LITTLE ZIGZAG CREEK

Site Information

Site Location: Mt Hood NF, Forest Rd 2639 MP 1.4

Year Installed: 2000

Lat/Long: 121°48'43.92"W
45°18'52.57"N

Watershed Area (mi2): 4.1

Stream Slope (ft/ft)[1]: 0.0421

Channel Type: Step-pool

Bankfull Width (ft): 14

Survey Date: April 6, 2007

[1]Water surface slope extending up to 20 channel widths up and downstream of crossing.

Culvert Information

Culvert Type: Open-bottom arch

Culvert Material: Concrete

Culvert Width: 15.5 ft

Outlet Type: Wingwalls

Culvert Length: 133 ft

Inlet Type: Wingwalls

Pipe Slope (structure slope): 0.045

Culvert Bed Slope: 0.039

(First hydraulic control upstream of inlet to first hydraulic control downstream of outlet.)

Culvert width as a percentage of bankfull width: 1.09

Alignment Conditions: Inline with natural channel. It is possible that this or previous installation has changed the course of the stream and possibly altered where it joins with the mainstem of Zigzag Creek.

Bed Conditions: Small to large boulders and embedded cobbles in culvert. One large boulder-formed step near downstream end of culvert. One small step near culvert inlet.

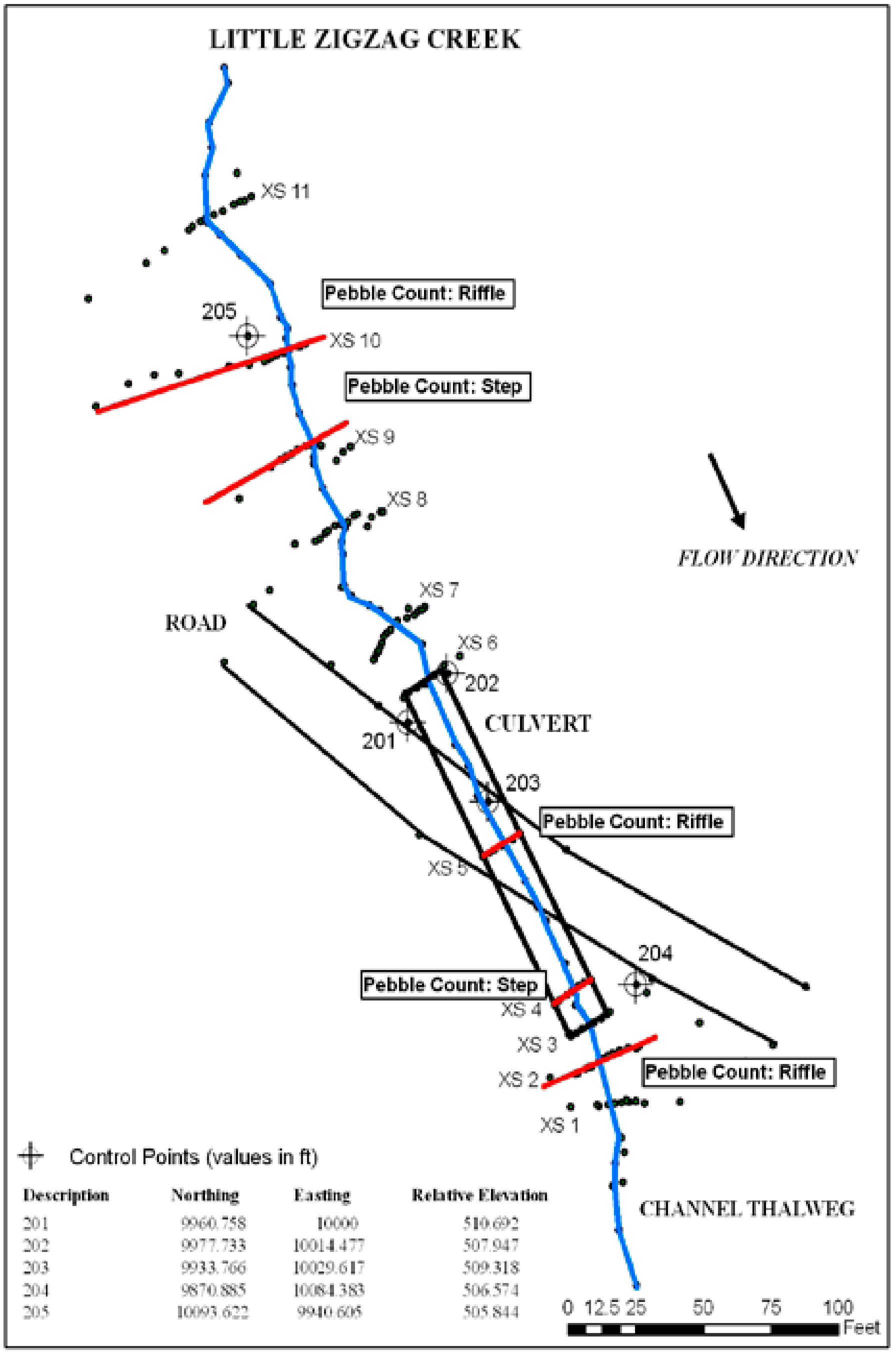
Pipe Condition: Good condition.

Hydrology

Discharge (cfs) for indicated recurrence interval

25% 2-yr	2-year	Q_{bf}[2]	5-year	10-year	50-year	100-year
30	118	130	168	204	292	333

[2]Bankfull flow estimated by matching modeled water surface elevations to field-identified bankfull elevations.



Description	Northing	Easting	Relative Elevation
201	9960.758	10000	510.692
202	9977.733	10014.477	507.947
203	9933.766	10029.617	509.318
204	9870.885	10084.383	506.574
205	10093.622	9940.605	505.844

Points represent survey points

Figure 1—Plan view map.

Culvert Scour Assessment

HISTORY

There is no information available for site history.

SITE DESCRIPTION

The Little Zigzag Creek culvert is a Con/Span® concrete bottomless arch with wingwalls and headwalls at both the inlet and outlet. The banks along the inlet are stabilized by riprap, bedrock, and concrete.

Upstream of the inlet, the gradient increases and the channel flows over a series of boulder steps. The extreme angle of the crossing to the road means that the channel through here flows along the roadfill (riprap) along the right bank. There is a small step at the inlet and then the grade flattens out once the channel enters the culvert. A large boulder step just prior to the outlet presumably controls the grade through the remainder of the culvert. The majority of the length of the culvert consists of a relatively low gradient plane-bed channel made up of small boulders and large cobbles. The substrate through this riffle was embedded. Flow in the culvert during the time of the survey was wall to wall.

The upstream representative reach consists of a series of steps, steep riffles/cascades, and pools. Bedrock influences the structure and controls grade through the reach. The channel abuts a bedrock wall along the left bank and flows over a bedrock cascade towards the bottom of the reach. Fallen trees span the stream and small pieces of wood had collected along the edges of the channel.

Downstream of the outlet, the channel runs through a steep riffle before joining the mainstem of Zigzag Creek.

SURVEY SUMMARY

Ten cross sections and a longitudinal profile were surveyed along Little Zigzag Creek in April 2007 to characterize the culvert and an upstream reference reach. No downstream reference reach was established due to the proximity of the culvert with the confluence of the mainstem Zigzag Creek. In the culvert, representative cross sections were taken through the long riffle and at the step near the outlet. One additional cross section was surveyed upstream to characterize the inlet as well as the contraction of flow. Another cross section was surveyed downstream of the culvert to characterize the outlet and the expansion of flow.

In the upstream reach, representative cross sections were taken through a riffle and along a step. An additional two sections were taken to characterize the upstream and downstream ends of the reach.

A cross section and pebble count were taken through the riffle downstream of the outlet.

PROFILE ANALYSIS SEGMENT SUMMARY

The profile analysis resulted in a total of seven profile segments. Two segments in the upstream channel with similar gradients were not combined in order to separate out the portion of the channel affected by riprap from the upstream representative channel. The culvert consisted of one profile segment. The culvert segment was comparable to one representative profile segment in the upstream channel. Two upstream transition segments were comparable to representative profile segments in the upstream channel. The downstream transition segment was comparable to two representative profile segments in the upstream channel. See figure 2 and table 1.

SCOUR CONDITIONS

Observed conditions

Footing scour – There was no observed scour threatening structure integrity.

Culvert-bed adjustment – The channel within the culvert has reduced slope to less than the constructed slope (assuming the channel bed was originally constructed at the same gradient as the structure). This may be related to the large step at the downstream end of the culvert that controls grade and has aggraded bed material behind it.

Profile characteristics – The profile is mostly uniform, with a slight concavity centered near the culvert inlet. Natural valley transition from the Little Zigzag valley to the mainstem Zigzag valley may account for some of this, but it may also be partly related to slope adjustment (flattening) of the culvert bed (figure 2) as discussed above.

Residual depths – Culvert residual depths are lower than the single residual depth in the corresponding profile segment (F) (figure 21). The single residual depth in the upper of the upstream transition segments (D) is less than half the residual depth of the corresponding profile segment (E). The residual depth in the downstream transition segment is at the upper end of the range of depths in corresponding profile segments (E and G).

Substrate – Culvert bed material distributions vary considerably between the two sample cross sections. The upstream culvert cross section represents the bed material in the plane-bed section that makes up 80 percent of the length of the culvert. This bed is made up of coarse gravel to large cobble. The step at the downstream end of the culvert has a greater frequency of very large cobbles to medium boulders. The natural channel is more poorly sorted, with a wider representation of particle sizes and a large portion of sand at the downstream cross section. Pebble-count data is presented at the end of this document.

Predicted conditions

Cross-section characteristics – Flow area, top width, and wetted perimeter are reduced considerably by the culvert, but hydraulic radius and maximum depth do not dramatically differ (figures 5-9 and 12-17). Differences are most apparent at modeled flows above the 25 percent Q_2. The upstream transition segments (C and D) also differ from the natural channel, but less so. The downstream transition segment (A) is mostly within the range of conditions found in the natural channel (E and G) but generally has a greater range of values.

Shear stress – Shear stress in the culvert is very similar to that found in the corresponding profile segment (F) (figure 10). Shear-stress values in the upstream transition segments are similar to or greater than their corresponding profile segments. Shear in the downstream transition segment is within the range of the corresponding profile segments (E and G).

Excess shear – The excess shear values in the culvert are just within or lower than the range of values in the natural channel (figure 20). This is a result of a combination of lower applied shears and higher critical shears depending on the cross section and modeled flow.

Velocity – Velocity in the culvert is greater than the corresponding profile segment for all flows but is most pronounced at the Q_{bf} and above (figure 18). Velocity in the upstream transition segments is within the range of that found in corresponding profile segments. Velocity in the downstream transition segment has a greater range than the natural channel but the median values are similar.

Scour summary

There are no significant signs of scour or structure settlement. The structure appears adequate to transport flows up to at least the Q_{100} without backwatering or significant bed load mobilization.

The culvert has the greatest affect on flow area and the width-related parameters top width and wetted perimeter. Hydraulic radius and maximum depth are affected but to a lesser degree. It therefore follows that velocity is increased in the culvert. Shear is not significantly affected but excess shear is estimated to be less in the culvert. This is due to a flatter slope at the upstream end of the culvert and larger bed material at the large step near the downstream end (these are the locations where excess shear was modeled).

The culvert appears to have been placed lower in the profile than the original stream. This could relate to channel adjustments from the previous culvert or may also be a result of restrictions in height imposed by the current road prism. The reduced slope of the crossing and the grade control at the downstream end reduces shear stress and the potential for scour, but it may also prevent the efficient transport of material through the pipe, resulting in potential aggradation of bed material in the pipe that could reduce capacity.

AOP CONDITIONS

Cross-section complexity – The sum of squared height differences in the culvert cross sections are both within the range of those in the channel cross sections (table 3).

Profile complexity – Vertical sinuosity in the culvert is the same as that in the corresponding profile segment (F) (table 4). Vertical sinuosity in the upstream transition segments (C and D) is lower than their corresponding channel segments (E and G). Vertical sinuosity in the downstream transition segment (A) is within the range of the corresponding channel segments (E and G).

Depth distribution – The downstream cross section in the culvert has less shallow channel margin habitat at the 25 percent Q_2 and the upstream cross section has more when compared to the natural channel (table 5).

Habitat units – The culvert is nearly all riffle, whereas the natural channel is comprised of a greater proportion of pool habitat (table 6).

Residual depths – Culvert residual depths are lower than the single residual depth in the corresponding profile segment (F) (figure 21). The single residual depth in the upper of the upstream transition segments (D) is less than half the residual depth of the corresponding profile segment (E). The residual depth in the downstream transition segment is at the upper end of the range of depths in corresponding profile segments (E and G).

Substrate – Culvert bed material distributions vary considerably between the two sample cross sections. The upstream culvert cross section represents the bed material in the plane-bed section that makes up 80 percent of the length of the culvert. This bed is made up of coarse gravel to large cobble. The step at the downstream end of the culvert has a greater frequency of very large cobbles to medium boulders. The natural channel is more poorly sorted, with a wider representation of particle sizes and a large portion of sand at the downstream cross section. Pebble count data is presented at the end of this document.

Large woody debris – There was a small amount of LWD present in the culvert (table 8). The representative channel had moderate LWD abundance. LWD formed occasional steps and scour pools in the channel outside the crossing. Features in the culvert did not mimic the role of wood in the natural channel.

AOP summary

Site observations suggest that AOP conditions may be less desirable at this site than the metrics suggest. Nearly 80 percent of the length of the culvert is made up of a plane-bed riffle type unit that has very little complexity. The substrate also appeared embedded in fines, with few protrusions of larger substrate that can provide important velocity refuge for fish passage. The flows spread out over the entire channel during low flows, and the channel through the culvert is wider than the reference channel in many places. This may create flows that are too shallow for passage during low flow periods. There are no bank features that would provide passage for terrestrial organisms.

DESIGN CONSIDERATIONS

This is a good installation with respect to scour and structure integrity. The greatest impacts with this site relate to AOP. This site could benefit from the placement of stable boulders as bank structures intermittently along the structure edge in order to concentrate flows for low water fish passage and to provide banks for terrestrial passage. Additional rock steps could also be placed across the channel to better mimic conditions found in the channel outside the crossing.

Segment	Segment Length (ft)	Segment Gradient
A	71	0.050
B	97	0.024
C	58	0.051
D	38	0.069
E	42	0.051
F	35	0.018
G	78	0.046

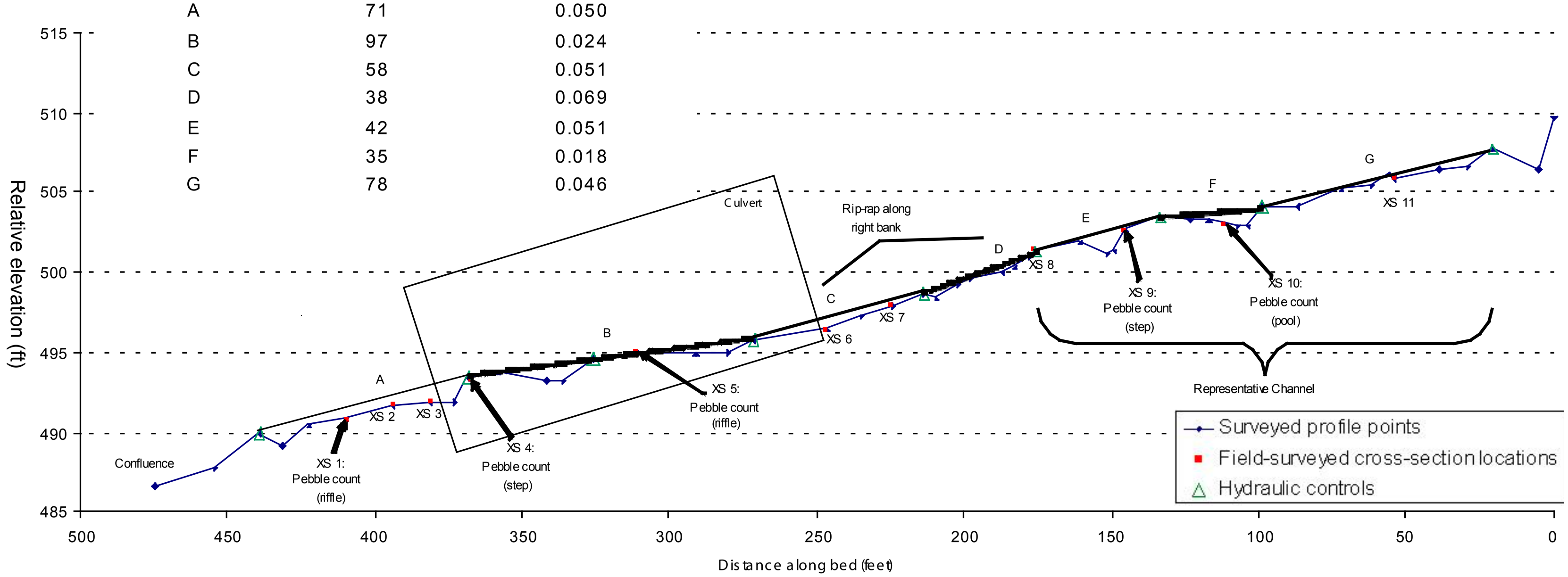


Figure 2—Little Zigzag Creek longitudinal profile.

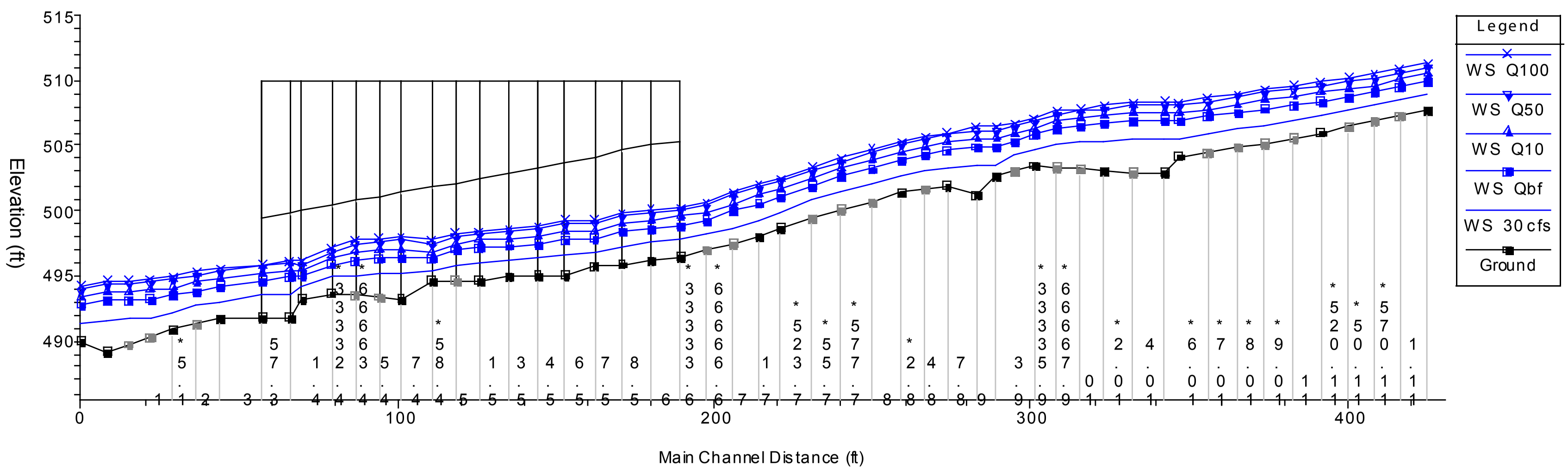
Table 1—Segment comparisons

Culvert Segment	Representative Channel Segment	% Difference in Gradient
B	F	23.4%
Upstream Transition		
C	E	1.0%
C	G	9.4%
D	E	26.0%
Downstream Transition		
A	E	2.0%
A	G	8.5%

Table 2—Summary of segments used for comparisons

Segment	Range of Manning's n values[1]	# of measured XSs	# of interpolated XSs
A	0.0898 – 0.1167	4	6
B	0.0788 – 0.1006	2	10
C	0.0968 – 0.1465	2	6
D	0.1437 – 0.146	1	4
E	0.1063 – 0.1437	2	5
F	0.098 – 0.1089	1	6
G	0.1085 – 0.1089	1	9

[1]*Obtained using equation from Jarrett (1984): n = 0.39S0.38R-0.16, where S=stream slope; R=hydraulic radius. Jarrett's equation only applied within the following ranges: S = 0.002 to 0.08, R = 0.5 ft to 7 ft. For cross sections outside these ranges, n was computed either from adjacent sections that fell within the ranges, using the guidance of Arcement and Schneider (1987), or from the HEC-RAS recommendations for culvert modeling.*



Stations with decimal values are interpolated cross sections placed along the surveyed profile.

Figure 3—HEC-RAS profile.

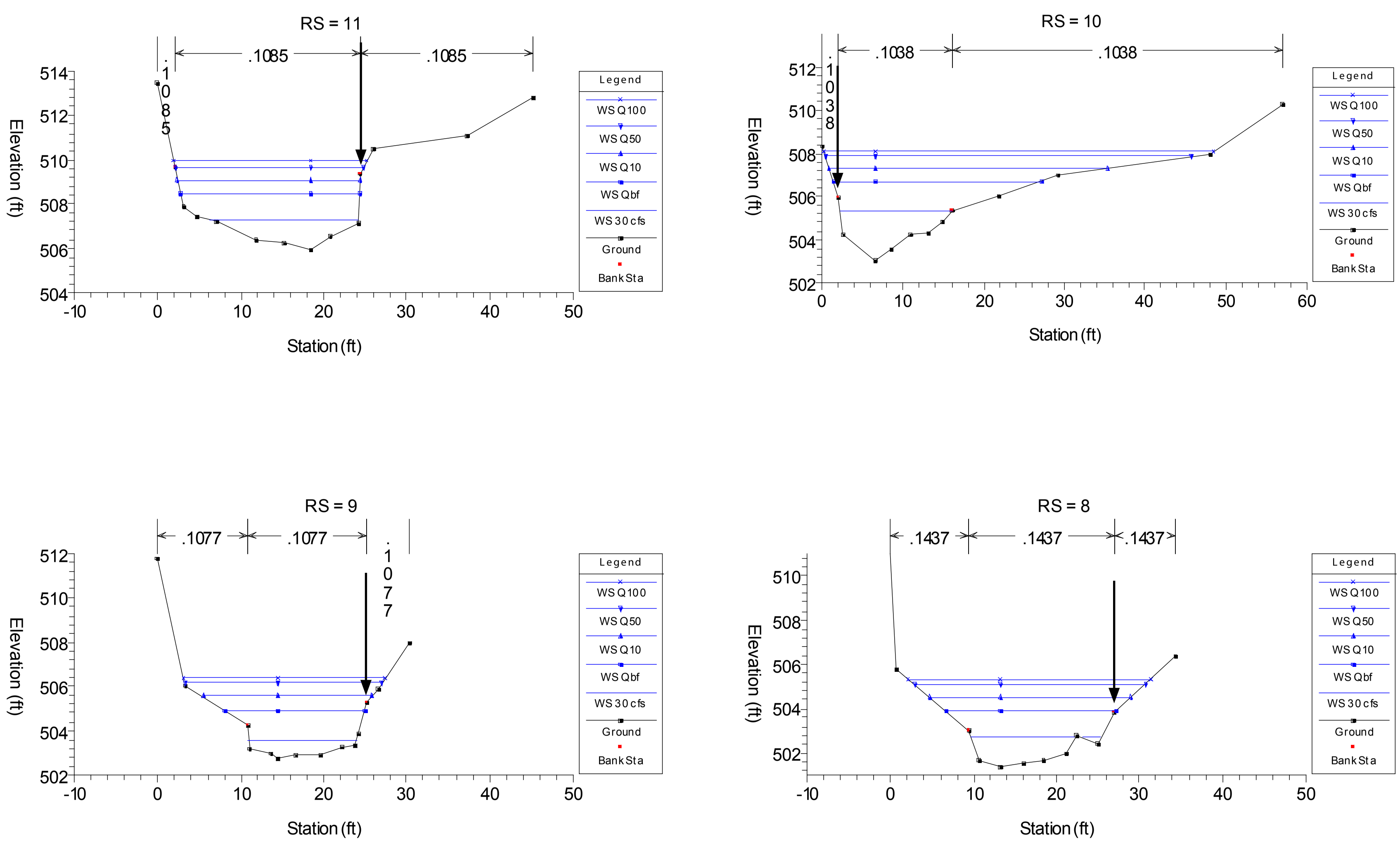
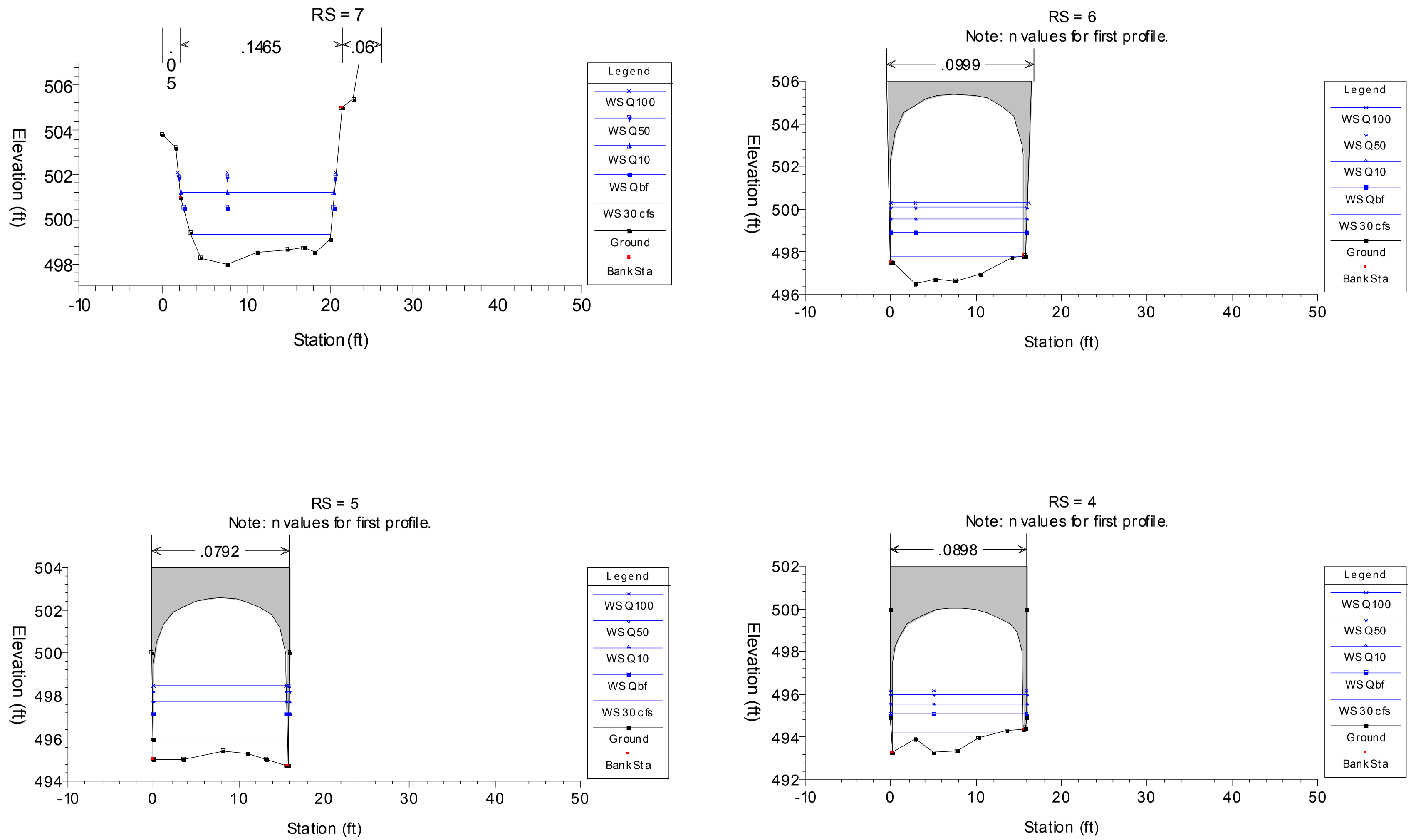


Figure 4—Cross-section plots. Only measured cross sections are included. Manning's n values are included at the top of the cross section. The stationing (RS) corresponds to the stationing on the HEC-RAS profile. Green arrows define the ineffective flow areas. Black arrows represent points identified in the field as the bankfull channel boundary. Only those points identified in the field and supported by hydraulic and topographic analyses are shown below.



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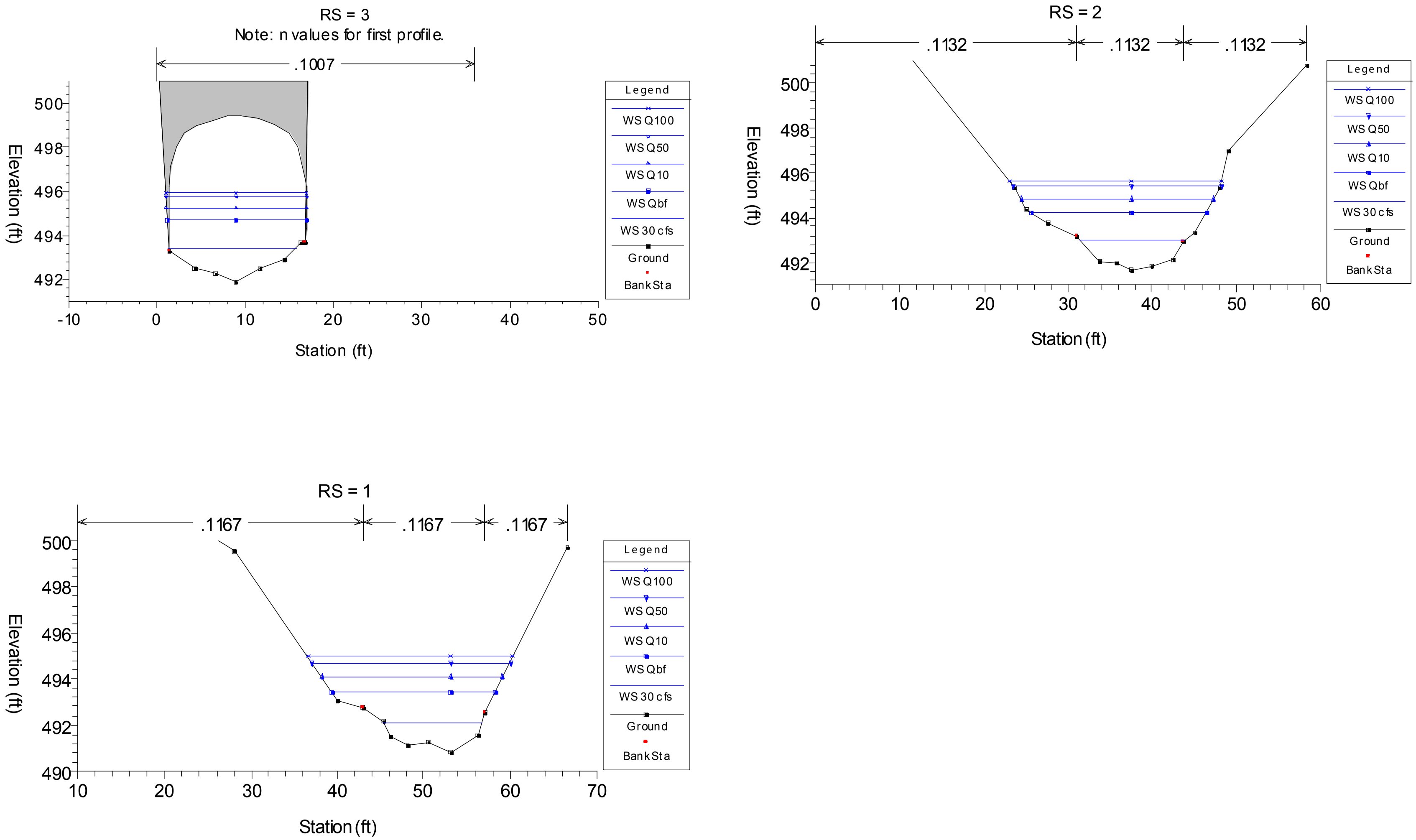

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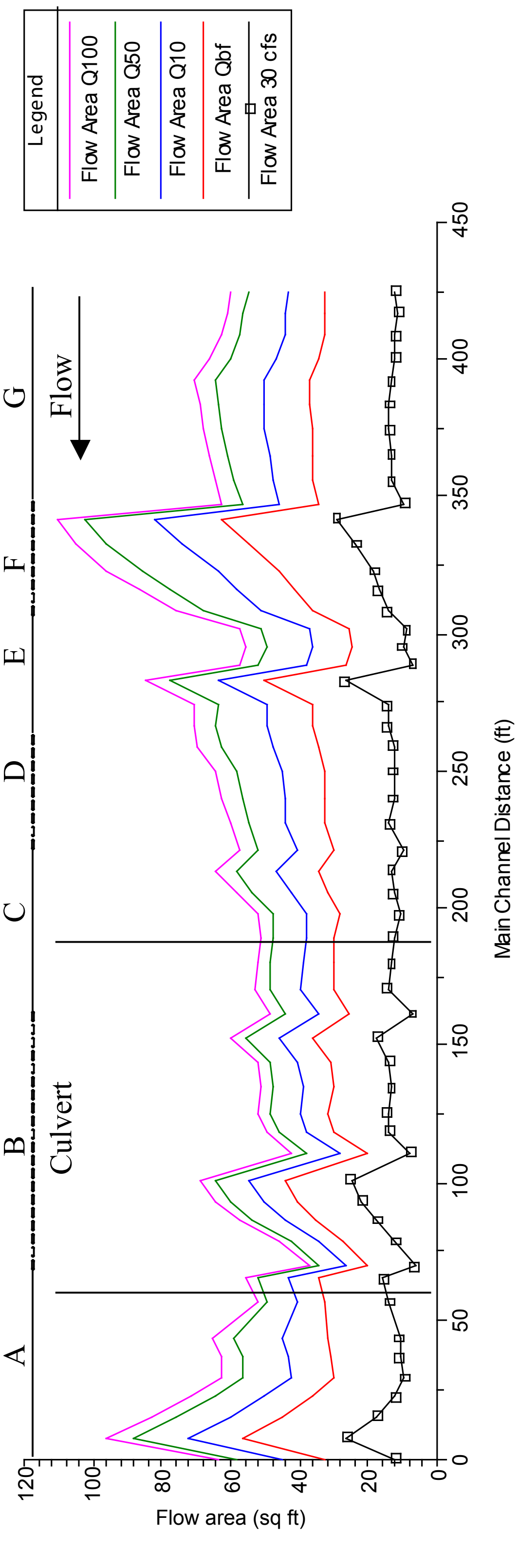


Figure 5—Flow area (total) profile plot.

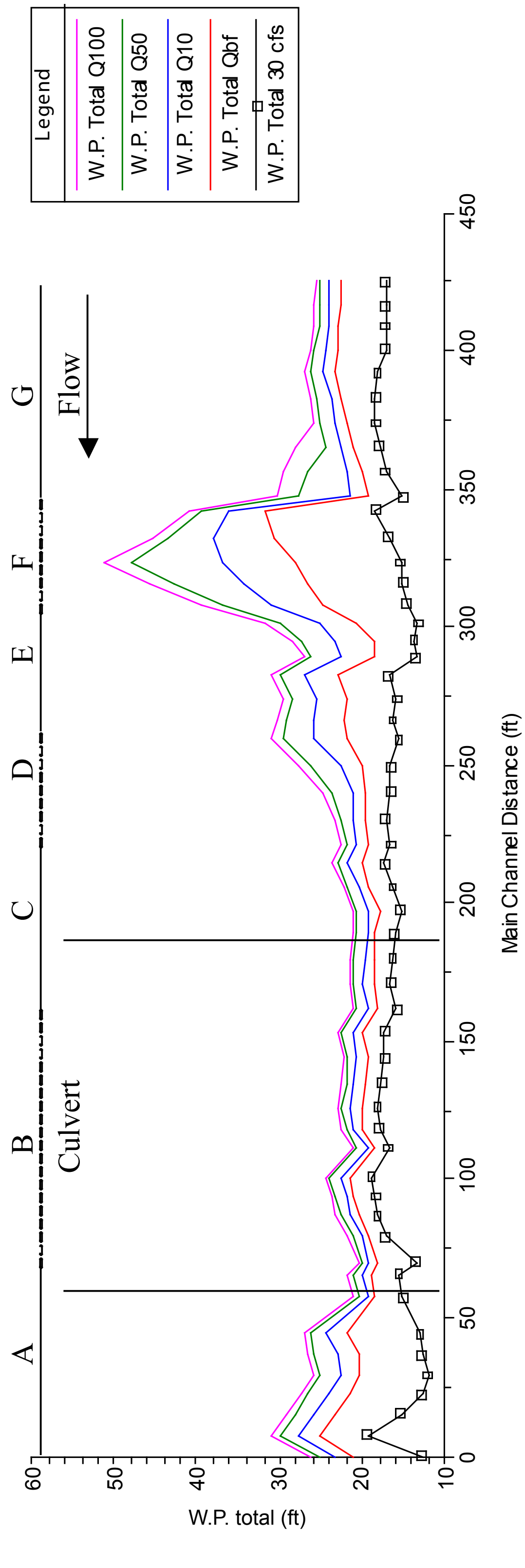


Figure 6—Wetted perimeter.

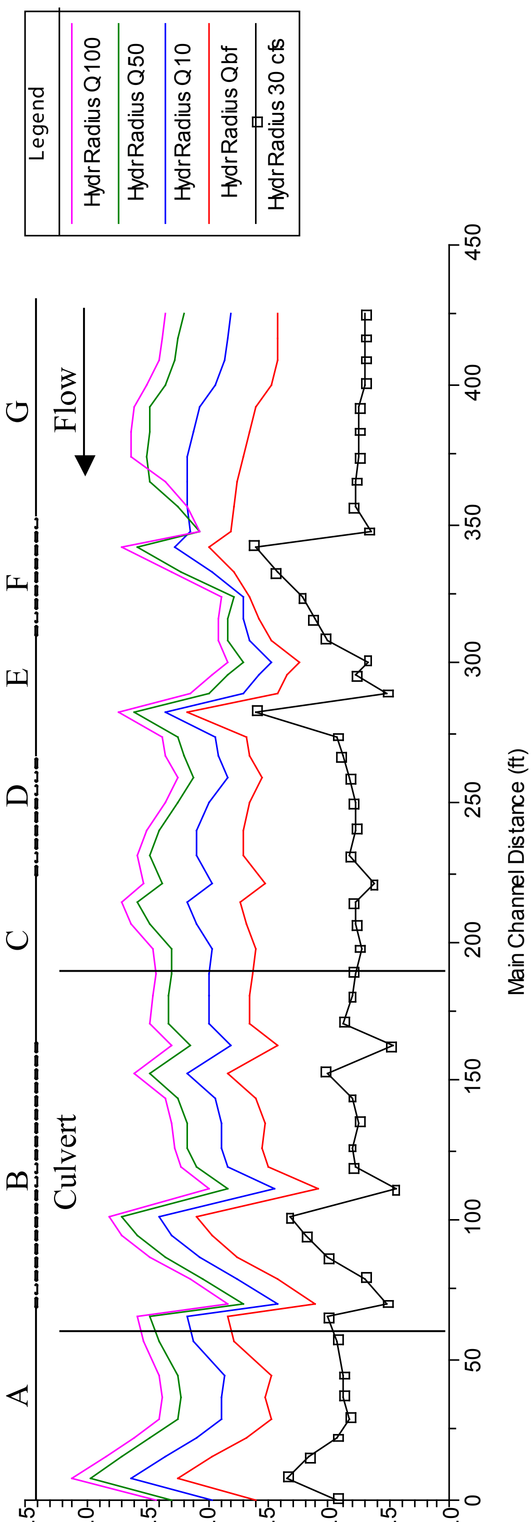


Figure 7—Hydraulic radius.

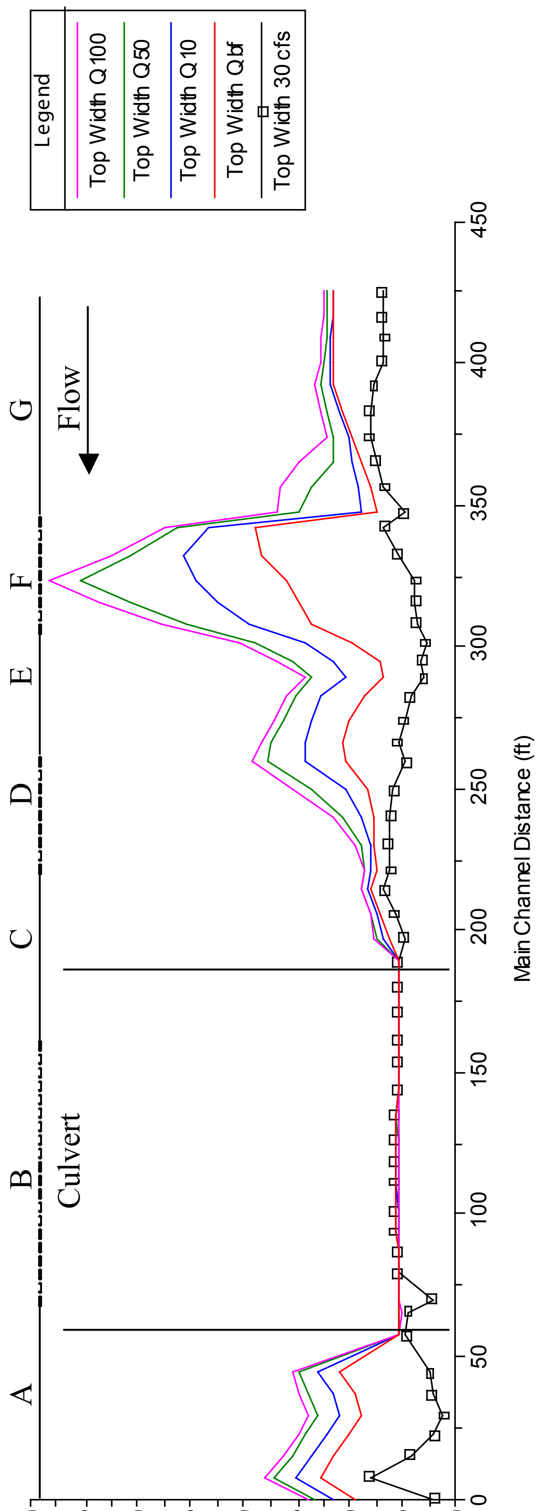


Figure 8—Top width.

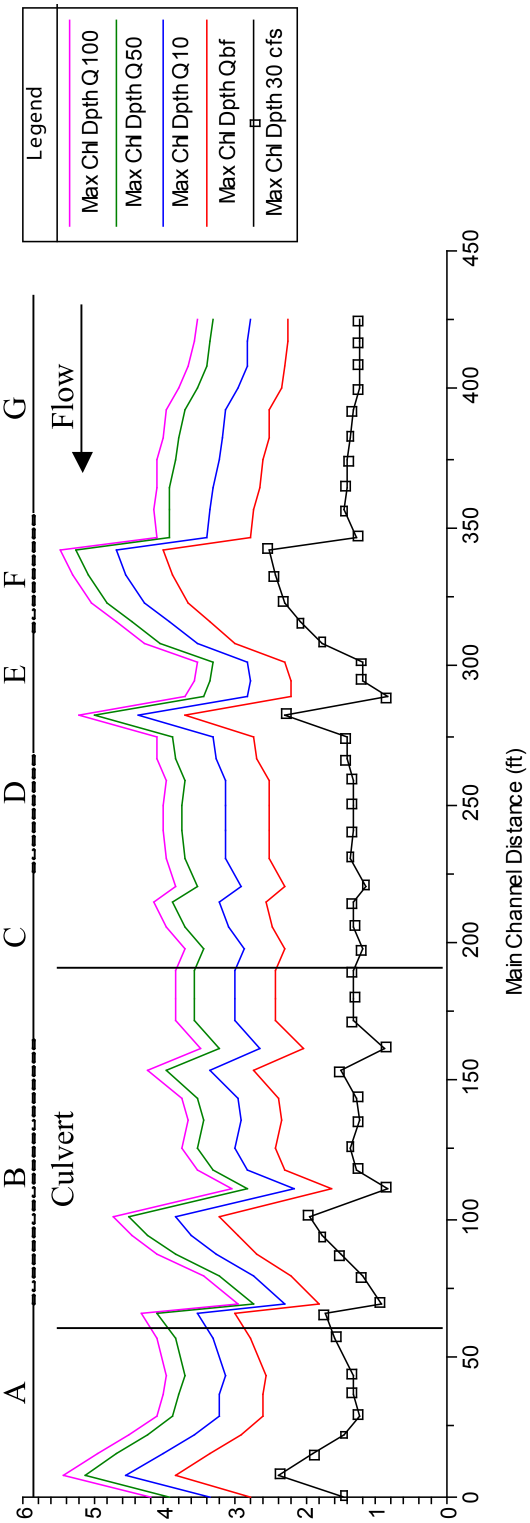


Figure 9—Maximum depth.

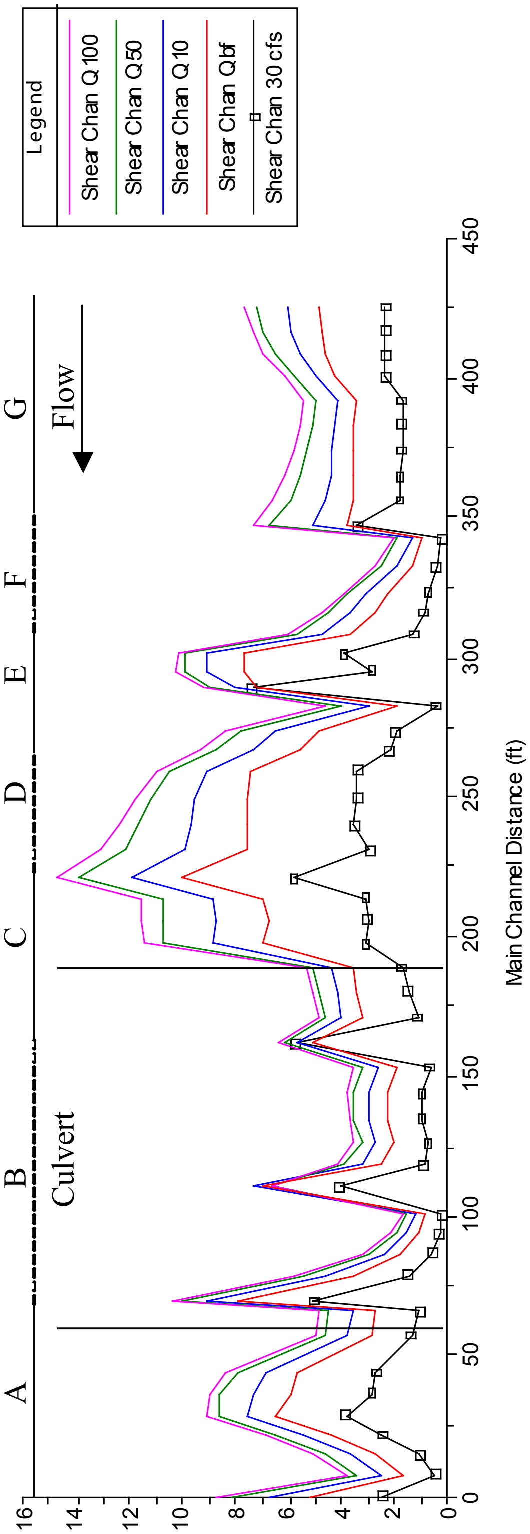


Figure 10—Shear stress (channel) profile.

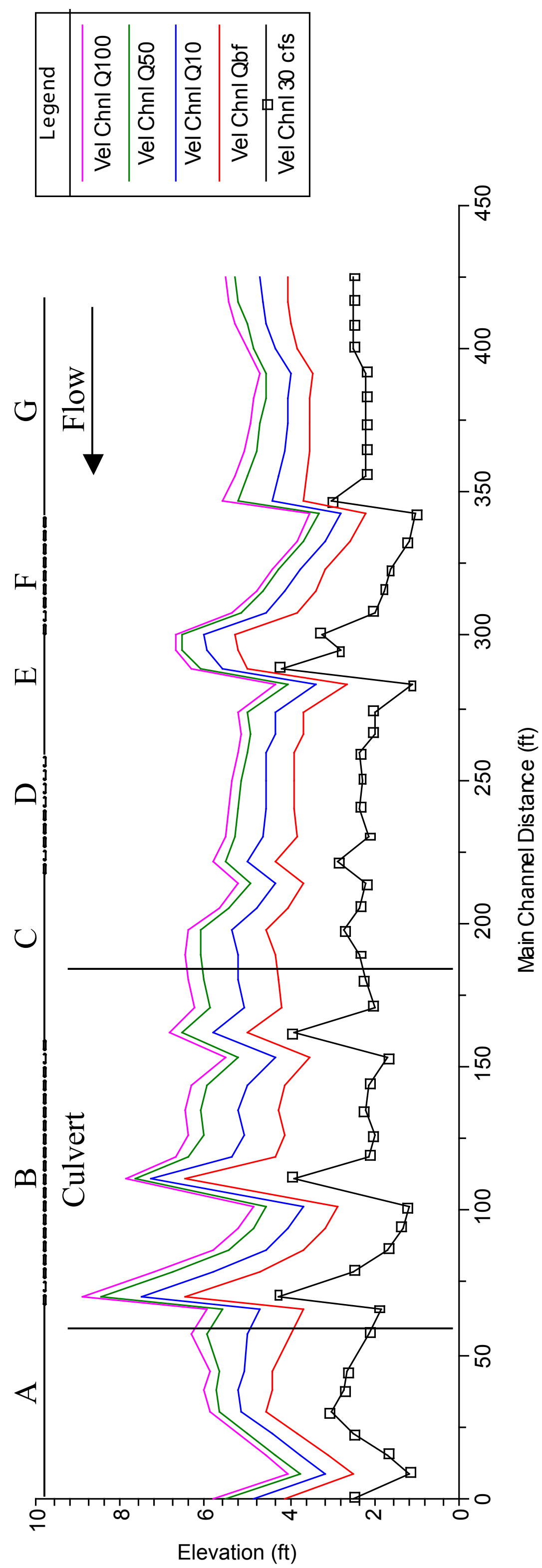
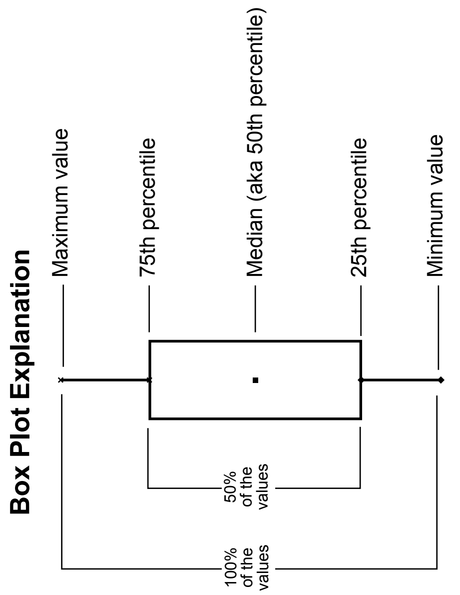


Figure 11—Velocity (channel) profile plot.



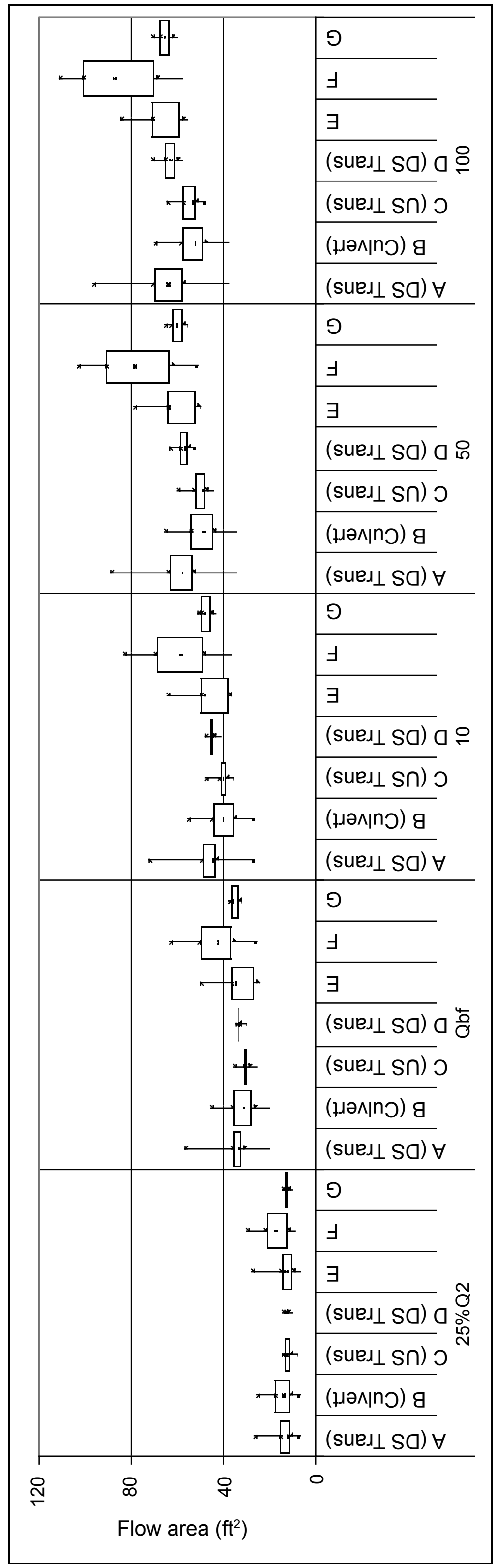


Figure 12—Flow area (total).

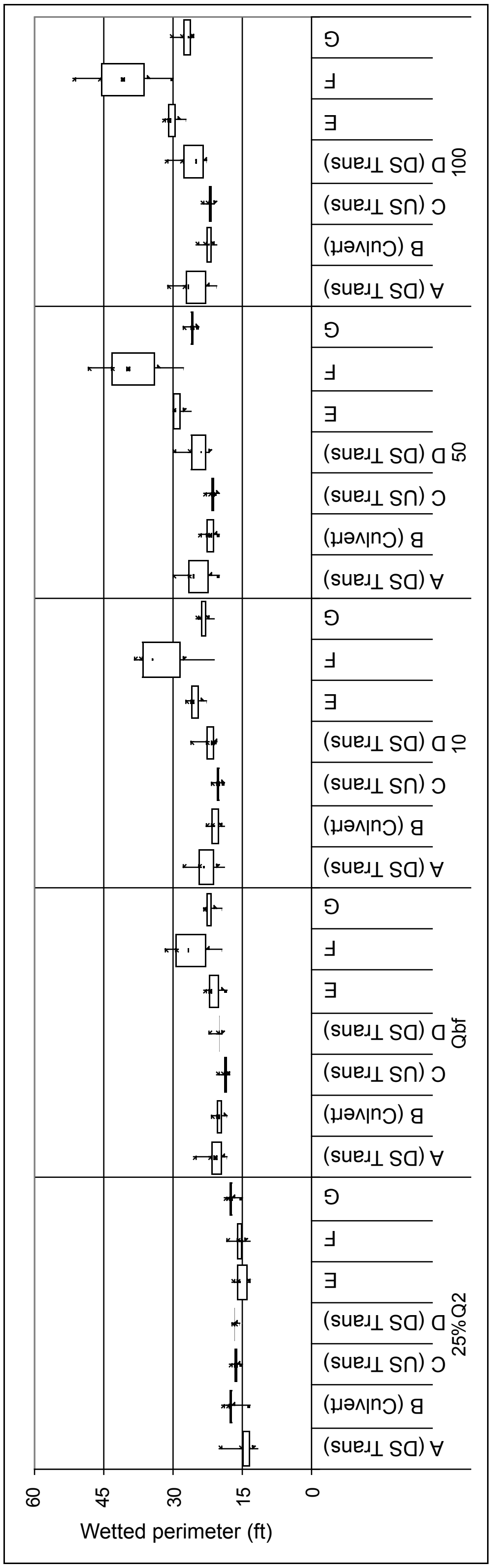


Figure 13—Wetted perimeter.

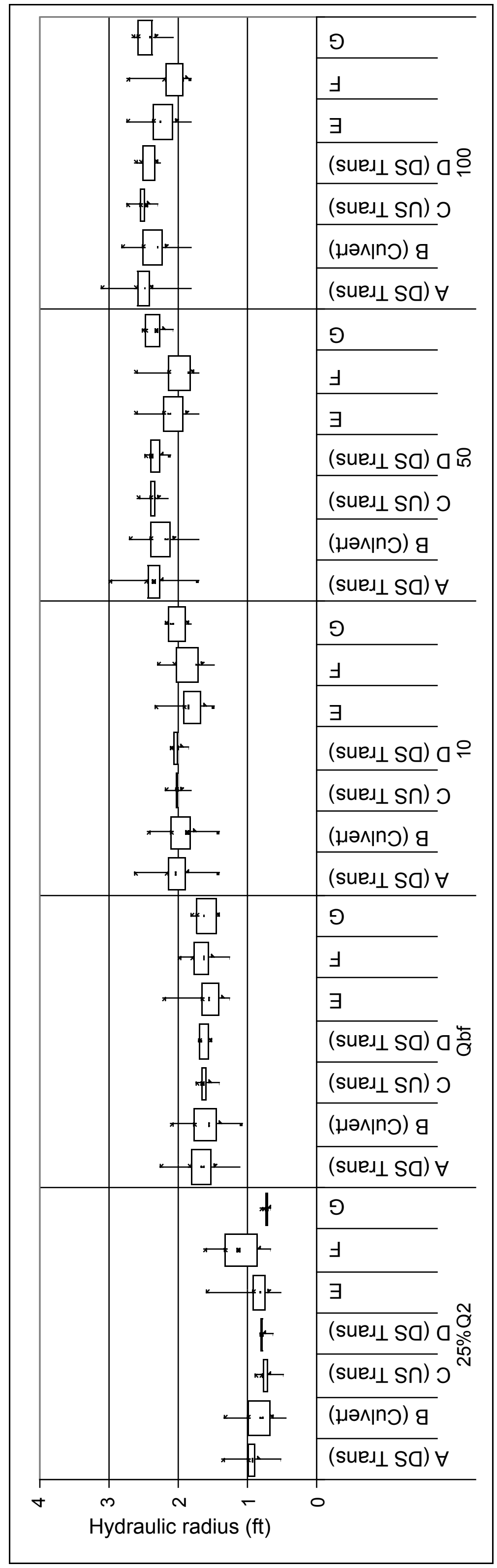


Figure 14—Hydraulic radius.

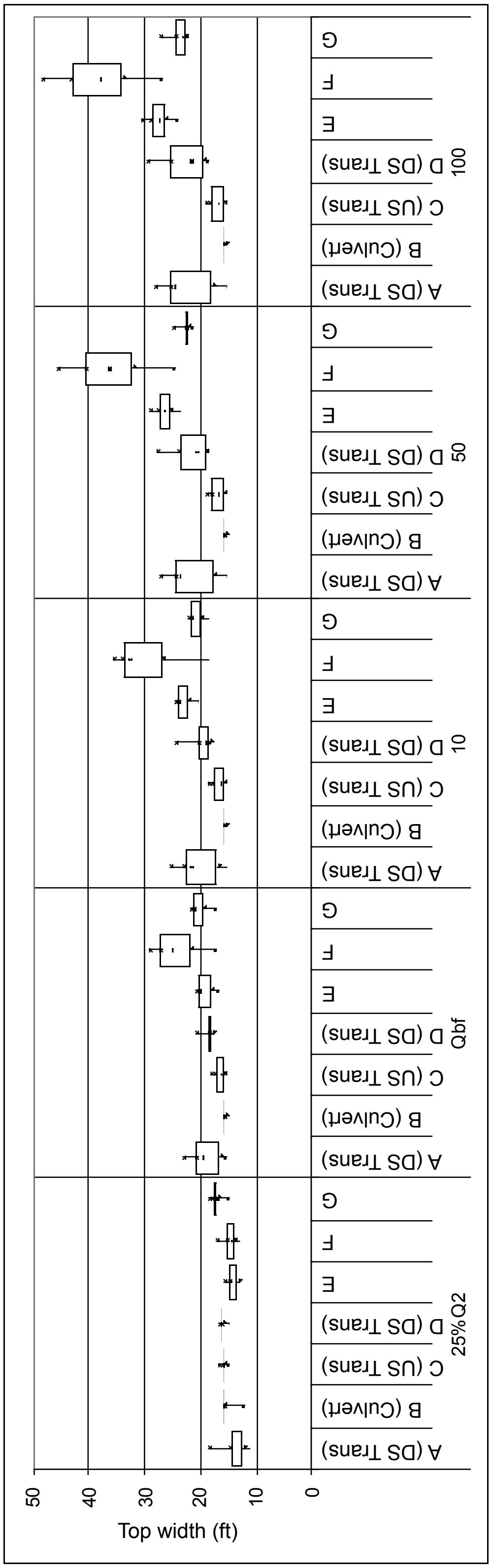


Figure 15—Top width.

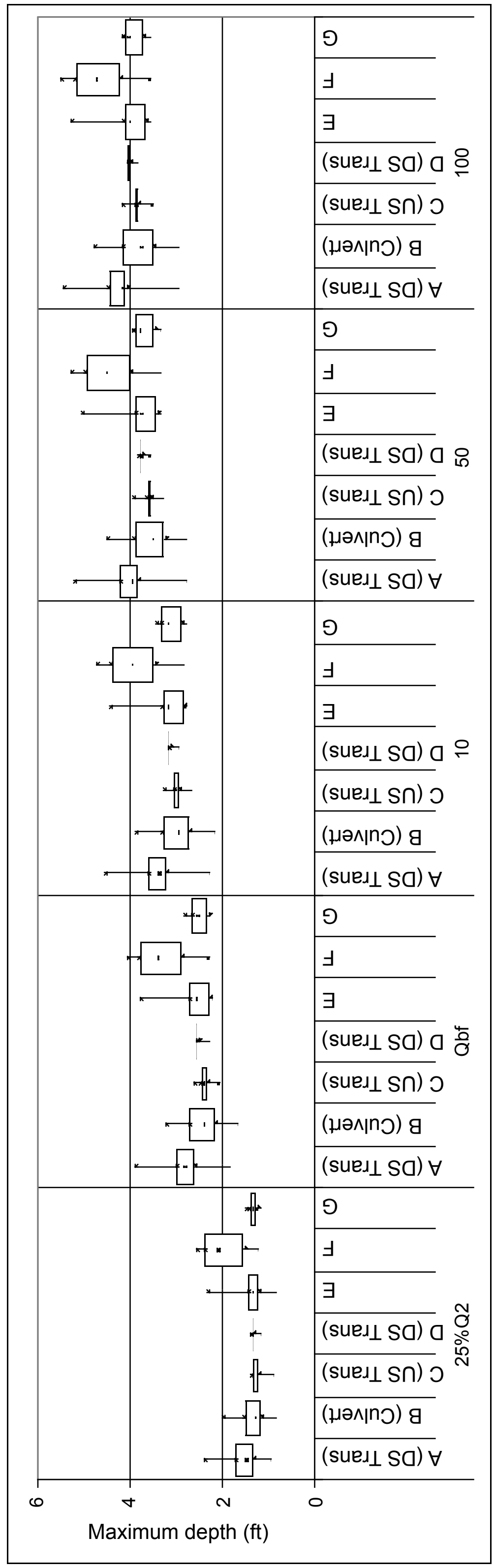


Figure 16—Maximum depth.

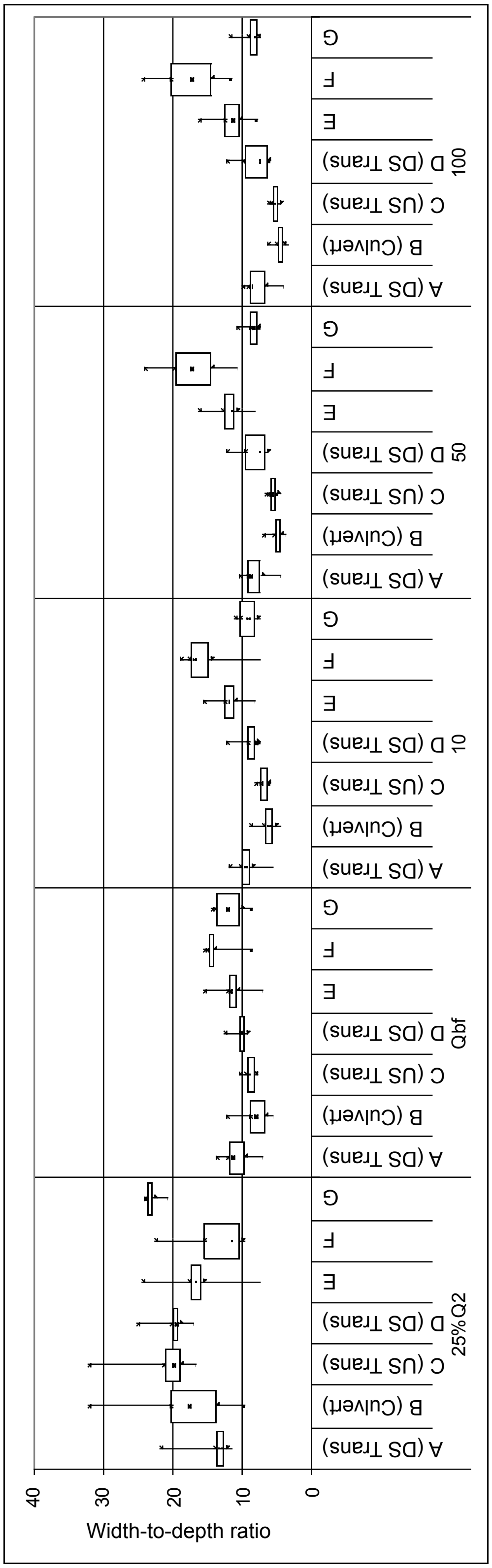


Figure 17—Width-to-depth ratio.

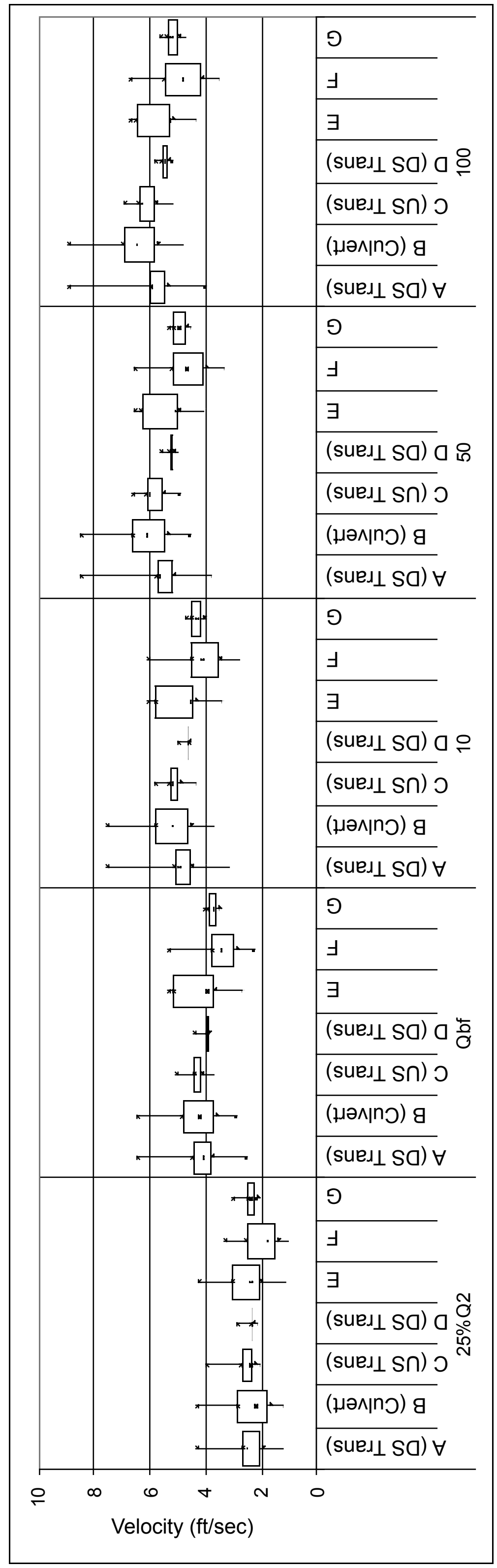


Figure 18—Velocity (channel).

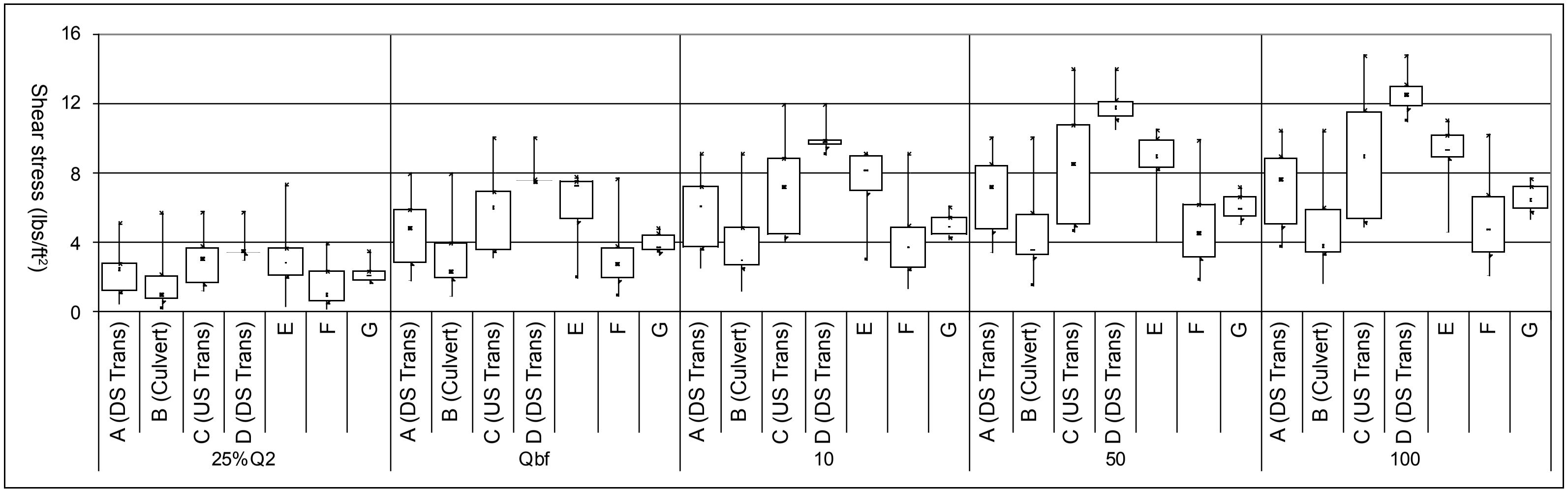
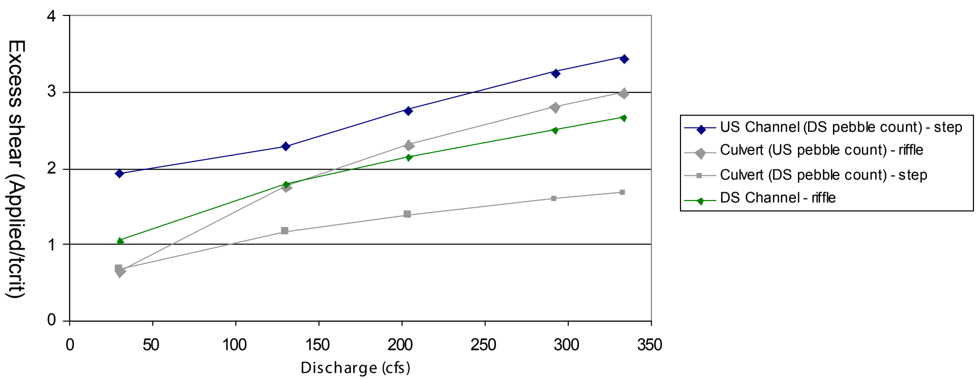


Figure 19—Shear stress (channel).



Excess shear stress is the channel shear divided by the critical shear for bed entrainment of the D_{84} particle size. Values of excess shear greater than 1 indicate bed movement for the D_{84} particle size.

Figure 20—Excess shear stress.

Table 3—Sum of squared height difference

Reach	XS Location	Unit type	Sum of squared height difference	Within range of channel conditions?
Culvert	US	Riffle	0.02	Yes
	DS	Step	0.08	Yes
Upstream	US	Pool	0.20	
	DS	Step	0.02	

Table 4—Vertical sinuosity

Segment	Location	Vertical Sinuosity (ft/ft)
A	DS transition	1.004
B	Culvert	1.001
C	US transition	1.002
D	US transition	1.004
E	US channel	1.009
F	US channel	1.001
G	US channel	1.004

Table 5—Depth distribution

Reach	XS Location	25% Q_2	Within range of channel conditions?
Culvert	US	0	No
	DS	5	No
Upstream	US	2	
	DS	3	

Table 6—Habitat unit composition

	Percent of surface area			
Reach	Pool	Glide	Riffle	Step
Culvert	0%	0%	97%	2%
Upstream Channel	22%	0%	63%	3%

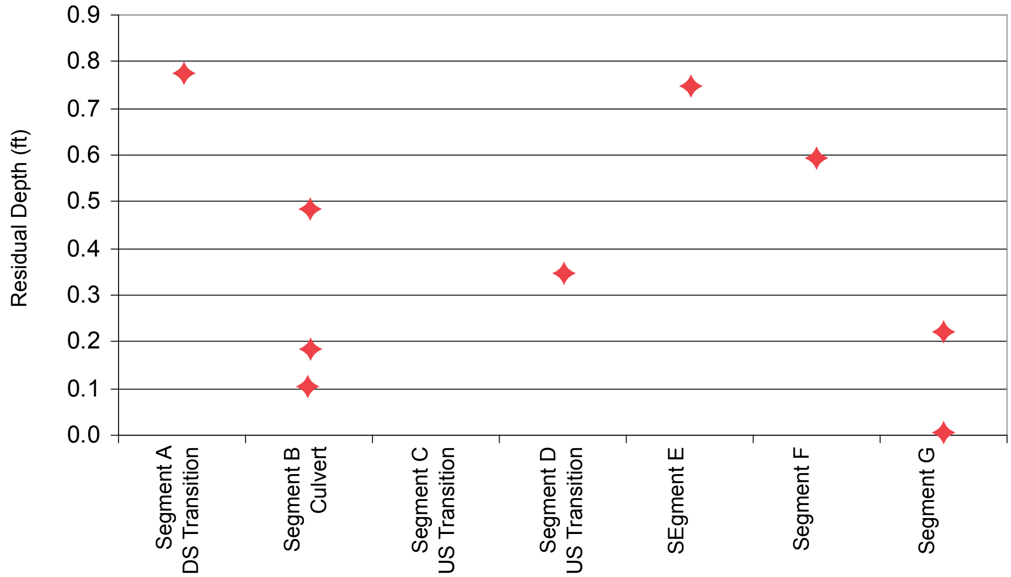


Figure 21—Residual depths.

Table 7—Bed material sorting and skewness

Reach	XS Location	Unit Type	Sorting	Within range of channel conditions?	Skewness	Within range of channel conditions?
Culvert	US	Riffle	1.30	No	0.22	No
	DS	Step	2.07	No	0.48	No
Upstream	US	Pool	2.49		0.43	
	DS	Step	3.08		0.47	

Table 8—Large woody debris

Reach	Pieces/Channel Width
Culvert	0.21
Upstream	1.32

Terminology:

US = Upstream

DS = Downstream

RR = Reference reach

XS = Cross section

View upstream of culvert outlet.

View downstream towards culvert inlet.

View upstream from inlet crown.

View downstream from outlet crown.

Upstream reference reach from upstream end.

Upstream reference reach – upstream pebble count, pool.

Upstream reference reach – downstream pebble.

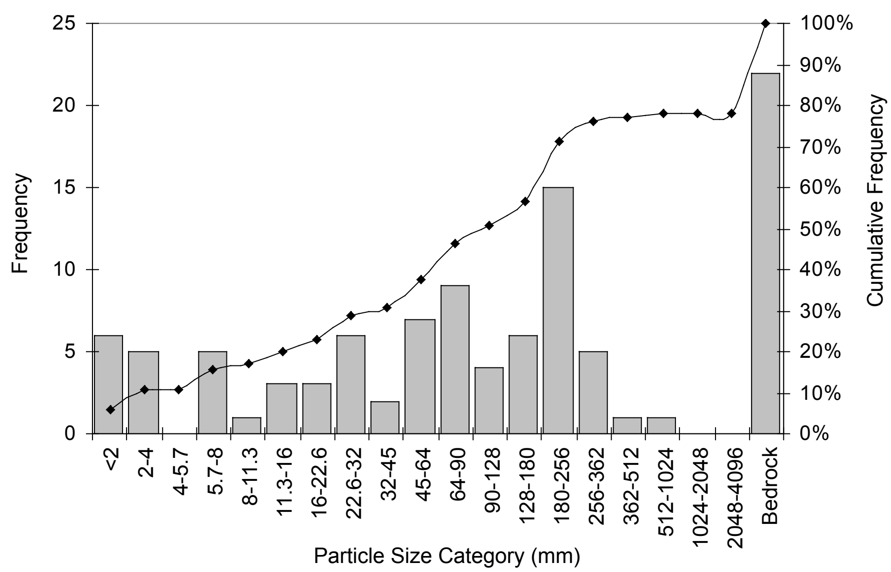
View of step in culvert near outlet (pebble count count, step location).

View downstream in culvert – upstream pebble count at flagging (riffle).

Survey set up upstream of inlet.

Cross Section: Upstream Reference Reach – Upstream Pebble Count

Material	Size Range (mm)	Count	Item %	Cumulative %
sand	<2	6	6%	6%
very fine gravel	2 - 4	5	5%	11%
fine gravel	4 - 5.7	0	0%	11%
fine gravel	5.7 - 8	5	5%	16%
medium gravel	8 - 11.3	1	1%	17%
medium gravel	11.3 - 16	3	3%	20%
coarse gravel	16 - 22.6	3	3%	23%
coarse gravel	22.6 - 32	6	6%	29%
very coarse gravel	32 - 45	2	2%	31%
very coarse gravel	45 - 64	7	7%	38%
small cobble	64 - 90	9	9%	47%
medium cobble	90 - 128	4	4%	50%
large cobble	128 - 180	6	6%	56%
very large cobble	180 - 256	15	15%	71%
small boulder	256 - 362	5	5%	76%
small boulder	362 - 512	1	1%	77%
medium boulder	512 - 1024	1	1%	78%
large boulder	1024 - 2048	0	0%	78%
very large boulder	2048 - 4096	0	0%	78%
bedrock	> 4096	22	22%	100%



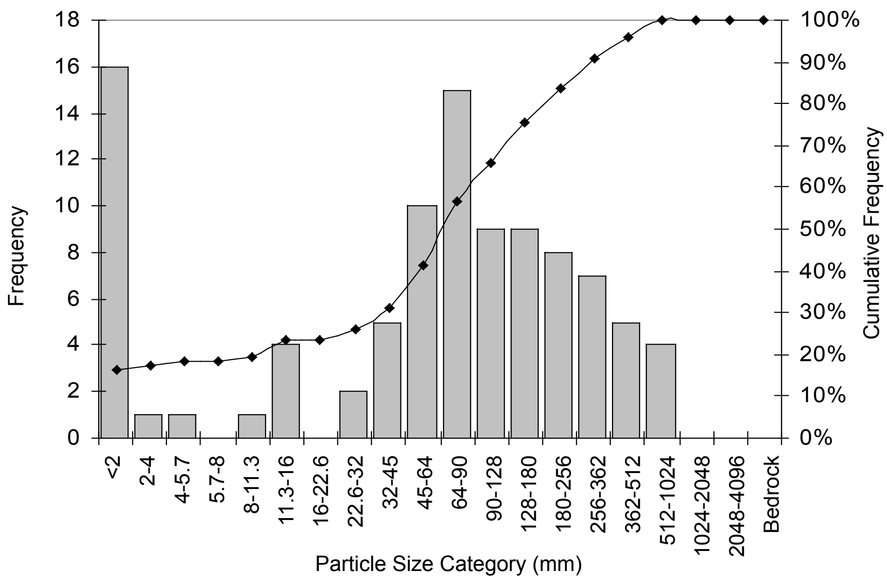
Size Class	Size percent finer than (mm)
D5	1
D16	6
D50	70
D84	215
D95	277
D100	600

Material	Percent Composition
Sand	6%
Gravel	32%
Cobble	34%
Boulder	7%
Bedrock	22%

Sorting Coefficient: 2.49
Skewness Coefficient: 0.43

Cross Section: Upstream Reference Reach – Downstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	16	16%	16%
very fine gravel	2 - 4	1	1%	18%
fine gravel	4 - 5.7	1	1%	19%
fine gravel	5.7 - 8	0	0%	19%
medium gravel	8 - 11.3	1	1%	20%
medium gravel	11.3 - 16	4	4%	24%
coarse gravel	16 - 22.6	0	0%	24%
coarse gravel	22.6 - 32	2	2%	26%
very coarse gravel	32 - 45	5	5%	31%
very coarse gravel	45 - 64	10	10%	41%
small cobble	64 - 90	15	15%	57%
medium cobble	90 - 128	9	9%	66%
large cobble	128 - 180	9	9%	75%
very large cobble	180 - 256	8	8%	84%
small boulder	256 - 362	7	7%	91%
small boulder	362 - 512	5	5%	96%
medium boulder	512 - 1024	4	4%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



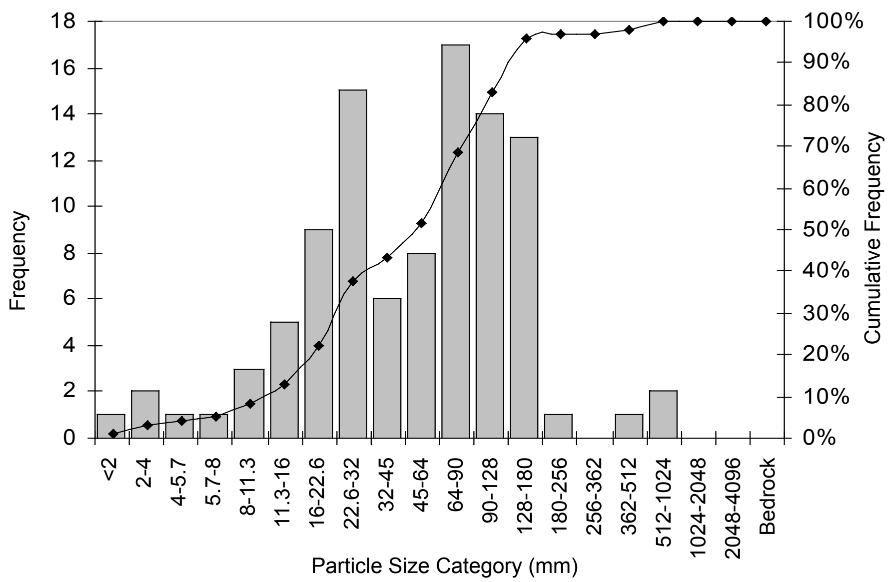
Size Class	Size percent finer than (mm)
D5	1
D16	2
D50	80
D84	263
D95	452
D100	600

Material	Percent Composition
Sand	16%
Gravel	25%
Cobble	42%
Boulder	16%
Bedrock	0%

Sorting Coefficient: 3.08
Skewness Coefficient: 0.47

Cross Section: Culvert – Upstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	1	1%	1%
very fine gravel	2 - 4	2	2%	3%
fine gravel	4 - 5.7	1	1%	4%
fine gravel	5.7 - 8	1	1%	5%
medium gravel	8 - 11.3	3	3%	8%
medium gravel	11.3 - 16	5	5%	13%
coarse gravel	16 - 22.6	9	9%	22%
coarse gravel	22.6 - 32	15	15%	37%
very coarse gravel	32 - 45	6	6%	43%
very coarse gravel	45 - 64	8	8%	52%
small cobble	64 - 90	17	17%	69%
medium cobble	90 - 128	14	14%	83%
large cobble	128 - 180	13	13%	96%
very large cobble	180 - 256	1	1%	97%
small boulder	256 - 362	0	0%	97%
small boulder	362 - 512	1	1%	98%
medium boulder	512 - 1024	2	2%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



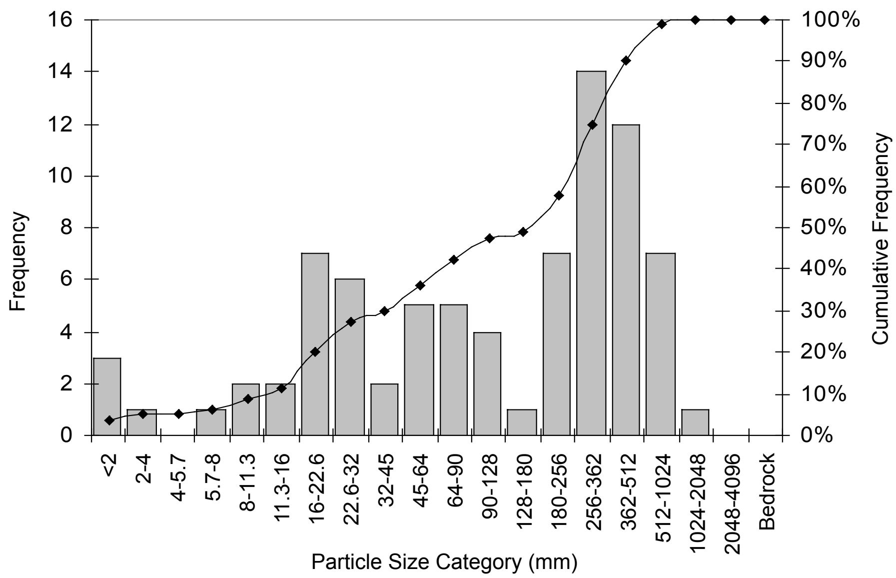
Size Class	Size percent finer than (mm)
D5	10
D16	20
D50	60
D84	130
D95	171
D100	520

Material	Percent Composition
Sand	1%
Gravel	51%
Cobble	45%
Boulder	3%
Bedrock	0%

Sorting Coefficient: 1.30
Skewness Coefficient: 0.22

Cross Section: Culvert – Downstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	3	4%	4%
very fine gravel	2 - 4	1	1%	5%
fine gravel	4 - 5.7	0	0%	5%
fine gravel	5.7 - 8	1	1%	6%
medium gravel	8 - 11.3	2	3%	9%
medium gravel	11.3 - 16	2	3%	11%
coarse gravel	16 - 22.6	7	9%	20%
coarse gravel	22.6 - 32	6	8%	28%
very coarse gravel	32 - 45	2	3%	30%
very coarse gravel	45 - 64	5	6%	36%
small cobble	64 - 90	5	6%	43%
medium cobble	90 - 128	4	5%	48%
large cobble	128 - 180	1	1%	49%
very large cobble	180 - 256	7	9%	58%
small boulder	256 - 362	14	18%	75%
small boulder	362 - 512	12	15%	90%
medium boulder	512 - 1024	7	9%	99%
large boulder	1024 - 2048	1	1%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



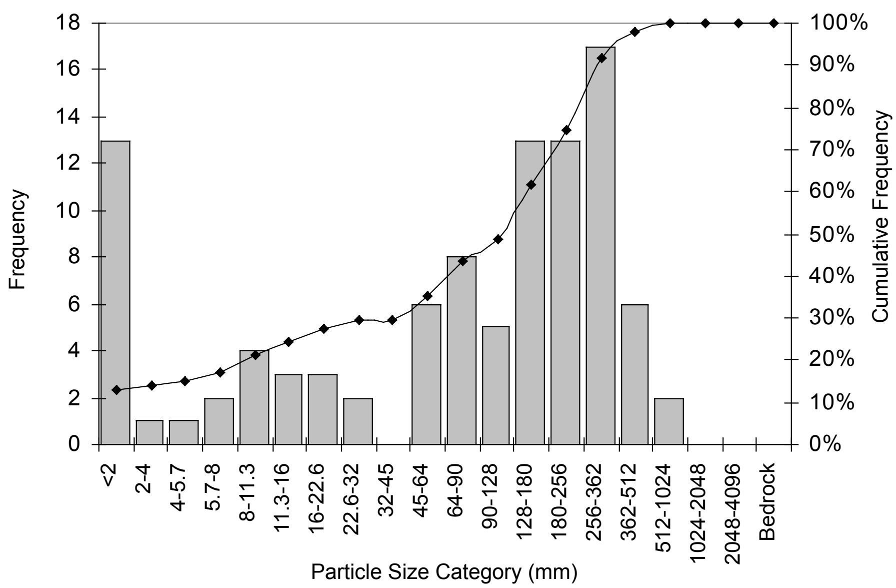
Size Class	Size percent finer than (mm)
D5	8
D16	20
D50	195
D84	444
D95	602
D100	1100

Material	Percent Composition
Sand	4%
Gravel	33%
Cobble	21%
Boulder	43%
Bedrock	0%

Sorting Coefficient: 2.07
Skewness Coefficient: 0.48

Cross Section: Downstream of Culvert – Only Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	13	13%	13%
very fine gravel	2 - 4	1	1%	14%
fine gravel	4 - 5.7	1	1%	15%
fine gravel	5.7 - 8	2	2%	17%
medium gravel	8 - 11.3	4	4%	21%
medium gravel	11.3 - 16	3	3%	24%
coarse gravel	16 - 22.6	3	3%	27%
coarse gravel	22.6 - 32	2	2%	29%
very coarse gravel	32 - 45	0	0%	29%
very coarse gravel	45 - 64	6	6%	35%
small cobble	64 - 90	8	8%	43%
medium cobble	90 - 128	5	5%	48%
large cobble	128 - 180	13	13%	62%
very large cobble	180 - 256	13	13%	75%
small boulder	256 - 362	17	17%	92%
small boulder	362 - 512	6	6%	98%
medium boulder	512 - 1024	2	2%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



Size Class	Size percent finer than (mm)
D5	1
D16	8
D50	130
D84	286
D95	405
D100	800

Material	Percent Composition
Sand	13%
Gravel	22%
Cobble	39%
Boulder	25%
Bedrock	0%

Sorting Coefficient: 2.52
Skewness Coefficient: 0.44

**This pebble count was not used in the analysis because the downstream reach was not used as a representative reach.*