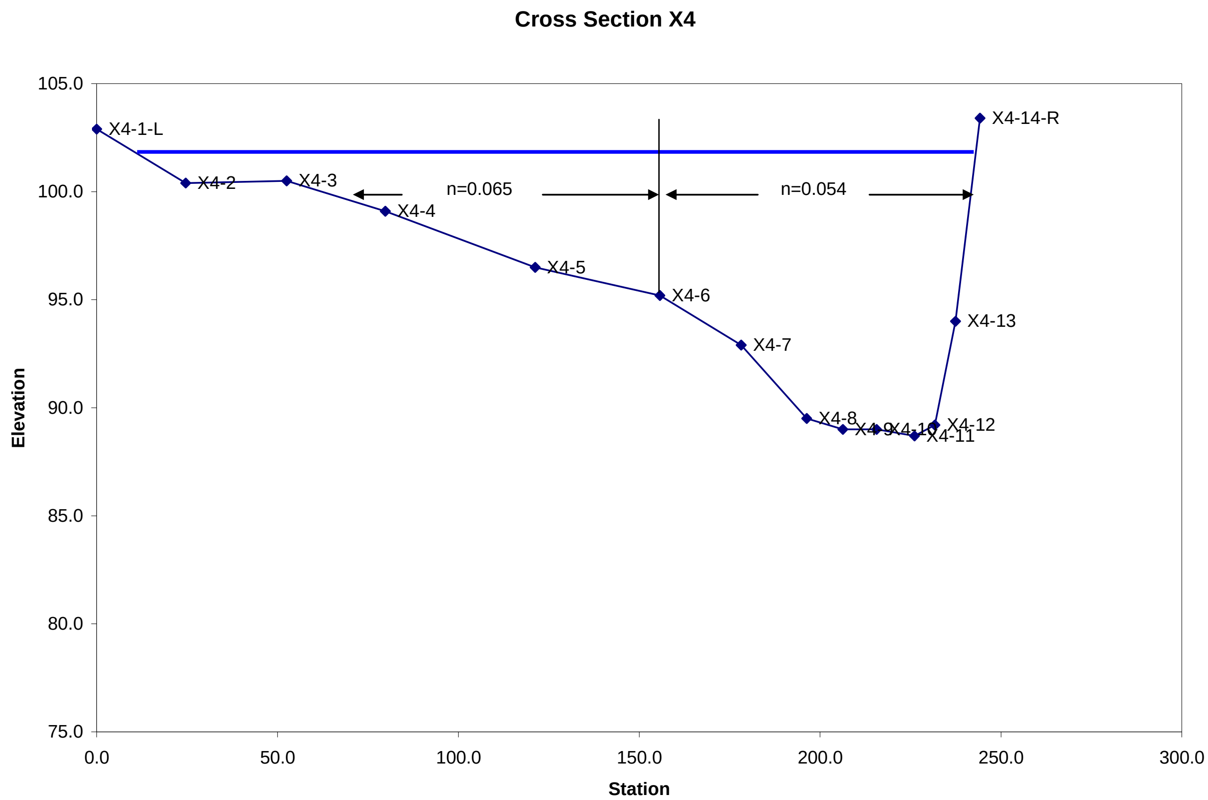

Cross Section X1
100.0
95.0
90.0
85.0
80.0
75.0
Elevation
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Station
X1-1-L
X1-2
X1-3
X1-4
X1-5
X1-6
X1-7
X1-8
X1-9
X1-10
X1-11
X1-12
X1-13
X1-14
X1-15
X1-16-R
n=0.07
n=0.061

Cross Section X2



Cross Section X3





Roughness Estimates

The roughness changed through the reach of the indirect. As such, each xsection and subsection will have a different n values. A sensitivity analysis was performed to look at the max, min, and estimated values for the subsections.

XS 4 and XS 3(most upstream cross sections)

Cross Section 3 & 4 were similar in cross section geometry and roughness. Both cross sections were subdivided into 2 subsections.

The left overbank contains open timber of medium density with trees ranging from sapling to 1 foot in diameter size. Cross sections 3 and 4 overbank was more open than in the lower cross sections (XS1 and XS2). The composite n value for the left overbank was estimated to be 0.065 based on engineering judgment.

The main channel/right bluff has gravel, rock, and boulders, with trees on left bank and the right bank. The right bank is the bluff. A composite n value for the main channel and banks was estimated to be 0.054 based on engineering judgment.

XS1 and XS2 (lower two cross sections)

Cross sections 1 and 2 were similar in cross section geometry and roughness. Both cross sections were subdivided into two subsections. The left overbank and the main channel/right bluff. From the XS3 to XS2, it is noted that the left overbank becomes less panhandled in shape and narrows as the valley constricts. The left overbank was suddivided out mainly because of the roughness differences from the main channel and less because of geometrical differences.

The left overbank contains timber of medium to high density. The trees range from saplings to 1 foot in diameter and larger. Undergrowth of weeds and bushes are more prevalent in XS1 and XS2 than the upstream cross sections. As such a slightly larger value of roughness was estimated based on engineering judgment. The n value was estimated to be 0.070 based on engineering judgment.

The main channel/right bluff has gravel, rock, and boulders, with trees on left bank and the right bank. The right bank is the bluff. An island begins to form at XS2 and continues down to XS1. This resulted in the composite n value estimate being slightly higher for XS1 and XS2 than what was estimated upstream. A composite n value for the main channel and banks was estimated to be 0.061 based on engineering judgment.

SAC INPUT DATA

```
T1      SAC/WSPRO Input for Blaylock Creek  (99995)
T2
Q
WS      90.85
XS   X1   1147
GR      0,97.8 36.1,92.6 73.3,87.4 101.3,85.6 132.1,81.8 143.7,81 153,78.3
GR      162.1,78.9 167.8,81.1 174,81.5 189.5,80.4 207.1,81.2 228.6,80.7
GR      247.6,81.3 260.3,85.8 293.5,95.6
N      .070  .061
SA      143.7
HP 4 X1   90.85
XS   X2   1024
GR      0,95.7 51.8,91.8 84.6,91.5 140.6,88.3 159.8,86.9 170.2,86 213.5,82.4
GR      217.8,80.6 234.9,81 247.8,82.5 258,81.2 278.1,80.9 297.2,81.6
GR      308.7,87.1 326.7,92.4
N       .070  .061
SA      213.5
HP 4 X2   92.1
XS   X3   529
GR      0,98.3 58.4,95.6 105.4,95.1 146.6,93.9 190,91.6 218.2,91.6 245.5,94
GR      270.4,93.6 301,89.8 315,88.6 323.1,87.5 338.7,87.1 346.7,86.6
GR      350.8,85 360.4,86.5 366.6,92.1 371.2,101.6
N       0.065    0.054
SA      270.1
HP 4 X3   97.35
XS   X4   131
GR      0,102.9 24.6,100.4 52.5,100.5 79.8,99.1 121.2,96.5 155.7,95.2
GR      178.2,92.9 196.3,89.5 206.3,89 215.6,89 226.1,88.7 231.7,89.2
GR      237.4,94 244.2,103.4
N      0.065    0.054
SA      155.7
HP 4 X4   101.55
```

SAC OUTPUT

DISCHARGE COMPUTATIONS

Reach	dH,fall (ft)	length (ft)	Discharge (cfs)	Spread (%)	HF (ft)	CX	RC	RX	ER
X4 - X3	4.20	398.	13919.	9	4.594	0.952	0.000	-0.172	
X3 - X2	5.25	495.	14144.	1	5.346	0.991	0.000	-0.036	
X2 - X1	1.25	123.	15910.	12	1.393	0.941	0.000	-0.205	#
X4 - X2	9.45	893.	14043.	5	9.946	0.973	0.000	-0.100	
X3 - X1	6.50	618.	14439.	3	6.718	0.983	0.000	-0.065	
X4 - X1	10.70	1016.	14228.	6	11.324	0.970	0.000	-0.110	

Definitions:

Spread, the percent difference between discharge computed with no expansion loss (k=0) and discharge computed with full expansion loss (k=1.0), divided by the discharge computed with full expansion loss

HF, friction head- HF = sum of Q*Q*L/(K1*K2) over subreaches; Q, discharge; L, reach length; K1, upstream section conveyance; K2, downstream section conveyance

CX, the computed discharge divided by the discharge computed with no expansion loss (k=0)

RC, velocity head change in contracting section divided by friction head

RX, velocity head change in expanding section divided by friction head

ER, warnings, *-fall <' 0.5ft, @-conveyance ratio exceeded, #-reach too short error, 1-negative or 0 fall

******, terms that can not be computed because' of strong expansion in reach

```
                  CROSS  SECTION  PROPERTIES
-------------------------------------------------------------------------------
 I.D. X1              Velocity head    1.21ft    Discharge    14228.cfs
  Ref.distance    1147.ft           Q/K    0.0082       Alpha 1.113

 Sub  Water              Top   Wetted   Hydraulic   Conveyance
 area surface   n     Area   width perimeter   radius   x 0.001      Vel.    F
 no. el.(ft)      (sq.ft)   (ft)   (ft)       (ft)     (cfs)   %   (fps)
   1   90.85 0.070    494.2    95.1   95.6      5.17     31.443  20.  5.8  0.45
   2   90.85 0.061   1202.9   133.7  136.1      8.84    125.602  80.  9.5  0.56
Total   90.85   ---    1697.    229.   232.      7.32    157.045 100.  8.4  0.54
-------------------------------------------------------------------------------
Definitions:
 n, Manning's coefficient of roughness    Q/K = discharge/conveyance
 F, Froude number F = Ki*Q/(K*A sqrt(g*(Ai/TWi)); Q, discharge; A, total cross-
    section area; g, acceleration of gravity; Ai, sub-section area; TWi, sub-
    section top width


                   CROSS  SECTION  PROPERTIES
-------------------------------------------------------------------------------
 I.D. X2              Velocity head    1.44ft    Discharge    14228.cfs
  Ref.distance    1024.ft           Q/K    0.0100       Alpha 1.271

 Sub  Water              Top   Wetted   Hydraulic   Conveyance
 area surface   n     Area   width perimeter   radius   x 0.001      Vel.    F
 no. el.(ft)      (sq.ft)   (ft)   (ft)       (ft)     (cfs)   %   (fps)
   1   92.10 0.070    625.8   165.7  166.0      3.77     32.261  23.  5.2  0.47
   2   92.10 0.061   1037.8   112.2  114.7      9.05    110.069  77. 10.6  0.61
Total   92.10   ---    1664.    278.   281.      5.93    142.330 100.  8.6  0.62
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
 I.D. X3              Velocity head    1.64ft    Discharge    14228.cfs
  Ref.distance     529.ft           Q/K    0.0120       Alpha 1.397

 Sub  Water              Top   Wetted   Hydraulic   Conveyance
 area surface   n     Area   width perimeter   radius   x 0.001      Vel.    F
 no. el.(ft)      (sq.ft)   (ft)   (ft)       (ft)     (cfs)   %   (fps)
   1   97.35 0.065    817.8   249.6  249.8      3.27     41.336  32.  5.5  0.54
   2   97.35 0.054    819.5    99.0  105.3      7.78     88.813  68. 11.8  0.73
Total   97.35   ---    1637.    349.   355.      4.61    130.149 100.  8.7  0.71
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
 I.D. X4              Velocity head    2.46ft    Discharge    14228.cfs
  Ref.distance     131.ft           Q/K    0.0122       Alpha 1.352

 Sub  Water              Top   Wetted   Hydraulic   Conveyance
 area surface   n     Area   width perimeter   radius   x 0.001      Vel.    F
```

no.	el.(ft)	n	(sq.ft)	(ft)	(ft)	(ft)	(cfs)	%	(fps)	
1	101.55	0.065	436.9	142.4	142.6	3.06	21.123	16.	5.3	0.54
2	101.55	0.054	877.0	87.2	93.2	9.41	107.832	84.	13.6	0.75
Total	101.55	---	1314.	230.	236.	5.57	128.955	100.	10.8	0.80

Definitions:

n, Manning's coefficient of roughness Q/K = discharge/conveyance

F, Froude number F = Ki*Q/(K*A sqrt(g*(Ai/TWi)); Q, discharge; A, total cross-section area; g, acceleration of gravity; Ai, sub-section area; TWi, sub-section top width