Indirect Measurement Summary

Little Missouri River above Long Creek near Albert Pike, Arkansas
Ouachita River Basin
Miscellaneous Site
Q= 28,800 ft^3/s
Flood of June 11, 2010

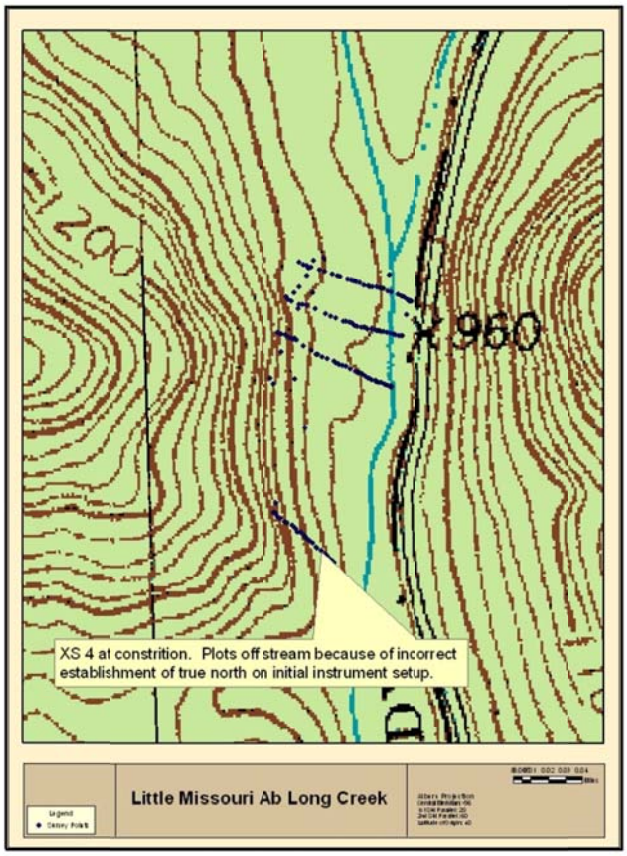
Type of measurement: Slope Area

Location of site: A miscellaneous site above the inflow of Long Creek on the Little Missouri River. Lat N 34˚23'21", Long W 93˚52'43" This site was selected because it was a straight converging reach upstream of Long Creek. This reach runs almost due south. A low water bridge crosses the river approximately 4300 feet downstream of the indirect measurement location. Long Creek comes into Little Missouri River on the right bank approximately 4860 ft downstream. A constriction occurs 800 ft downstream of the indirect measurement site as the valley walls narrow from a highly resistant layer of novaculite. Surveys were also conducted in the area of the constriction to check if critical depth computations for flow can be made in this constricted area.

The site is Approximately 5.72 miles northwest of Langley, Arkansas, 12.08 miles southwest of Norman, Arkansas, 14.9 miles west of Caddo Gap, Arkansas, and 31.1 miles east of Cove, Arkansas.

Survey of site: Site was selected on Tuesday June 15, 2010 by Robert Holmes during reconnaissance of the flood area. High water marks were flagged on the evening of June 15, 2010 by Robert Holmes. A survey commenced on the morning of June 16, 2010 by Ferrell Killian, Aaron Pugh, and Jonathon Gillip. The initial occupation point (OC-1)was a pin driven into the gravel bar at the upstream cross section. 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 horizontal (NAD83) and vertical position (NAVD88) of each survey point. The survey was continued downstream of the indirect measurement site in order to capture additional high water marks along the river as well as the channel geometry of the constricted area.

The Survey of the indirect measurement site was made using a Sokkia Set 3c 3-second total station, serial number 23110. The survey plots off from the DRG as the result of the original survey azimuth not starting at true north. XS-4 is the channel (and floodplain) cross section at the constriction.



Cross Section Locations

Discharge and Gage Height: 28,800 cfs. No Gage Height was determined as this is a miscellaneous site.

Drainage area: 18.2 mi^2 as determined by Albert Rea of the USGS using NHD Plus.

Unit Discharge: 1,580 cfs/mi^2. Crippen and Bue (1977) envelope curve for this region (Region 8) is below, with this flood approximately plotted.

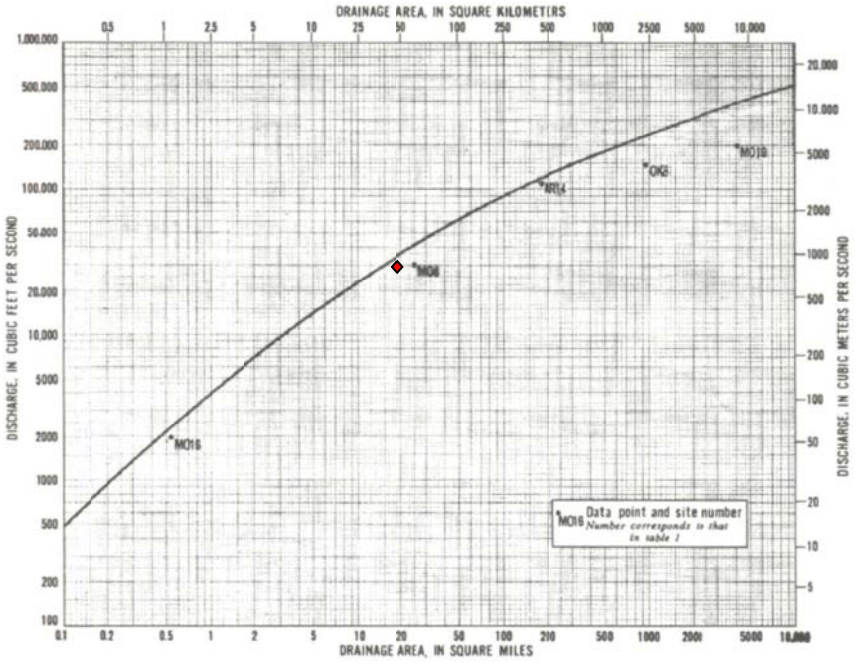


FIGURE 10.—Peak discharge versus drainage area, and envelope curve for region 8.

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 10 miles downstream were as much as 8 ft/hour. Anecdotal accounts of the rates of rise from survivors in the Albert Pike Campground indicate as much as 3 feet in a few minutes. The Ouachita mountains are a known "flood hotspot" in the United States.

Field conditions: The indirect reach is fairly straight with nearly uniform boundary roughness through the reach. Each of the three cross sections was subdivided into 3 subsections: 1) the left overbank which consists of the gravel road bed and left valley wall, the 2) main channel, which included the two bank areas with the trees, and 3) the right overbank, which is a panhandle subsection of the total cross section. XS1 is the most upstream cross section, XS2 is the middle cross section, and XS3 is the most downstream cross section.

See the following video clips to view the channel and floodplain conditions for the indirect reach.

M4H01773.MP4---Little Missouri River above Long Creek at the Indirect reach. This is right overbank of XS 3

M4H01776.MP4---Little Missouri River above Long Creek at the indirect reach. This is right overbank upstream of XS1 (most upstream XSECT)

M4H01799.MP4—Little Missouri River above Long Creek at the indirect reach. Left overbank along road at XS1

M4H01800.MP4—Little Missouri River above Long Creek at indirect reach. Main channel at XS1

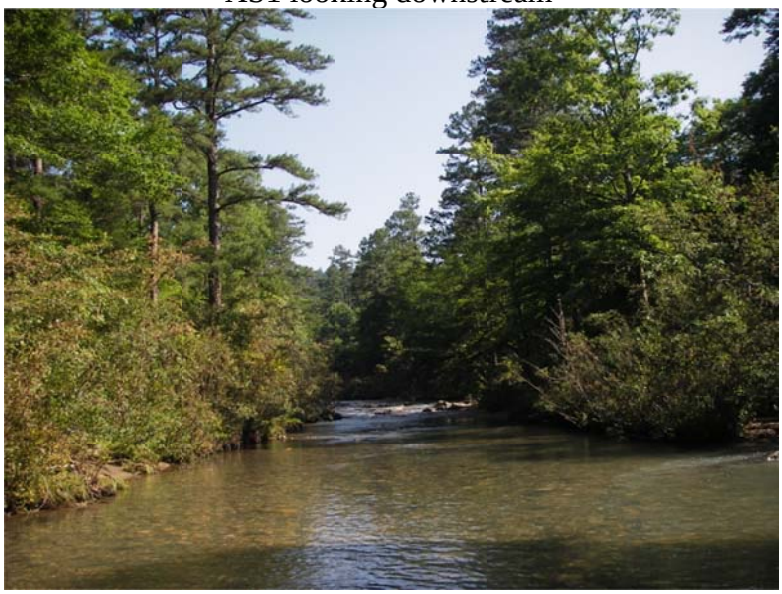
M4H01801.MP4---Little Missouri River above Long Creek at Indirect reach. Left overbank at XS 3.

The left overbank was estimated to have an n value of 0.039. The left overbank is made up of the gravel road with a small amount of trees/brush on the right edge and grass on the left valley wall that is the left edge of the left overbank. The estimate of n=0.039 is based on engineering judgment.

At XS1 looking downstream through left overbank along gravel road.

The main channel consists of gravel/cobble bed in the main channel with trees/brush on the left edge and willows/brush on right edge. N value assigned to main channel subsection was 0.058 based on engineering judgment and weighted composite n.

XS1 looking downstream



XS1 looking upstream

At XS3 looking on right bank looking toward left bank. Hydrologist pointing out tree scar resulting from flood.

Right overbank is made up of trees. An n value of 0.08 was assigned to this subsection based on engineering judgment.

In right overbank area at XS3. Hydrographer is holding pole horizontal at approximate level of HWMs

Right overbank subsection at XS1. Note hydrographer holding rod at approximate level of HWMs

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 reach was contracting from X1 to X2 and slightly expanding from X2 to X3. The original discharge computed for this measurement was 28,200 cfs. After review by Mark Smith, it was found there was a small computational bias in SAM2.1 in the determination of baseline length. Using the newly determined correct baseline length, the final discharge was computed to be 28,800 cfs. Following are the output diagnostics from SAC:

Reach	dH,fall (ft)	length (ft)	Discharge (cfs)	Spread (%)	HF (ft)	CX	RC	RX	ER
X1 - X2	**0.60**	**104.**	**29806.**	**1**	**0.611**	**0.991**	**0.000**	**-0.037**	**#**
X2 - X3	**0.90**	**143.**	**28204.**	**0**	**0.828**	**1.000**	**0.087**	**0.000**	**#**
X1 - X3	**1.50**	**247.**	**28813.**	**0**	**1.435**	**0.997**	**0.052**	**-0.015**	**#**

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

CROSS SECTION PROPERTIES

XSECT	Subarea	WS	n	Area (ft^2)	T	P	R	K (x 0.001)	%	V	F

X1	LOB	113.1	0.039	80.5	21.6	23.3	3.45	7.025	2	6.9	0.63
X1	Main	113.1	0.058	1996.1	157.8	162.7	12.27	272.77	77	10.9	0.54
X1	ROB	113.1	0.08	1237.1	205.4	206.7	5.99	75.964	21	4.9	0.35
X1	Total	113.1		3314	385	393	8.44	355.759	100	8.5	0.51
X2	LOB	114	0.039	161.9	24.4	27.7	5.84	20.061	5	9.1	0.62
X2	Main	114	0.058	2008.1	146.2	151	13.3	289.558	75	10.5	0.5
X2	ROB	114	0.08	1254.5	210.4	211.5	5.93	76.556	20	4.5	0.32
X2	Total	114		3424	381	390	8.78	386.174	100	8.2	0.48
X3	LOB	114.6	0.039	182.4	24.7	28.3	6.44	24.124	6	9.5	0.62
X3	Main	114.6	0.058	2157.6	159.4	163.5	13.2	309.518	79	10.4	0.5
X3	ROB	114.6	0.08	995.2	180.1	180.6	5.51	57.832	15	4.2	0.31
X3	Total	114.6		3335	364	372	8.96	391.473	100	8.5	0.49

Sensitivity analysis was conducted on the n values for the main channel and both overbank subsections. The value of n was allowed to range from 0.042 to 0.070 in the main channel, from 0.032 to 0.060 in the left overbank (LOB) and from 0.060 to 0.100 in the right overbank (ROB).

Original Sensitivity Analysis Results of Holmes

FALL	N LOB	N Main	N ROB	Q	Q(1-2)	Q(2-3)	Q st. dev.	XS2 V LOB	XS2 Vmain	XS2 ROB	XS2 Froude
1.50	0.039	0.051	0.080	30,800	32,600	29,800	1,419	9.00	11.90	4.40	0.53
1.50	0.039	0.051	0.100	29,200	30,400	28,500	961	8.80	11.70	3.50	0.50
1.50	0.039	0.051	0.060	33,000	35,200	31,800	1,724	9.10	12.00	6.00	0.57
1.50	0.039	0.056	0.080	28,900	30,600	28,000	1,320	9.00	10.90	4.50	0.50
1.50	0.039	0.042	0.080	34,800	36,300	33,900	1,212	8.70	14.00	4.30	0.60
1.50	0.045	0.051	0.080	30,700	32,400	29,700	1,365	7.80	11.90	4.40	0.53
1.50	0.051	0.051	0.080	30,700	32,300	29,700	1,311	6.90	11.90	4.40	0.53
1.50	0.039	0.060	0.080	27,600	29,100	26,700	1,212	9.10	10.20	4.50	0.47
1.50	0.051	0.046	0.080	32,900	34,300	32,000	1,159	6.80	13.10	4.40	0.56
1.50	0.039	0.058	0.080	28,200	29,800	27,300	1,266	9.10	10.50	4.50	0.48
1.50	0.032	0.058	0.080	28,700	30,300	27,700	1,311	11.10	10.60	4.50	0.49
1.50	0.060	0.058	0.080	27,900	29,200	27,148	1,038	5.90	10.60	4.50	0.48
1.50	0.039	0.070	0.080	24,900	26,080	24,188	956	9.20	8.80	4.50	0.43
1.50	0.039	0.058	0.100	26,900	28,100	26,100	1,007	9.00	10.40	3.30	0.46
1.50	0.039	0.058	0.060	30,300	32,100	29,300	1,419	9.10	10.60	6.00	0.52

The sensitivity analysis reveals the following

1. A change in the LOB n value from the minimum (0.032) to the maximum (0.060) resulted in a decrease of the discharge of 3%
2. A change in the main channel n value from the minimum (0.042) to the maximum (0.070) resulted in a decrease of the discharge of 40%
3. A change in the ROB n value from the minimum (0.060) to the maximum (0.10) resulted in a decrease in discharge of 13%

Evaluation:

Use 28,800 cfs and consider it good to fair reliability. The indirect is graded at good to fair (10 to 15%) based on the following:

1. The high water marks were flagged and surveyed within 4 days of the flood. A good wash line was evident on the left valley wall and a several good high water marks were found in the right overbank. However, there was some variability in the high water marks.
2. The reach was nearly uniform in cross sectional area (neither expanding or contracting), with total Area being 3314, 3424, and 3335 square feet in XS1, XS2, and XS3.
3. The diagnostics (Spread near 0, CX approaching 1, and small values of RX) all look very good.
4. The velocity head change from XS1 to XS3 is less than 5% of the friction head in this reach. 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.
7. During the field recon, it was thought that the constriction 427 ft downstream of XS3 might induce critical flow depth. As such a surveyed cross section and high water marks were collected at the constriction. Using HWMs at the constriction, the mean hydraulic depth (D=A/T) computes as 9.63 ft with a cross sectional area of 2,196 ft2. From critical flow equation ($V = \sqrt{gD}$), the flow (assuming the computed depth was critical depth) was 38,600 cfs, which way overestimated the flow given from SAC. In addition, a new four section SAC run that included XS4 estimated the Froude number at the constriction to be 0.67, much less than the critical flow state. The critical flow computation was not helpful in determining the actual flow, but puts an definitive upper bound on the possible peak flow at this location.

Previous computations:

None

Remarks: After review by Mark Smith, peak streamflow was changed from 28,200 cfs to 28,800 cfs. Also measurement quality was slightly downgraded from good to good-fair based on recommendation from Smith.

Computed By: Robert R. Holmes, Jr. PhD, P.E., D.WRE
National Flood Specialist
Date: July 29, 2010

Checked By: Daniel M. Wagner
Arkansas Water Science Center
Date:October 6, 2010

Reviewed By: Mark Smith
Regional Surface Water Specialist
Date: December 10, 2010

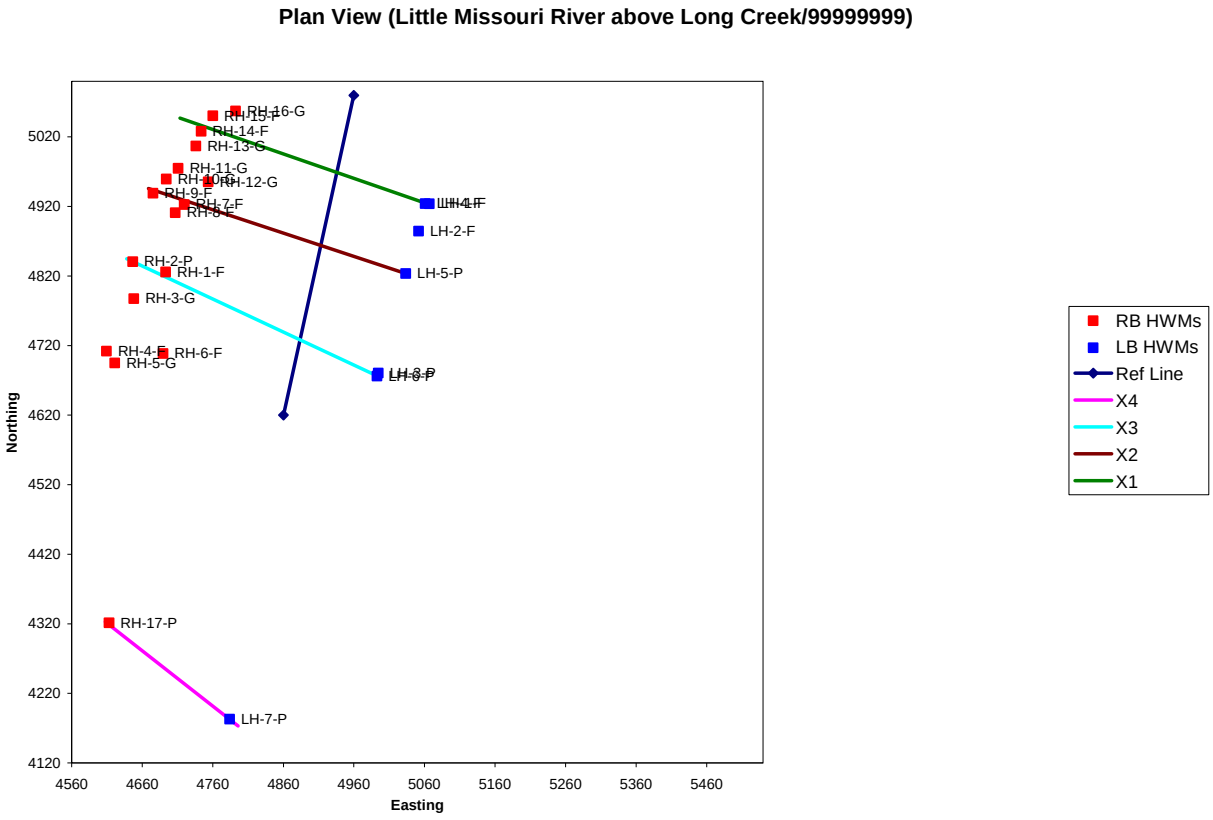
Approval: Mark E. Smith
Surface Water Specialist,
Central Water Science Field Team
Date: January 21, 2011

Appendix

Little Missouri River above Long Creek near Albert Pike, Arkansas

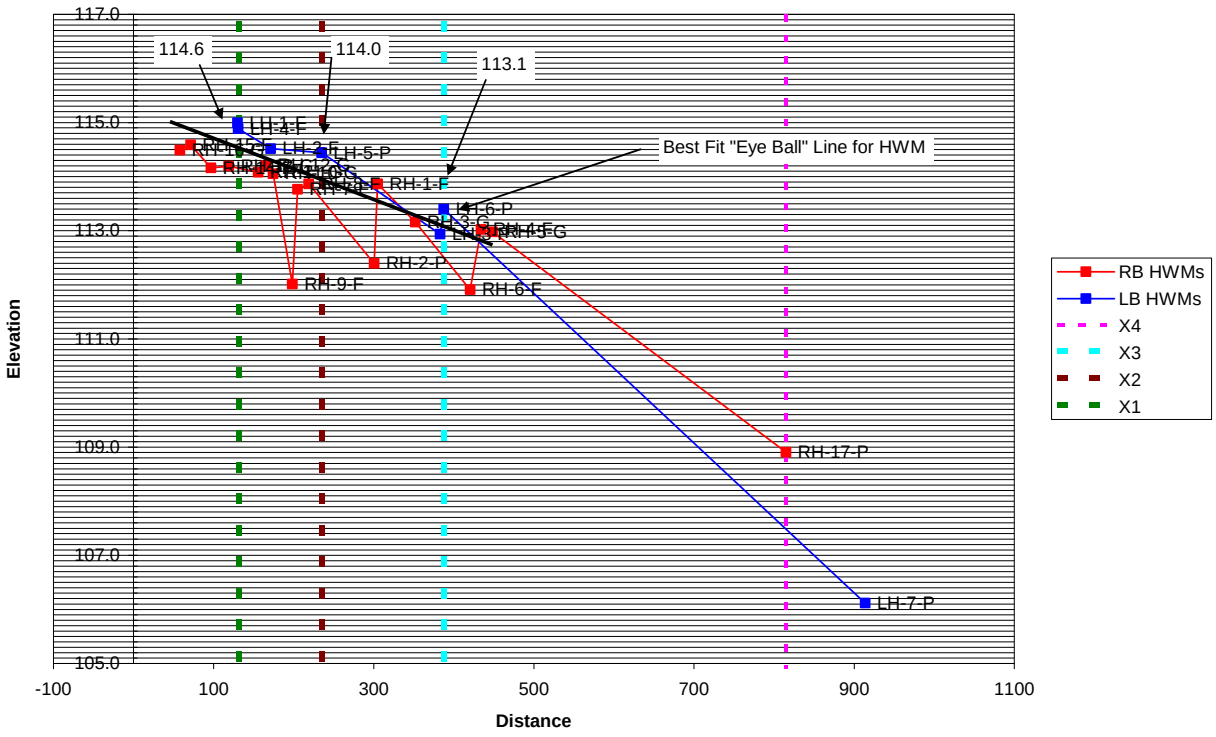
Flood of June 11, 2010

Graphs from SAM

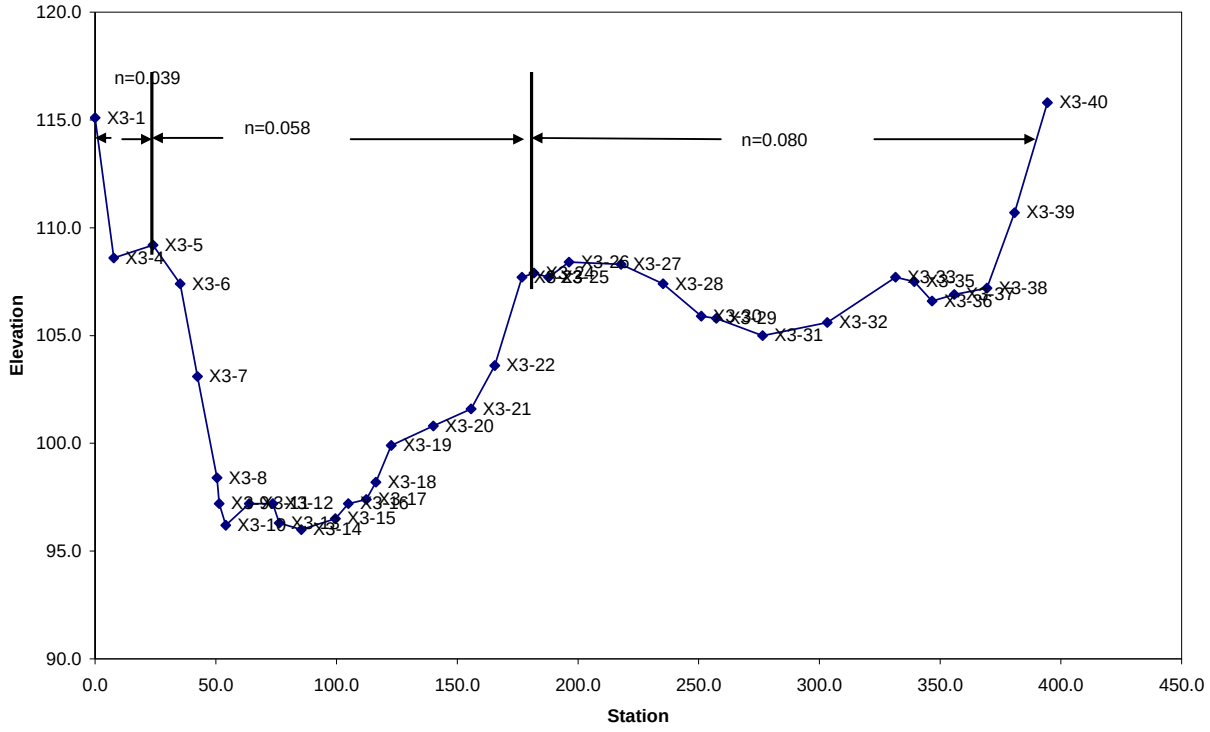


Note: Smith, in his review, recomputed the baseline distances due to the fact that SAM used the left edge of each cross section to determine the baseline distances rather than the baseline itself.

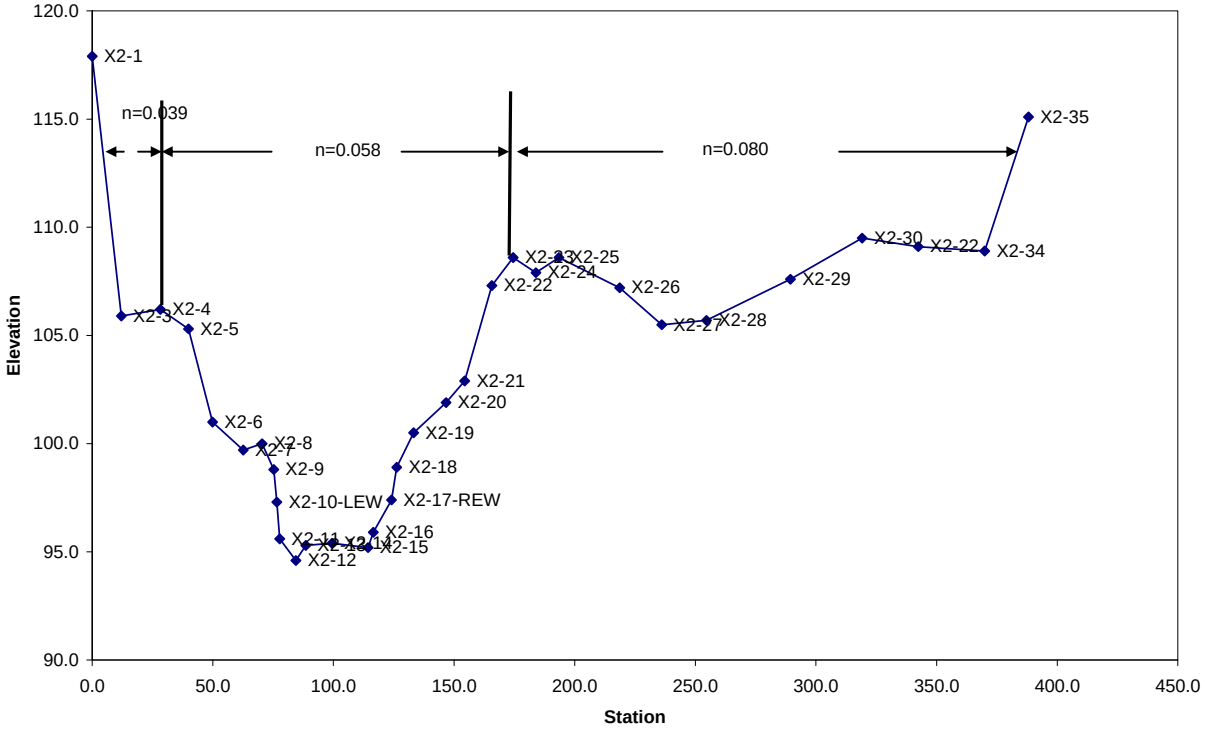
High Water Marks Profile (Little Missouri River above Long Creek/99999999)

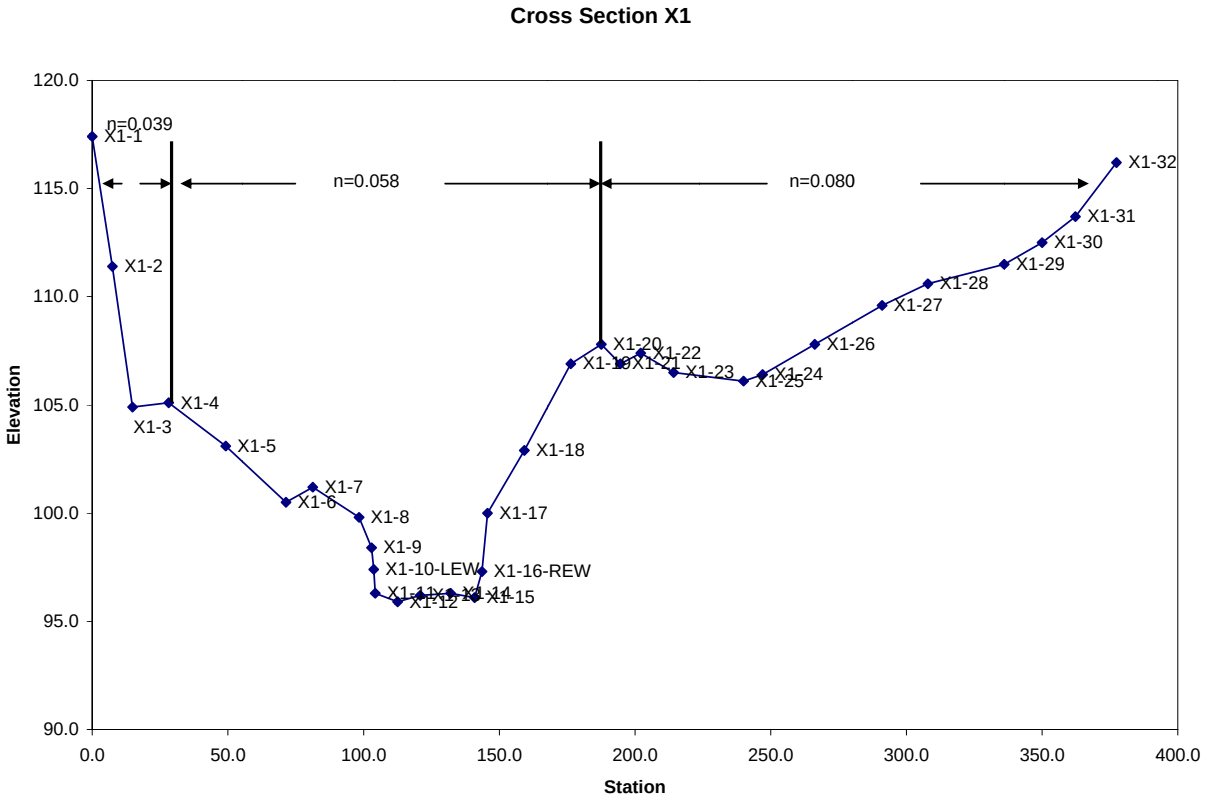


Cross Section X3



Cross Section X2





Roughness Estimates

Main Channel

Main channel was estimated by doing a weighted (by width) estimate of the main channel composite n value. The main channel had brush and trees on the left shore (70 ft in width), a rock and gravel bed low water channel (47 ft in width) and a treed/brush right shore (42 ft in width).

The left shore was estimated to be n= 0.090.

The right shore was estimated to be n = 0.080.

The low water channel was estimated to be 0.031. This was based on published n values in Chow (1959), engineering judgetment, and several theoretical equations based on bed material. The Bed material size data came from the gravel bar 1700 feet below the reach but was judged to be representative of the size of gravel present at the indirect location. The data for the theoretical equations are as follows:

D90= 0.15 meters
D84=0.38 ft
D50 = 0.15 ft; 0.048 m
S (friction slope)=0.0043
R = 16 ft; 4.9 meters
T=148 ft,

Following are computations:

Meyer-Peter Muller(1948) equation for gravel bed streams $n = \frac{1}{26} d_{90}^{1/6}$ (metric units) ---n = 0.028,

Jarretts (1984) equation for mountain streams $n = 0.47S^{0.38}R^{-0.16}$ (English units) --- n = 0.038;

Limerinos (1970) for gravel streams in California $n = \frac{0.0926R^{1/6}}{1.16 + 2.00\log\frac{R}{d_{84}}}$ (English units) ---n =0.033;

Froelich's (1978) equation for gravel and cobble streams $n = 0.245R^{0.14}\chi\left(\frac{R}{d_{50}}\right)^{-0.44}\left(\frac{T}{R}\right)^{-0.3}$ (English units)----- n = 0.024;

Griffiths (1981) equation for gravel rivers $n = \frac{0.113R^{1/6}}{0.76 + 1.98\log\frac{R}{d_{50}}}$ (all SI units) ---- n = 0.031.

A weighted value of n for the main channel is 0.056.

Width(W)	n	W*n
70'	0.090	6.3
47.4	0.031	1.469
42'	0.080	3.36
159.9		11.13

$n_c = 11.13/159.9 = 0.0698$

For this indirect, a n value of 0.058 was used for the main channel. This was based on engineering judgment, weighting of n values from channel width (above), examination of photos from Barnes (1967, http://pubs.usgs.gov/wsp/wsp_1849/pdf/wsp_1849.pdf), and review of the sensitivity analysis data.

SAC INPUT DATA

```
T1       SAC/WSPRO Input for Little Missouri River above Long Creek  (99999999)
T2       Shortened reach 3-2 by 10 feet (to 143 ft) - MES
Q
WS        112.9
XS   X3   378
GR        0,115.1 7.7,108.6 24,109.2 35.2,107.4 42.4,103.1 50.5,98.4 51.4,97.2
GR        54.1,96.2 63.8,97.2 73.6,97.2 76.3,96.3 85.4,96 99.5,96.5 104.9,97.2
GR        112.3,97.4 116.3,98.2 122.7,99.9 140.1,100.8 155.7,101.6 165.5,103.6
GR        176.8,107.7 181.8,107.9 187.9,107.7 196.3,108.4 217.8,108.3
GR        235.3,107.4 251.1,105.9 257.3,105.8 276.5,105 303.3,105.6
GR        331.5,107.7 339.3,107.5 346.7,106.6 355.8,106.9 369.4,107.2
GR        380.8,110.7 394.4,115.8
N        .039   .058   0.08
SA        24.0    181.8
HP 4 X3    113.1
XS   X2   235
GR        0,117.9 12.1,105.9 28.3,106.2 39.9,105.3 49.9,101 62.6,99.7 70.4,100
GR        75.2,98.8 76.5,97.3 77.7,95.6 84.4,94.6 88.5,95.3 99.4,95.4
GR        114.3,95.2 116.5,95.9 124,97.4 126.2,98.9 133.2,100.5 146.7,101.9
GR        154.4,102.9 165.7,107.3 174.5,108.6 183.9,107.9 193.5,108.6
GR        218.6,107.2 236.1,105.5 254.6,105.7 289.4,107.6 319.1,109.5
GR        342.4,109.1 369.9,108.9 388.1,115.1
N        .039     .058     .08
SA        28.3   174.5
HP 4 X2    114.0
XS   X1   131
GR        0,117.4 7.4,111.4 14.9,104.9 28.2,105.1 49.2,103.1 71.4,100.5
GR        81.3,101.2 98.3,99.8 102.9,98.4 103.7,97.4 104.3,96.3 112.5,95.9
GR        120.8,96.2 132.1,96.3 140.9,96.1 143.6,97.3 145.6,100 159.2,102.9
GR        176.3,106.9 187.6,107.8 194.6,106.9 202.1,107.4 214.2,106.5
GR        240,106.1 247,106.4 266.2,107.8 291,109.6 307.9,110.6 336,111.5
GR        350,112.5 362.3,113.7 377.4,116.2
N        0.039    0.058     0.08
SA        28.2    187.6
HP 4 X1    114.6
```

SAC OUTPUT

DISCHARGE COMPUTATIONS

Reach	dH,fall (ft)	length (ft)	Discharge (cfs)	Spread (%)	HF (ft)	CX	RC	RX	ER
X1 - X2	0.60	104.	29806.	1	0.611	0.991	0.000	-0.037	#
X2 - X3	0.90	143.	28204.	0	0.828	1.000	0.087	0.000	#
X1 - X3	1.50	247.	28813.	0	1.435	0.997	0.052	-0.015	#

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)

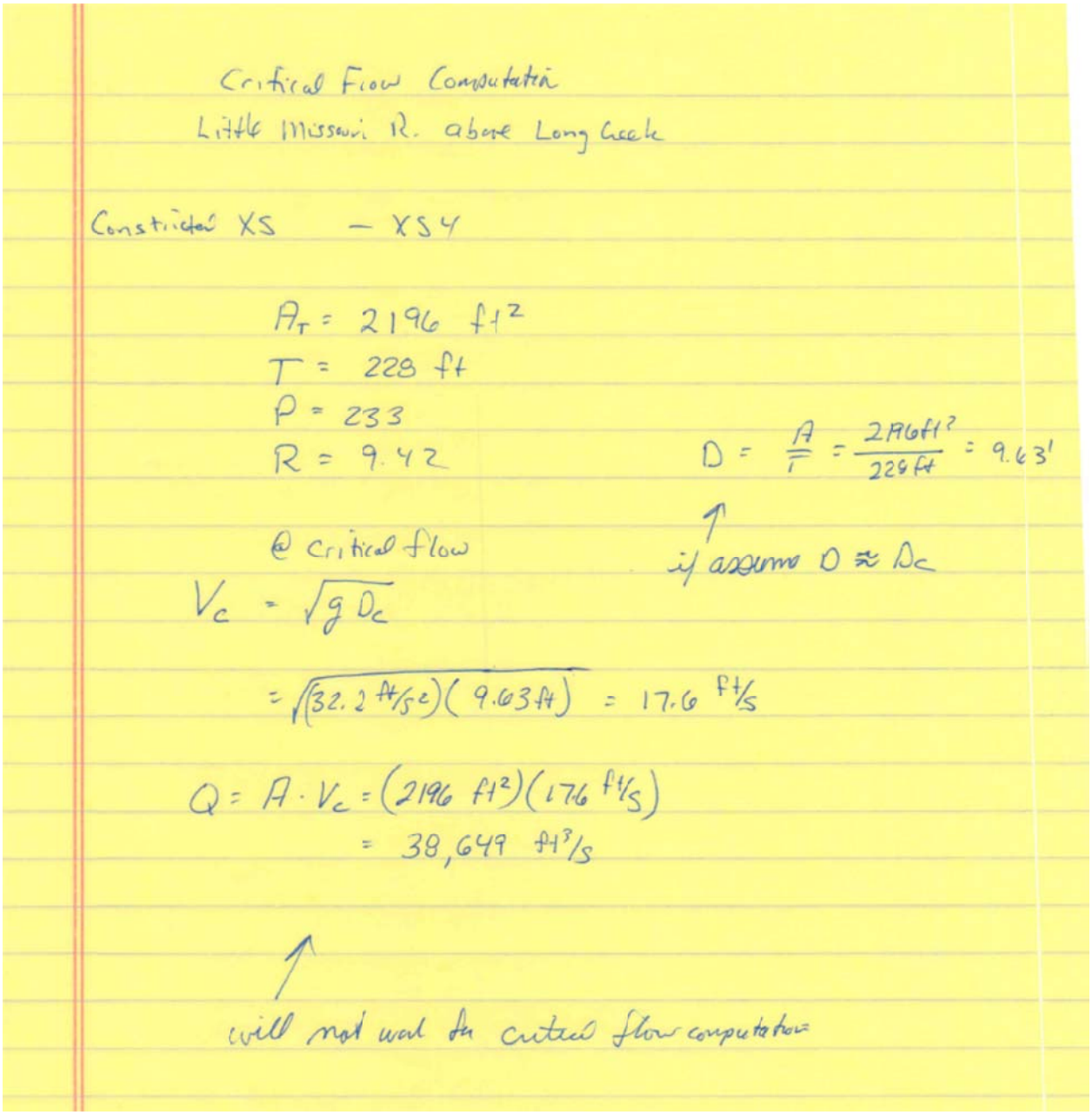
RC, velocity head change in contracting section divided by friction head

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

Appendix1—Ancillary Computation of Q at Constriction Downstream



Critical Flow Computation
Little Missouri R. above Long Creek

Constricted XS — XS4

$A_T = 2196\ ft^2$
$T = 228\ ft$
$P = 233$
$R = 9.42$

$D = \frac{A}{T} = \frac{2196 ft^2}{228 ft} = 9.63'$

↑ if assume $D \approx D_c$

@ critical flow

$V_c = \sqrt{g D_c}$

$= \sqrt{(32.2\ ft/s^2)(9.63 ft)} = 17.6\ ft/s$

$Q = A \cdot V_c = (2196\ ft^2)(17.6\ ft/s)$
$= 38{,}649\ ft^3/s$

↑ will not work for critical flow computations