14. Exercises 5a, 5b, 6a, 6b, 7, 9, and 10: Tributary to Schafer Creek Example

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Site History and Aquatic Organism Passage Concerns

USDA Forest Service Rd 22 (Wynoochee Rd) crosses the tributary to Schafer Creek about 1.9 km (1.2 mi) from the stream's confluence with Schafer Creek and approximately 8 km (5 mi) from the Wynoochee River. Most of the drainage is located on private land with Simpson Timber being the primary landowner. Much of the watershed has been logged at various times by Simpson Timber. Although the USDA Forest Service does not have property in this watershed, it is responsible for the road. The road right-of-way is 40 m wide centered on the road centerline.

The existing culvert at the crossing is undersized, in a deteriorated condition, and is a partial barrier to anadromous fish at various life stages and flows. The culvert is a round corrugated pipe with a diameter of 1.52 m (5 ft) diameter and a length of 30.5 m (100 ft) long corrugated pipe. There is a 0.4 to 0.5 m drop at the culvert outlet, high velocities in the culvert, sediment accumulation at the culvert inlet, and the sharp channel bend at the culvert inlet.

A railroad grade crosses the stream about 0.30 km upstream from the USFS 22 road crossing, and is a barrier to passage of aquatic organisms. There is an additional 1.3 km of accessible habitat for these species upstream of the railroad crossing. The quality of that habitat is unknown but it is assumed to be good. The owner of the railroad has indicated that the barrier at the railroad crossing will be fixed once work is completed on USFS Rd 22.

From field surveys and local fish biologist knowledge, existing fish passage needs at both crossings include adult and juvenile steelhead trout, coho salmon, and resident cutthroat trout. Between the USFS Rd 22 crossing and railroad crossing, there is approximately 0.30 km of spawning and rearing habitat for adult and juvenile steelhead trout, coho salmon, and resident cutthroat trout. Habitat quality in the stream is in good condition.

Geomorphic Assessment

The channel upstream and downstream from the road crossing has a plane-bed to pool-riffle morphology and is slightly to moderately confined with greater channel confinement downstream from the crossing. The channel gradient is variable, but in general ranges between 1-2 percent. The channel-bed surface is composed primarily of gravel- and cobble-sized sediment. The channel-bed is moderately to well armored; the subarmor layer consists of a poorly sorted mixture of cobbles, gravels, and sands. These armoring characteristics indicate that the channel-bed is mobilized and coarse sediment is supplied to the channel on a relatively infrequent basis. Channel bed structures in the riffles or plane-bed channel segments consist primarily of transverse ribs or pebbles clusters composed of cobbles and small boulders. Large woody debris is present along the channel with diameters ranging from 20 to 55 cm. Channel spanning wood complexes form distinct grade controls, influencing channel form and processes.

Bankfull width ranges from 5.5 to 7.6 m upstream from the road crossing. Pool residual depths ranged from 0.3 to 0.5 m upstream and downstream from the crossing. The existing structure alignment with the channel is skewed at an angle of 54 degrees from the upstream channel. The skewed alignment has caused significant and chronic erosion on the fillslope and floodplain along the right bank near the culvert inlet.

A wedge of gravel/cobble-sized sediments (3-6 m wide, 15-20 m long, 0.5-1.0 m thick) has accumulated upstream from the existing culvert. There is a deep plunge pool at the culvert outlet and the channel has incised about 0.5 to 1.0 m extends at least 150 downstream from the USFS Rd 22 crossing based on evidence such as increased bank heights, undercut banks, and localized bank failures. There is no evidence of channel incision between USFS Rd 22 and the railroad crossing.

Tributary to Schafer Creek Photographs, Upstream of Road-Stream Crossing


Downstream view of channel between XS2-XS3.


Downstream view of channel between XS2-XS3.


Upstream of pool between XS2-XS3.


Downstream of channel view of channel between XS4-XS5. Debris jam just downstream of XS5.


Downstream view of channel from XS7 to culvert inlet.

Tributary to Schafer Creek Photographs, Downstream of Road-Stream Crossing


Upstream view of channel between XS9-XS10.


Upstream view of channel just downstream of XS9 to culvert outlet.


Upstream view of channel between XS9-XS10 and culvert outlet.


Downstream view of channel between XS10-XS11 and debris jam.


Channel-bed characteristics at XS10.


Downstream view of channel and large woody debris immediately downstream of XS11.

Tributary to Schafer Creek Photographs, Grade Controls

Upstream view of forced LWD step at station 0+0 on plan map.

Downstream view of LWD at station 0+75 on plan map.

Upstream view of plunge pool riffle crest on plan map (station 0+160).

Upstream view of riffle crest and pool at station 0+60 m near XS5 on plan map.

Upstream view of riffle between station 0+160 and 0+180 on plan map.

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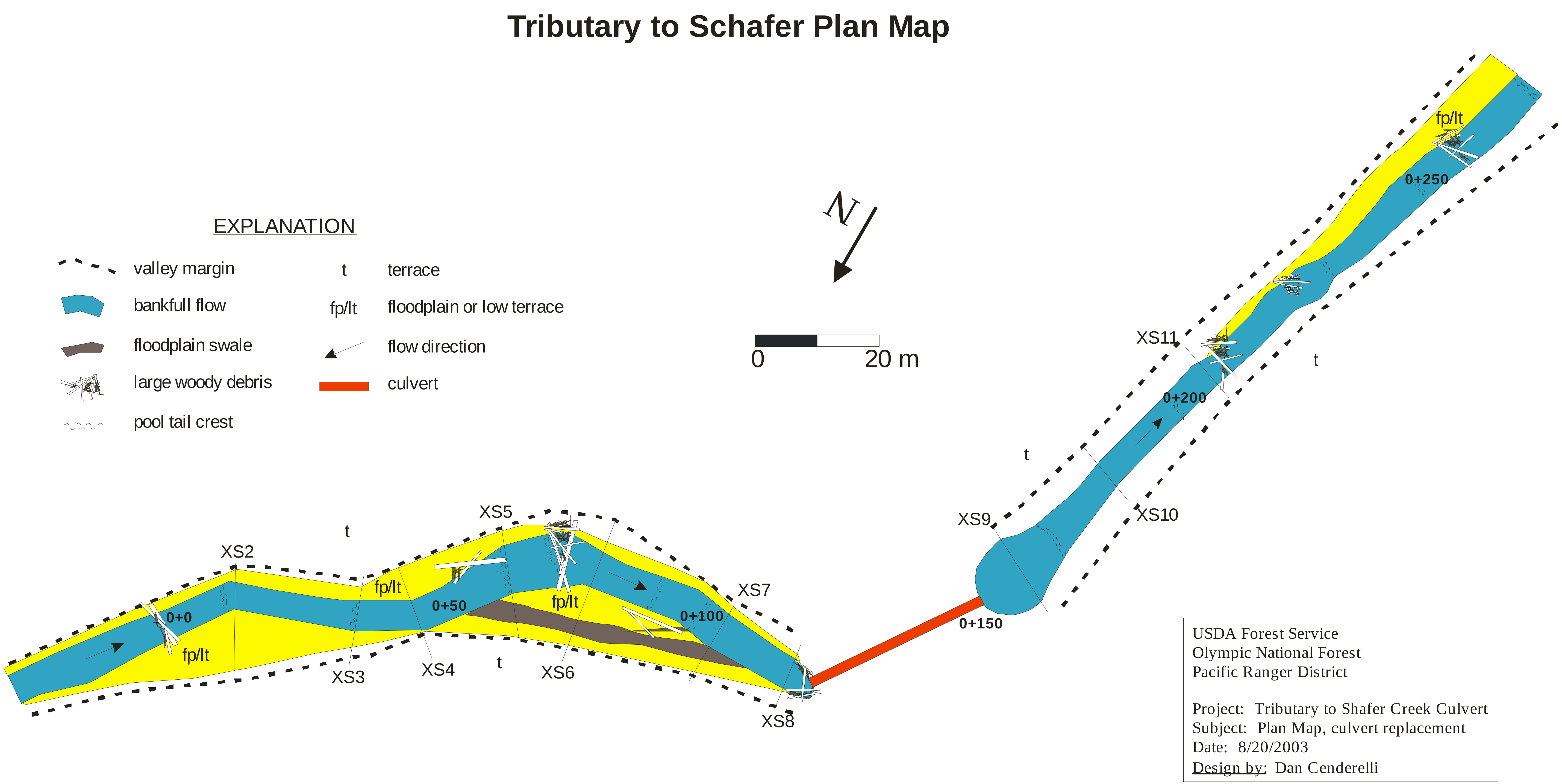
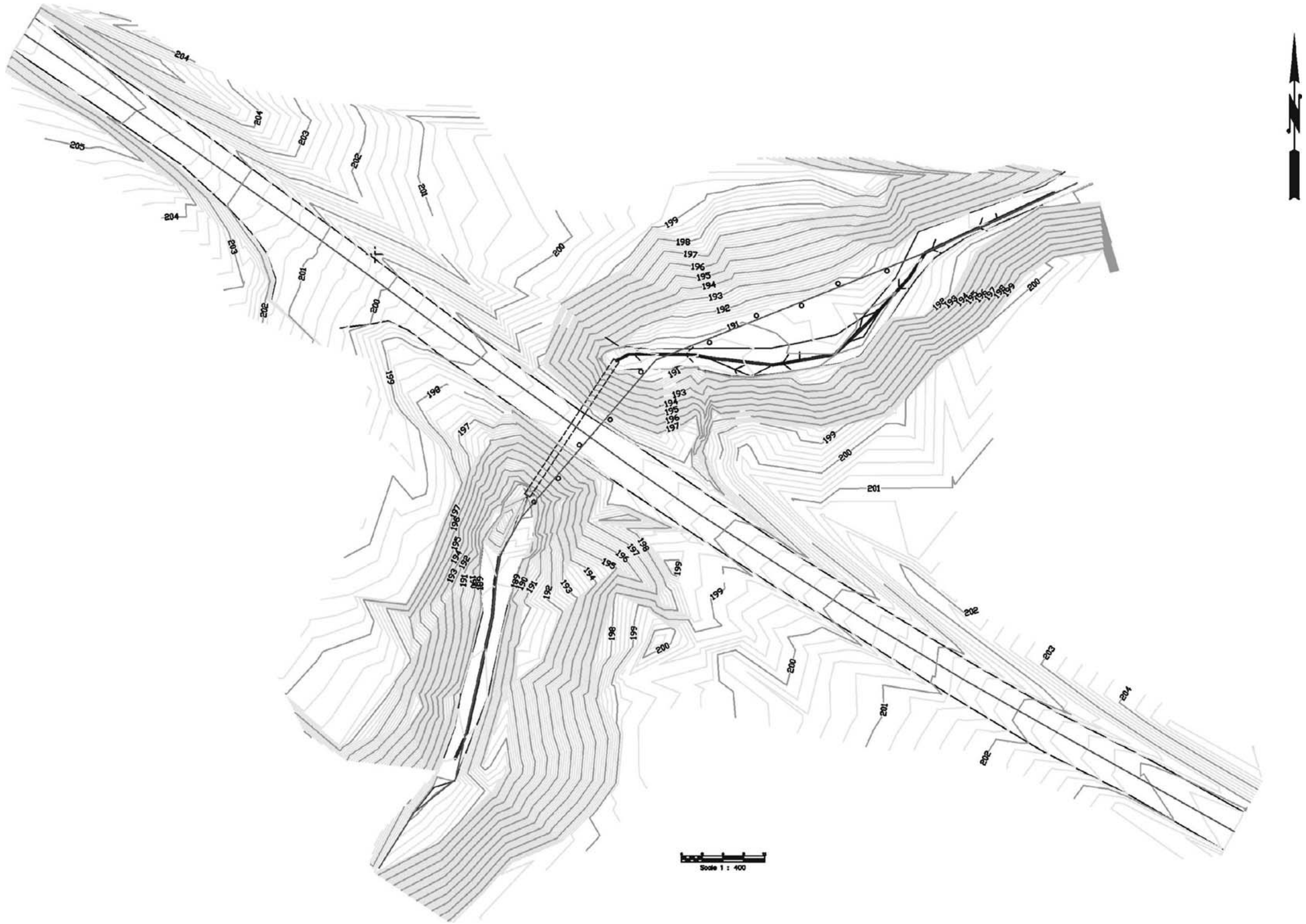
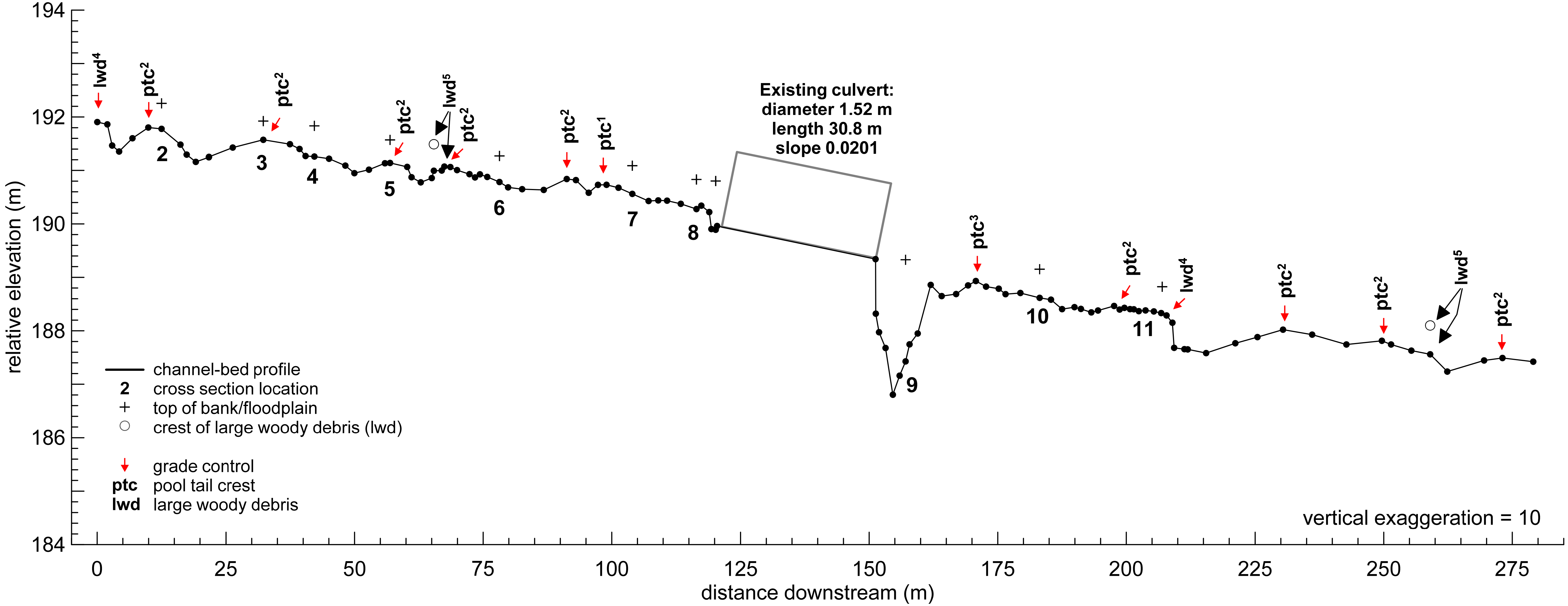
Geomorphic Map



Contour Map (meters)

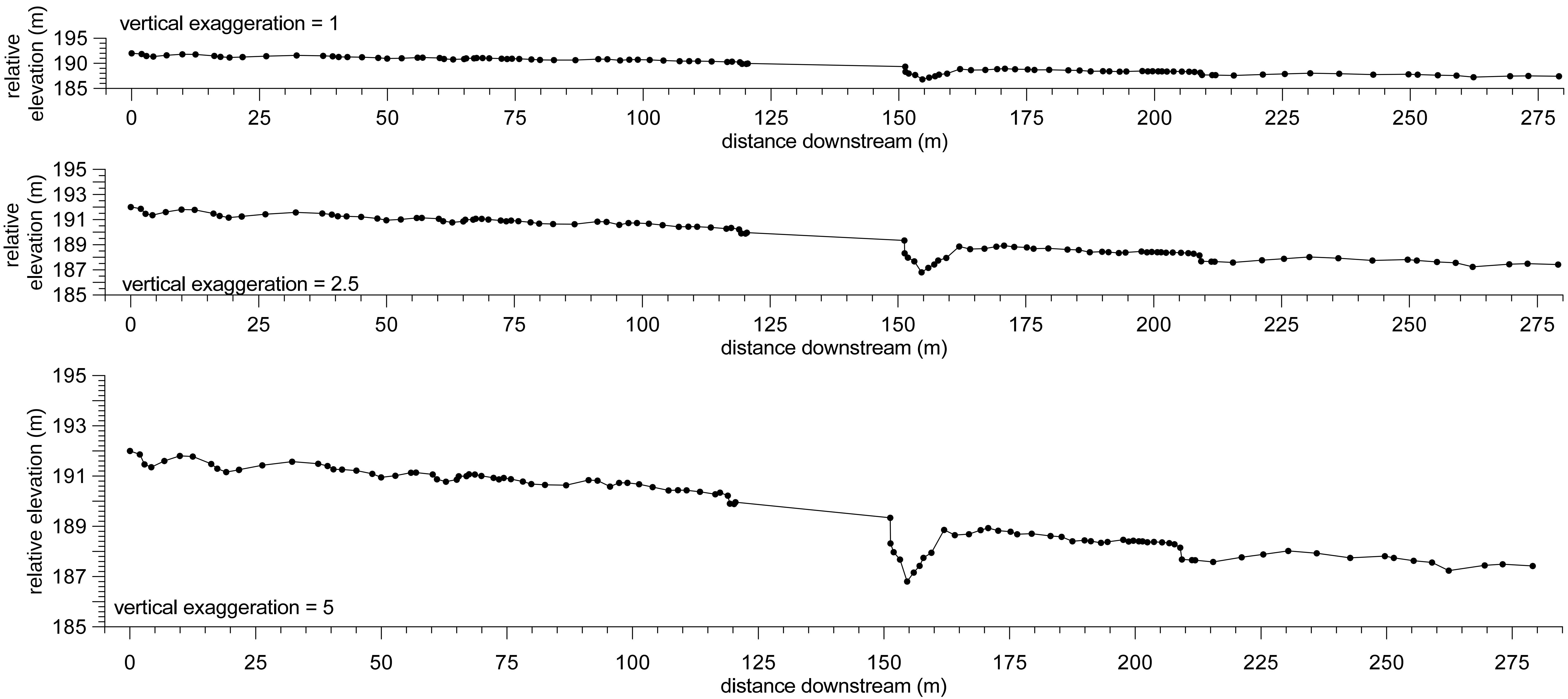


Longitudinal Profile

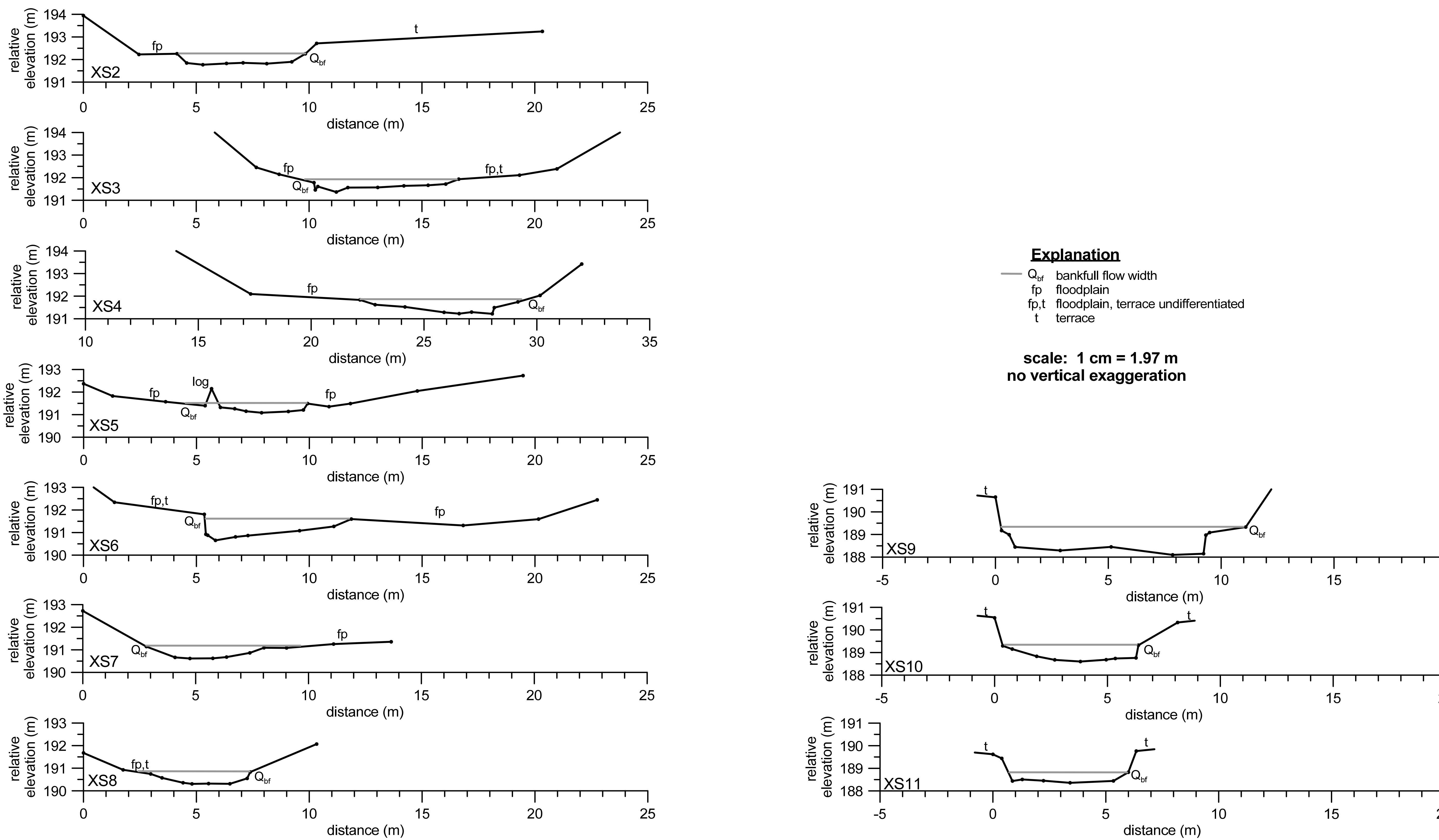


ptc[1]: pool-tail crest of downstream riffle; riffle particles (cobble-gravel) loosely packed and embedded.
ptc[2]: pool-tail crest of downstream riffle; riffle particles (cobble-coarse gravel) moderately packed and embedded.
ptc[3]: pool-tail crest of downstream riffle; riffle particles (boulder-cobble-coarse gravel) tightly packed and embedded.
lwd[4]: large woody debris that forms step, channel spanning, competent, diameter > 0.60 m, deeply embedded into channel and banks.
lwd[5]: large woody debris, channel spanning, competent, diameter 0.30-0.60 m, minimal embedment into channel and banks.

Longitudinal Profiles at different vertical exaggerations



Cross Sections

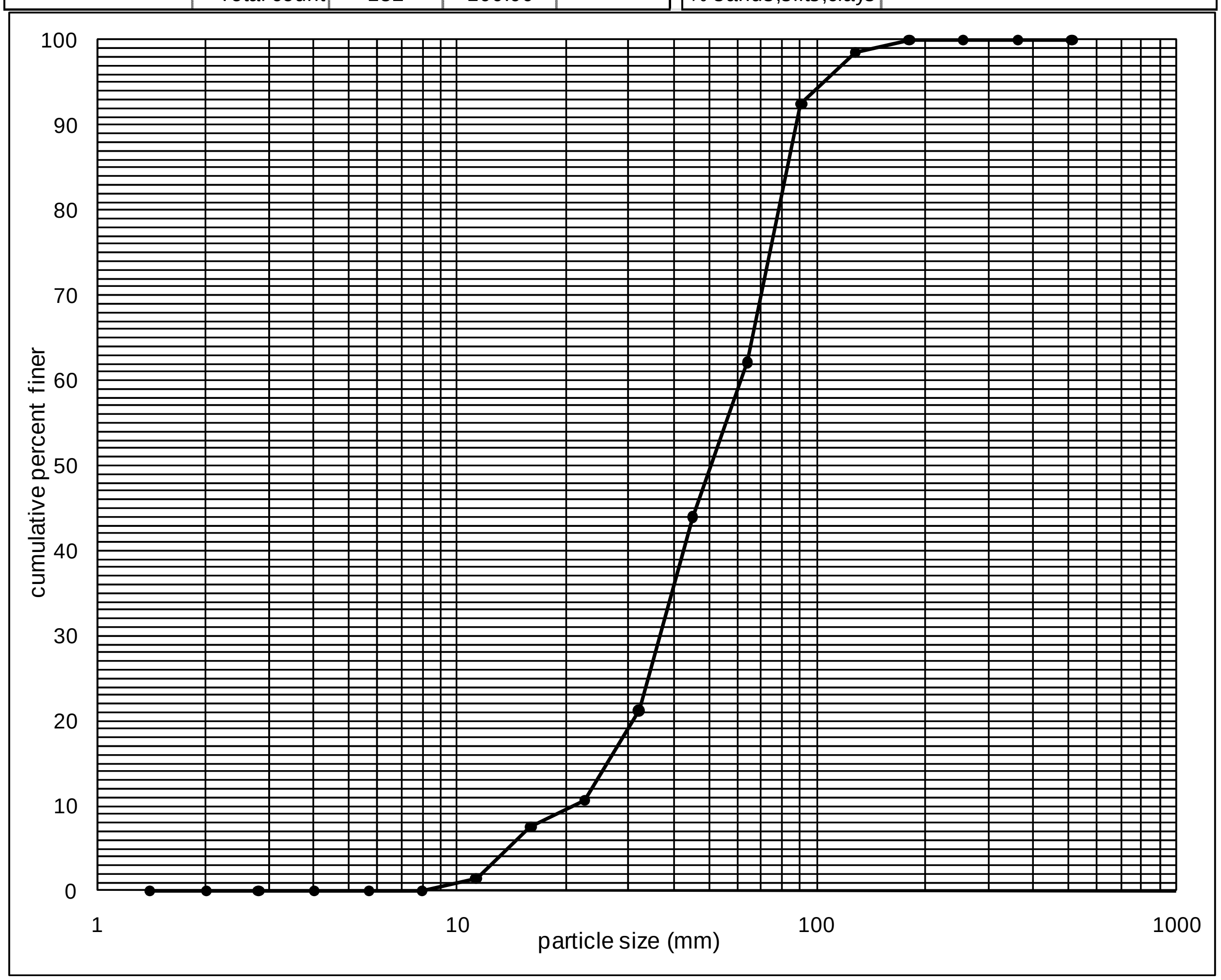


<u>Sediment data</u>

XS2 pebble count data and particle-size distribution curve.

particle size interval name	size interval (mm)	count or frequency	percent frequency	cumulative percent finer
medium boulders	512 to 724		0.00	100.00
	362 to 512		0.00	100.00
small boulders	256 to 362		0.00	100.00
	181 to 256		0.00	100.00
large cobbles	128 to 181	2	1.52	98.48
	90.5 to 128	8	6.06	92.42
small cobbles	64.0 to 90.5	40	30.30	62.12
	45.2 to 64.0	24	18.18	43.94
very coarse gravel	32.0 to 45.2	30	22.73	21.21
	22.6 to 32.0	14	10.61	10.61
coarse gravel	16.0 to 22.6	4	3.03	7.58
	11.3 to 16.0	8	6.06	1.52
medium gravel	8.0 to 11.3	2	1.52	0.00
	5.7 to 8.0		0.00	0.00
fine gravel	4.0 to 5.7		0.00	0.00
	2.8 to 4.0		0.00	0.00
very fine gravel	2.0 to 2.8		0.00	0.00
sand, silt, or clay	< 2		0.00	0.00
	Total count	132	100.00	

Project Name:	Schafer Tributary
Sample ID:	PC (XS2 channel, 8-20-03)
Sample Date:	8/20/2003
Sampler Name:	Cenderelli
Sample Location:	Riffle just ds from XS2
Sample Method:	grid method, 15 cm interval, 1 m spacing between transects, perpendicular to flow, bankfull.
percentile	particle size (mm)
d95	
d84	
d50	
d30	
d16	
d10	
d5	
% boulders	
% cobbles	
% gravels	
% sands,silts,clays	

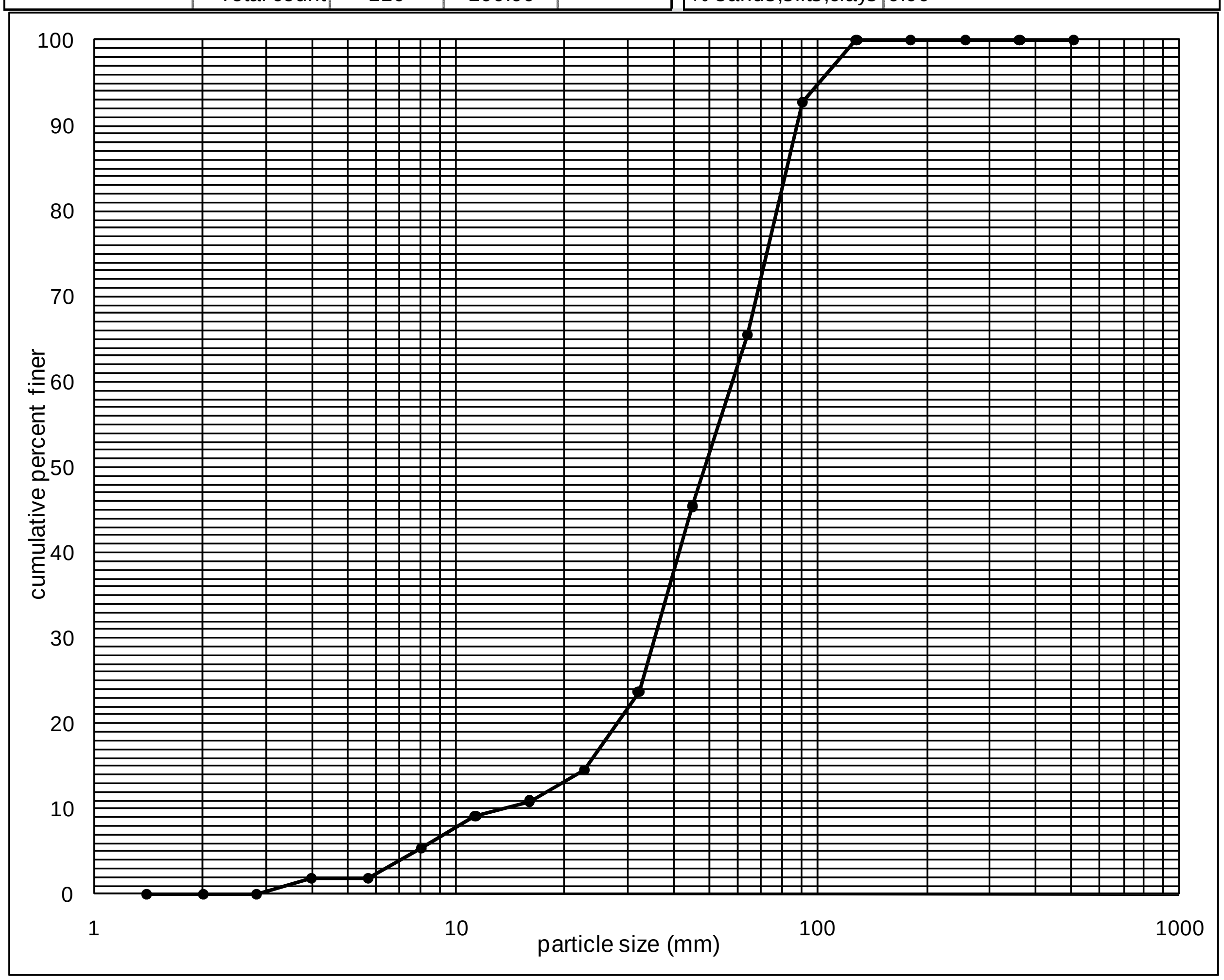


<u>Sediment data</u>

XS4 pebble count data and particle-size distribution curve.

particle size interval name	size interval (mm)	count or frequency	percent frequency	cumulative percent finer
medium boulders	512 to 724		0.00	100.00
	362 to 512		0.00	100.00
small boulders	256 to 362		0.00	100.00
	181 to 256		0.00	100.00
large cobbles	128 to 181		0.00	100.00
	90.5 to 128	8	7.27	92.73
small cobbles	64.0 to 90.5	30	27.27	65.45
	45.2 to 64.0	22	20.00	45.45
very coarse gravel	32.0 to 45.2	24	21.82	23.64
	22.6 to 32.0	10	9.09	14.55
coarse gravel	16.0 to 22.6	4	3.64	10.91
	11.3 to 16.0	2	1.82	9.09
medium gravel	8.0 to 11.3	4	3.64	5.45
	5.7 to 8.0	4	3.64	1.82
fine gravel	4.0 to 5.7		0.00	1.82
	2.8 to 4.0	2	1.82	0.00
very fine gravel	2.0 to 2.8		0.00	0.00
sand, silt, or clay	< 2		0.00	0.00
	Total count	110	100.00	

Project Name:	Schafer Tributary
Sample ID:	PC (XS4 channel, 8-20-03)
Sample Date:	8/20/2003
Sampler Name:	Cenderelli
Sample Location:	Riffle at XS4
Sample Method:	grid method, 15 cm interval, 1 m spacing between transects, perpendicular to flow, bankfull.
percentile	particle size (mm)
d95	101
d84	81
d50	49
d30	36
d16	24
d10	13
d5	7.7
% boulders	0.00
% cobbles	34.55
% gravels	65.45
% sands,silts,clays	0.00

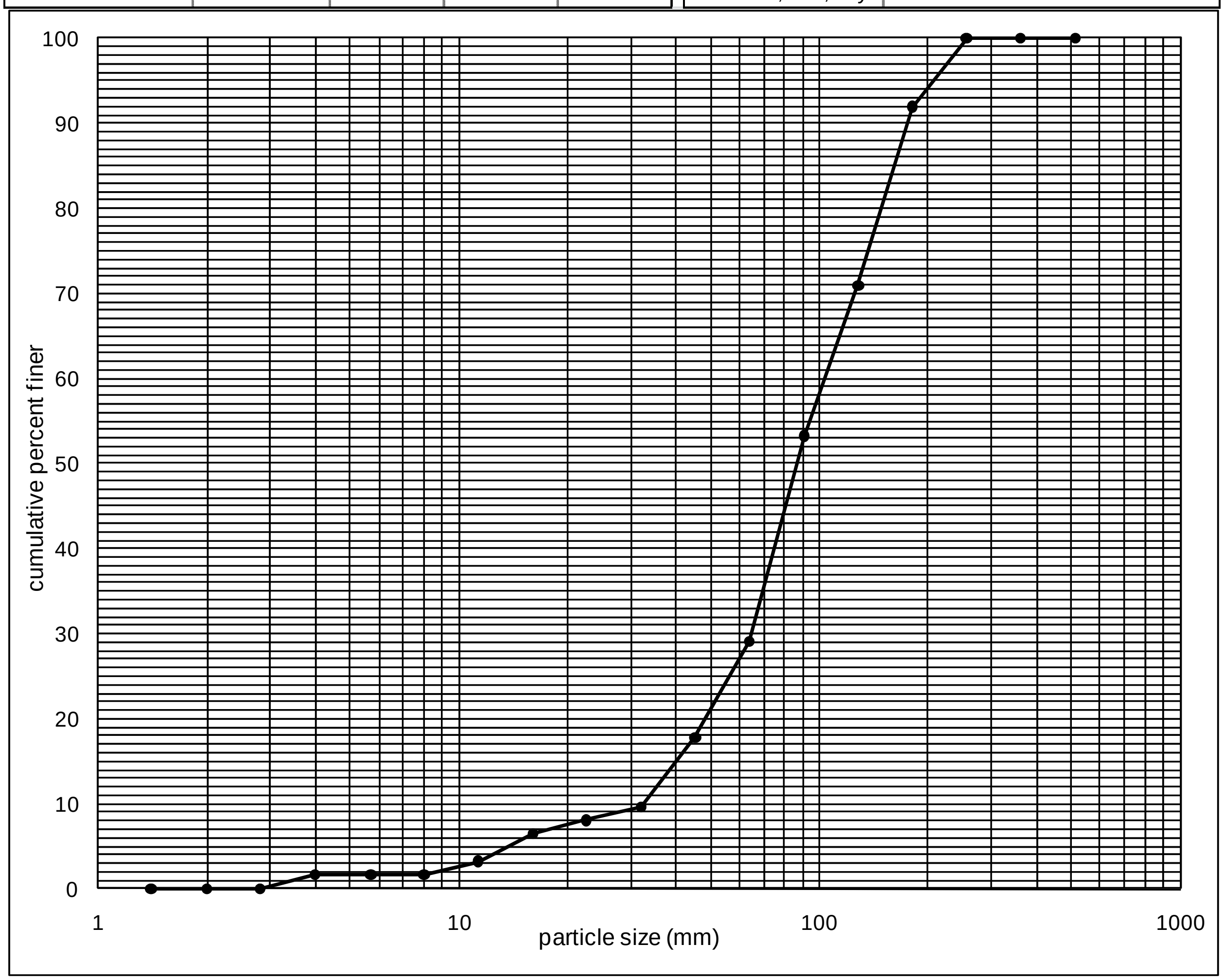


Sediment data

XS10 pebble count data and particle-size distribution curve.

particle size interval name	size interval (mm)	count or frequency	percent frequency	cumulative percent finer
medium boulders	512 to 724		0.00	100.00
	362 to 512		0.00	100.00
small boulders	256 to 362		0.00	100.00
	181 to 256	10	8.06	91.94
large cobbles	128 to 181	26	20.97	70.97
	90.5 to 128	22	17.74	53.23
small cobbles	64.0 to 90.5	30	24.19	29.03
	45.2 to 64.0	14	11.29	17.74
very coarse gravel	32.0 to 45.2	10	8.06	9.68
	22.6 to 32.0	2	1.61	8.06
coarse gravel	16.0 to 22.6	2	1.61	6.45
	11.3 to 16.0	4	3.23	3.23
medium gravel	8.0 to 11.3	2	1.61	1.61
	5.7 to 8.0		0.00	1.61
fine gravel	4.0 to 5.7		0.00	1.61
	2.8 to 4.0	2	1.61	0.00
very fine gravel	2.0 to 2.8		0.00	0.00
sand, silt, or clay	< 2		0.00	0.00
	Total count	124	100.00	

Project Name:	Schafer Tributary
Sample ID:	PC (XS10 channel, 8-22-03)
Sample Date:	8/22/2003
Sampler Name:	Cenderelli
Sample Location:	Riffle head, us from XS10
Sample Method:	grid method, 20 cm interval, 1 m spacing between transects, perpendicular to flow, bankfull.
percentile	particle size (mm)
d95	210
d84	159
d50	86
d30	64
d16	42
d10	32
d5	14
% boulders	0.00
% cobbles	70.97
% gravels	29.03
% sands,silts,clays	0.00

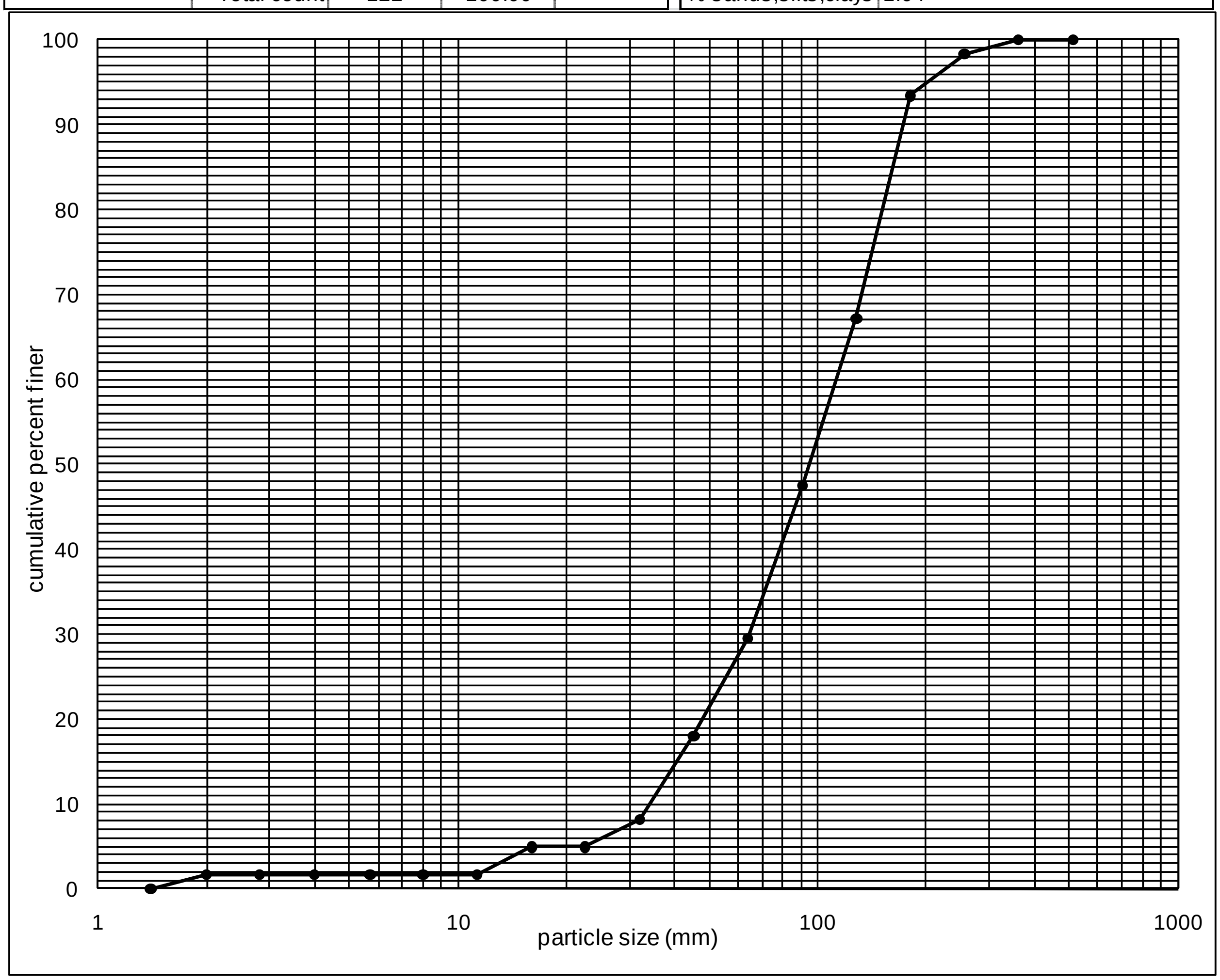


<u>Sediment data</u>

XS11 pebble count data and particle-size distribution curve.

particle size interval name	size interval (mm)	count or frequency	percent frequency	cumulative percent finer
medium boulders	512 to 724		0.00	100.00
	362 to 512		0.00	100.00
small boulders	256 to 362	2	1.64	98.36
	181 to 256	6	4.92	93.44
large cobbles	128 to 181	32	26.23	67.21
	90.5 to 128	24	19.67	47.54
small cobbles	64.0 to 90.5	22	18.03	29.51
	45.2 to 64.0	14	11.48	18.03
very coarse gravel	32.0 to 45.2	12	9.84	8.20
	22.6 to 32.0	4	3.28	4.92
coarse gravel	16.0 to 22.6		0.00	4.92
	11.3 to 16.0	4	3.28	1.64
medium gravel	8.0 to 11.3		0.00	1.64
	5.7 to 8.0		0.00	1.64
fine gravel	4.0 to 5.7		0.00	1.64
	2.8 to 4.0		0.00	1.64
very fine gravel	2.0 to 2.8		0.00	1.64
sand, silt, or clay	< 2	2	1.64	0.00
	Total count	122	100.00	

Project Name:	Schafer Tributary
Sample ID:	PC (XS11 channel, 8-22-03)
Sample Date:	8/22/2003
Sampler Name:	Cenderelli
Sample Location:	Riffle at XS11
Sample Method:	grid method, 20 cm interval, 1 m spacing between transects, perpendicular to flow, bankfull.
percentile	particle size (mm)
d95	205
d84	159
d50	95
d30	65
d16	43
d10	34
d5	23
% boulders	1.64
% cobbles	68.85
% gravels	27.87
% sands,silts,clays	1.64



Key piece data

XS4. Summary of 10 largest particles observed along this segment of channel.

particle number	long axis (mm)	inter-mediate axis (mm)	short axis (mm)	average cubic dimension (mm)	long axis/inter-mediate axis ratio	particle shape; roundness
1	250	160	75	144	1.56	bladed shape; subangular
2	225	170	50	124	1.33	platy shape; subangular
3	250	150	110	160	1.67	elongated shape; subangular
4	210	155	65	129	1.35	bladed shape; subangular
5	190	155	100	143	1.23	bladed shape; subangular
6	200	100	80	117	2.00	elongated shaped; subangular
7	180	95	75	108	1.90	elongated shaped; subangular
8	160	100	40	86	1.60	bladed shape; subangular
9	220	120	45	106	1.83	bladed shape; subangular
10	95	85	60	78	1.11	compact, bladed shape; subangular

250	**166**	**106**	**153**	**1.96**	d95 percentile (mm)
239	**158**	**91**	**144**	**1.87**	d84 percentile (mm)
205	**135**	**70**	**121**	**1.58**	d50 percentile (mm)
169	**97**	**47**	**95**	**1.27**	d16 percentile (mm)

XS10. Summary of 10 largest particles observed along this segment of channel.

particle number	long axis (mm)	inter-mediate axis (mm)	short axis (mm)	average cubic dimension (mm)	long axis/inter mediate axis ratio	particle shape; roundness
1	250	240	140	203	1.04	platy shape; subangular
2	450	190	150	234	2.37	elongated shape; subangular
3	420	320	70	211	1.31	platy shape; subangular
4	300	260	160	232	1.15	platy shape; subangular
5	310	210	125	201	1.48	bladed shape; subangular
6	260	210	180	214	1.24	compact, elongated shape; subangular
7	280	180	80	159	1.56	compact, bladed shape; subangular
8	230	140	65	128	1.64	bladed shape; subangular
9	270	170	125	179	1.59	elongated shape; subangular
10	225	165	100	155	1.36	bladed shape; subangular

437	**293**	**171**	**233**	**2.04**	d95 percentile (mm)
372	**251**	**156**	**224**	**1.62**	d84 percentile (mm)
275	**200**	**125**	**202**	**1.42**	d50 percentile (mm)
239	**167**	**74**	**157**	**1.19**	d16 percentile (mm)

Structure information: Minimum cover heights, maximum cover heights, and costs

Structures with a 6.10 m span

Shape	Material	Span/Rise (m)	Minimum Cover (cm)		[b]Maximum Cover (m)		Assemble Cost/Foot ($/m)	
			Steel	Aluminum	Steel	Aluminum	Steel	Aluminum
round	multi-plate	6.10	76.2	61.0	18.3	6.1	1690	2513
pipe arch	multi-plate	6.07 x 4.06	91.4	61.0	2.4	4.0	1145	1739
ellipse	super-span	6.10 x 4.27	91.4	61.0	2.4	3.7	1227	1811
low arch[a]	multi-plate	6.10 x 2.13	76.2	61.0	18.3	6.1	994	1178
med arch[a]	multi-plate	6.10 x 2.69	76.2	61.0	18.3	6.1	1060	1326
high arch[a]	multi-plate	6.10 x 3.15	76.2	61.0	18.3	6.1	1158	1476
low box[a]	multi-plate	6.22 x 1.63	55.9	50.8	1.2	1.5	1887	2405
high box[a]	multi-plate	6.12 x 2.95	55.9	50.8	1.2	1.5	2218	2828
conc box	reinf conc	6.10 x 3.66	0		6.10 m plus		~ 1624	

a. Assembled in place on footings. Footings can be designed to any height.
b. Maximum theoretical fill heights. NOT FOR DESIGN USE.

Structures with a 7.62 m span

Shape	Material	Span/Rise (m)	Minimum Cover (cm)		[b]Maximum Cover (m)		Assemble Cost/Foot ($/m)	
			Steel	Aluminum	Steel	Aluminum	Steel	Aluminum
round	multi-plate	7.62	106.7	91.4	11.9	3.7	3084	4584
ellipse	multi-plate	7.62 x 5.33	91.4	91.4	4.3	3.7	2848	4200
low arch[a]	multi-plate	7.62 x 2.67	91.4	91.4	11.9	3.7	1365	2038
med arch[a]	multi-plate	7.62 x 3.35	91.4	91.4	11.9	3.7	1542	2297
high arch[a]	multi-plate	7.62 x 3.94	91.4	91.4	11.9	3.7	1936	2887
low box[a]	multi-plate	7.77 x 2.03	45.7	91.4	1.5	1.5	2517	4269
high box[a]	multi-plate	7.64 x 3.66	45.7	91.4	1.5	1.5	2900	4659
conc box	reinf conc	7.62 x 3.66	0		6.10 m plus		~ 2953	

a. Assembled in place on footings. Footings can be designed to any height.
b. Maximum theoretical fill heights. NOT FOR DESIGN USE.

Structures with a 9.14 m span

Shape	Material	Span/Rise (m)	Minimum Cover (cm)		[b]Maximum Cover (m)		Assemble Cost/Foot ($/m)	
			Steel	Aluminum	Steel	Aluminum	Steel	Aluminum
ellipse	super span	9.14 x 6.40	91.4	91.4	6.1	1.5	6706	8718
low arch[a]	super span	9.14 x 3.02	91.4	91.4	6.1	1.5	3255	4229
high arch[a]	super span	9.14 x 4.70	91.4	91.4	6.1	1.5	3665	4764
low box[a]	multi-plate	9.14 x 1.93	45.7	n/a	1.5	n/a	3609	-
high box[a]	multi-plate	9.14 x 2.77	45.7	n/a	1.5	n/a	3609	-
conc box	reinf conc	9.14 x 5.66	0		6.10 m plus		~4593	

a. Assembled in place on footings. Footings can be designed to any height.
b. Maximum theoretical fill heights. NOT FOR DESIGN USE.

Hydrology

Summary of flood magnitudes at different recurrence intervals for the tributary to Schafer Creek.

Recurrence interval	a	b	c	Q (ft^3/s)	**Q (m^3/s)**	Std Error (%)
2	0.350	0.923	1.240	149	**4.22**	32
10	0.520	0.921	1.260	235	**6.67**	33
25	0.590	0.921	1.260	277	**7.83**	34
50	0.666	0.921	1.260	312	**8.84**	36
100	0.745	0.922	1.260	349	**9.89**	37

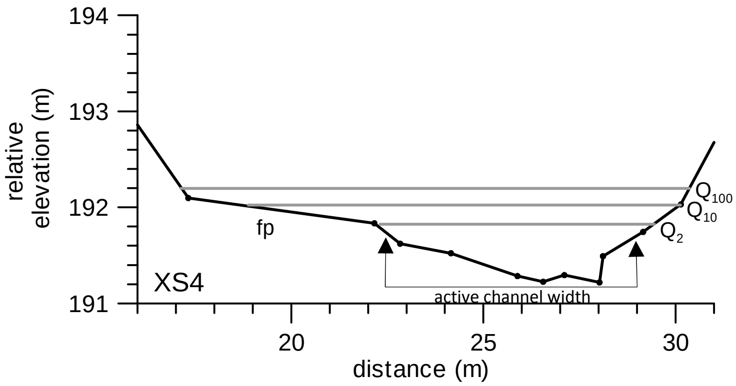
$Q = a\,A^b\,P^c$

- Q = flow (ft^3/s)
- A = basin area (mi^2)
- P = mean annual precipitation (inches)
- a, b, c = regression coefficients or exponents

Trib to Schafer Creek
Drainage area: $A = 1.16\ mi^2$
Mean annual precip: P = 130 inches

Using Washington State Magnitude and Frequency of Floods, USGS

Flow Hydraulics: XS4



horizontal scale: 1 cm = 1.97 m
vertical scale: 1 cm = 0.79 m
vertical exaggeration = 2.5

Explanation

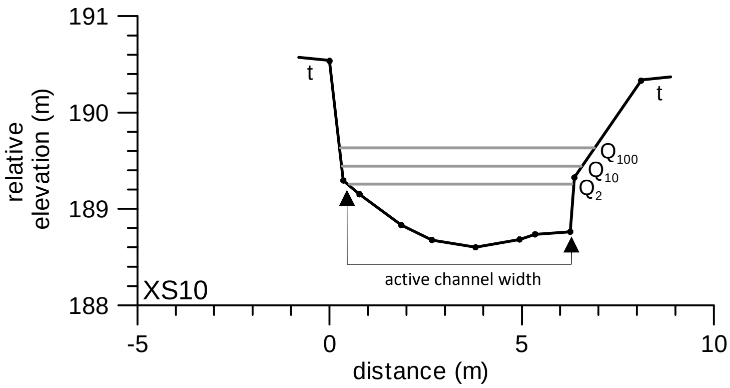
— Q_2, Q_{10}, Q_{100} water surfaces
fp floodplain
t terrace

Summary of flow hydraulics at XS4.

Recurrence interval	Discharge, Q (m^3/s)	Active channel width discharge, Q_a (m^3/s)	Channel slope, S_c	Energy slope, S_e	Total flow width, W_t (m)	Channel flow width, W_a (m)	Total hydraulic radius, R_t (m)	Channel hydraulic radius, R_a (m)	Total boundary shear stress, τ_t (N/m^2)[a]	Channel boundary shear stress, τ_a (N/m^2)[b]	Total unit discharge, q_t (m^2/s)[c]	Active channel unit discharge, q_a (m^2/s)[d]
	2.00	1.93	0.0176	0.0186	6.41	6.41	0.27	0.27	49.27	49.27	0.312	0.301
	3.00	2.76	0.0176	0.0183	6.98	6.84	0.32	0.33	57.45	59.24	0.430	0.404
bf	4.00	3.51	0.0176	0.0178	7.77	6.99	0.35	0.39				
2	4.20	3.66	0.0176	0.0177	8.05	6.99	0.35	0.40	60.77	69.45	0.522	0.524
	5.00	4.22	0.0176	0.0174	9.09	6.99	0.36	0.45	61.45	76.81	0.550	0.604
	6.00	4.89	0.0176	0.0172	10.28	6.99	0.37	0.50	62.43	84.37	0.584	0.700
10	6.70	5.35	0.0176	0.0170	11.07	6.99	0.37	0.53	61.70	88.39	0.605	0.765
	7.00	5.54	0.0176	0.0169	11.39	6.99	0.38	0.55	63.00	91.18	0.615	0.793
25	7.80	6.04	0.0176	0.0167	12.16	6.99	0.39	0.58	63.89	95.02	0.641	0.864
	8.00	6.17	0.0176	0.0167	12.35	6.99	0.39	0.59	63.89	96.66	0.648	0.883
50	8.80	6.65	0.0176	0.0165	12.94	6.99	0.41	0.63	66.36	101.97	0.680	0.951
	9.00	6.76	0.0176	0.0164	12.96	6.99	0.42	0.64	67.57	102.97	0.694	0.967
100	9.90	7.29	0.0176	0.0161	13.08	6.99	0.45	0.67	71.07	105.82	0.757	1.043
	10.00	7.34	0.0176	0.0161	13.10	6.99	0.46	0.68	72.65	107.40	0.763	1.050
	11.00	7.91	0.0176	0.0158	13.22	6.99	0.49	0.72	75.95	111.60	0.832	1.132

a. $\tau_t = \gamma R_t S_e$
b. $\tau_a = \gamma R_a S_e$
c. $q_t = Q / W_t$
d. $q_a = Q_a / W_a$

Flow Hydraulics: XS10



horizontal scale: 1 cm = 1.97 m
vertical scale: 1 cm = 0.79 m
vertical exaggeration = 2.5

Explanation

Q_2, Q_{10}, Q_{100} water surfaces
fp floodplain
t terrace

Summary of flow hydraulics at XS10.

Recurrence interval	Discharge, Q (m^3/s)	Active channel width discharge, Q_a (m^3/s)	Channel slope, S_c	Energy slope, S_e	Total flow width, W_t (m)	Channel flow width, W_a (m)	Total hydraulic radius, R_t (m)	Channel hydraulic radius, R_a (m)	Total boundary shear stress, τ_t (N/m^2)[a]	Channel boundary shear stress, τ_a (N/m^2)[b]	Total unit discharge, q_t (m^2/s)[c]	Active channel unit discharge, q_a (m^2/s)[d]
	2.00	1.96	0.0174	0.0161	5.22	5.22	0.31	0.31	48.96	48.96	0.383	0.375
	3.00	2.89	0.0174	0.0170	5.56	5.56	0.37	0.37	61.70	61.70	0.540	0.520
bf	4.00	3.80	0.0174	0.0173	5.81	5.81	0.43	0.43				
2	4.20	3.98	0.0174	0.0174	5.86	5.86	0.44	0.44	75.11	75.11	0.717	0.679
	5.00	4.68	0.0174	0.0176	6.01	6.01	0.47	0.47	81.15	81.15	0.832	0.779
	6.00	5.54	0.0174	0.0173	6.11	6.01	0.52	0.53	88.25	89.95	0.982	0.922
10	6.70	6.12	0.0174	0.0172	6.19	6.01	0.55	0.57	92.80	96.18	1.082	1.018
	7.00	6.37	0.0174	0.0171	6.22	6.01	0.56	0.58	93.94	97.30	1.125	1.060
25	7.80	7.03	0.0174	0.0169	6.31	6.01	0.59	0.62	97.82	102.79	1.236	1.170
	8.00	7.19	0.0174	0.0169	6.34	6.01	0.59	0.63	97.82	104.45	1.262	1.196
50	8.80	7.85	0.0174	0.0167	6.42	6.01	0.62	0.67	101.57	109.76	1.371	1.306
	9.00	8.01	0.0174	0.0166	6.44	6.01	0.63	0.68	102.59	110.74	1.398	1.333
100	9.90	8.74	0.0174	0.0164	6.54	6.01	0.66	0.73	106.18	117.45	1.514	1.454
	10.00	8.82	0.0174	0.0164	6.55	6.01	0.66	0.73	106.18	117.45	1.527	1.468
	11.00	9.62	0.0174	0.0162	6.65	6.01	0.69	0.78	109.66	123.96	1.654	1.601

a. $\tau_t = \gamma \ R_t \ S_e$
b. $\tau_a = \gamma \ R_a \ S_e$
c. $q_t = Q / W_t$
d. $q_a = Q_a / W_a$

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Exercise 5a. Interpreting geomorphic site assessment data: Planform and longitudinal profile

1. **Planform Assessment (spend no more than 10-15 minutes answering these questions).**
   a. Describe the differences (if any) of the channel pattern upstream and downstream from the road-stream crossing.

   b. Using the tributary to Schafer Creek geomorphic and contour maps (pages 14-7 and 14-8) assess the alignment of the channel with the existing culvert. Is it good or poor? Why?

   c. On the geomorphic and contour maps, delineate the natural channel pattern through the road-stream crossing as if the road was not there.

   d. How has the existing culvert affected the natural channel pattern through the road-stream crossing?

   e. What roadway considerations may affect our abilities to change the alignment of channel with the road-stream crossing structure and the project boundaries?

2. **Longitudinal Profile Assessment (use the longitudinal profile with the vertical exaggeration of 10, page 14-9)**
   a. Identify the pools and grade controls along the longitudinal profile (step 1). Delineate the residual pool depth water surface for each pool.

   b. Identify the primary grade controls along this channel (step 2) (i.e., steps, pool tail crests or head of riffles, large woody debris, bedrock, etc.). Where are the primary grade controls and pools located along the channel (hint: compare longitudinal profile with geomorphic map)?

   c. Rate the relative stability of each grade control based on the descriptions provided of the channel along the longitudinal profile and your observations of the grade control photos provided on page 14-5 (step 3). Be sure to use the grade control stability table provided in the site assessment presentation when completing this question. What criteria or factors were used to determine the relative stability of the grade controls along the channel?

   d. What causal features control the formation of the deepest pools along a given slope segment (step 4) (e.g., channel bend, obstruction plunge, obstruction backwater, constriction)? What causal feature(s) form the deepest pools. Use both the longitudinal profile and geomorphic map to answer this question.

   e. Delineate unique channel slope segments along the longitudinal profile (step 5).

Before proceeding to the next questions, have an instructor check your work and give you additional information on the grade controls and slope segments identified.

f. Calculate the elevation change, length, and gradient of each slope segment (step 6). Discuss how the gradient and lengths of each slope segment vary upstream of the crossing, through the crossing, and downstream of the crossing.

g. Determine the maximum scour depth (residual pool depth) for each slope segment and the culvert plunge pool (step 7). How does the residual pool depth of the culvert plunge pool compare the maximum scour depths of pools in the natural channel?

h. Determine the number and distance between grade controls for each slope segment (step 8). Discuss how the distance between the grade controls vary upstream and downstream of the crossing. Discuss how the length of riffles

i. Using the photographs and your knowledge of channels, identify the channel unit(s) between the pools (i.e., riffles, steps, etc.). Describe the differences (if any) of those channel unit lengths between the pools upstream and downstream from the road-stream crossing. If yes, what geomorphic factors are influencing those differences?

j. Identify and delineate the length and thickness of sediment aggradation upstream from the culvert inlet (step 9).

k. Identify the overall shape of the longitudinal profile (step 10) (i.e., uniform, concave, convex, complex, vertical offset, etc.). Based on the shape of the longitudinal profile, what (if any) geomorphic processes and/or channel responses are of concern at the crossing?

l. Delineate the upper vertical adjustment potential (VAP) line along the longitudinal profile (step 11)? What geomorphic features and criteria were used to draw the upper VAP line?

m. Delineate the lower vertical adjustment potential (VAP) lines along the longitudinal profile (step 12)? What geomorphic features and criteria were used to draw the upper VAP line?

n. What are the long-term and short-term risks are associated with headcutting, lateral adjustment, and vertical adjustment at this site?

Exercise 5b: Design profile and alignment

1. **Select a preliminary structure design alignment (use both the non-truncated and truncated plan view maps when delineating the alignment).**
   a. Draw the alignment of the new crossing on the plan view maps or on a separate sketch.

   b. What if any special design considerations would you recommend for the crossing-to-channel transitions?

   c. Would additional information help the decision regarding alignment?

2. **Select a preliminary design profile through the crossing (use both the non-truncated and truncated longitudinal profile and geomorphic map when identifying the features described in the questions below).**
   a. Identify an initial upstream and downstream elevation control point (grade control) on the longitudinal profile and geomorphic map (profile design step 1). What is the relative stability of those grade controls?

   b. Delineate the preliminary design profile through the crossing on longitudinal profile using the elevation control points identified in the previous question (step 2). Calculate the gradient of the preliminary design profile.

   c. The road right-of-way is 20 m on both sides of the road centerline. Is the design project profile within the right-of-way?

3. **Select a preliminary reference reach (use both the non-truncated and truncated longitudinal profile and geomorphic map when identifying the features described in the questions below).**
   a. Select a preliminary reference reach for the design on the both the longitudinal profile and geomorphic map (step 3)?

   b. What is the slope, length, and planform pattern of the preliminary reference reach?

c. Compare the slope, length, and planform pattern of the selected preliminary reference reach to the design channel? Describe any differences between these parameters and discuss how they may influence channel design through the crossing. Are the slope, length, and planform pattern of the preliminary reference reach suitable for the road-stream crossing design channel?

d. Determine the maximum scour depth (residual pool depth) for the reference reach. Will the maximum scour depth be similar along the design profile or are conditions such that greater or less scour depth is anticipated? Do you expect to adjust the VAP lines (step 4)?

4. Grade control (use both the non-truncated and truncated longitudinal profile and geomorphic map when identifying the features described in the questions below).

a. Determine the number and distance between grade controls for the preliminary reference reach (step 5). Do you expect to have to add grade controls to the design profile? If yes, what types of grade controls are recommended? Will the number and distance between grade controls in the design profile be similar to those in reference reach or will they be modified?

b. On the longitudinal profile and geomorphic map, delineate the approximate location of grade controls on the design profile through the crossing.

c. How will you treat the existing plunge pool (step 6)?

d. Knowing the grade control type and spacing, channel units expected, etc., delineate the long-term channel bed surface through the crossing (step 7).

Exercise 6a. Interpreting site assessment data: Channel cross-sections and bed material

1. Channel Cross-sections

Table 6a-1. Summary of bankfull width, flood prone width, and entrenchment ratio at each cross section.

Cross section	Bankfull width (m)	Flood prone width (m)	Entrench-ment ratio	Cross section	Bankfull width (m)	Flood prone width (m)	Entrench-ment ratio
Cross sections upstream of crossing				Cross sections downstream of crossing			
XS2		8.45	1.49	XS9		11.85	1.10
XS3		13.21	1.94	XS10		7.45	1.26
XS4		14.00	1.94	XS11		5.75	1.08
XS5		13.00	2.39	Average			
XS6							
XS7		17.50	2.54				
XS8		8.10	1.62				
Average							

a. Using the tributary to Schafer Creek cross sections (page 14-11), determine the range of bankfull flow widths in the reach. Summarize these measurements in the above table (Table 6a-1). Please note that the cross section locations are identified on the geomorphic map and longitudinal profile.

b. Determine the flood prone width (width at two times maximum bankfull depth) and entrenchment ratio (flood prone width / bankfull width) for XS6 and XS10. Summarize these measurements in the above table (Table 6a-1).

c. Based on the cross section measurements, discuss how bankfull flow widths, flood prone widths, and entrenchment ratios vary upstream and downstream from the crossing.

d. Discuss the factors influencing bankfull flow width, flood prone width, and entrenchment ratio along the channel (Note: Evaluate the cross sections with respect to their location the geomorphic map, longitudinal profile, and channel unit).

e. What do the cross sections, photographs, and above calculations suggest about bank stability and lateral adjustment potential immediately upstream and downstream from the road-stream crossing?

f. For your reference reach cross section, determine the active bed width and the height of banks.

2. **Bed material size. Particle sizes were measured using the grid count method at XS2, XS4, XS10, and XS11. These data and analyses are presented on pages 14-12 to 14-15 and summarized in the table below (Table 6a-2).**

Table 6a-2. Summary of sediment data at selected cross sections.

percentile	**XS2** particle size (mm)	**XS4** particle size (mm)	**XS10** particle size (mm)	**XS11** particle size (mm)
d95		101	210	205
d84		81	159	159
d50		49	86	95
d30		36	64	65
d16		24	42	43
d10		13	32	34
d5		7.7	14	23
particle interval	**XS2** (percent)	**XS4** (percent)	**XS10** (percent)	**XS11** (percent)
boulders	0.00	0.00	0.00	1.64
cobbles	37.88	34.55	70.97	68.85
gravels	62.12	65.45	29.03	27.87
sands,silts,clays	0.00	0.00	0.00	1.64

a. From the particle-size distribution graph of the channel-bed material at XS2 (page 14-12), determine the d95, d84, d50, d30, d16, d10, and d5 particle sizes. Summarize the data on the table provided on page 14-12 and the above table (Table 6a-2).

b. Discuss how the bed material sizes vary upstream and downstream of the crossing.

c. Discuss the geomorphic controls and other factors influencing the size and range of particles upstream and downstream of the crossing.

Exercise 6b. Design: cross section width/shape, sediment mix, key pieces, and bed/bank features

1. **Design Cross Section Shape**
   a. Develop a typical cross-section shape for the design channel; sketch it on the reference reach channel cross section (**see instructors for handout).** The design channel cross section shape should be simple enough so that it can be specified in a contract and constructed at the site while having similar topography (bank height and slope) and low flow channel margin habitat/diversity as the reference reach cross section.

   b. Delineate the upper and lower vertical adjustment potential lines on the design channel cross section.

2. **Design bed mix**
   a. Based on your reference reach selection, which pebble count data (specify cross section and slope segment) would you use to determine the initial grain size mix for the stream simulation bed design? Summarize those data from the reference reach in Table 6b-1 on the next page.

   b. Calculate the fine grain size mix for the stream simulation design bed using the Fuller-Thompson equations {[$d30=(0.60^{1/n})\ d50$]; [$d10=(0.20^{1/n})\ d50$]; where n=0.45 or n=0.70}.

   c. Plot the d30 and d10 percentile particle sizes for the Fuller-Thompson equations on the particle-size distribution curve for the reference reach cross section.

   d. Based on the Fuller-Thompson calculations for the fine grain size mix and your understanding of channel-bed characteristics, select the Fuller-Thompson grain size mix that is most appropriate for the stream simulation bed design (i.e., n=0.45 or n=0.70)? Summarize those data for the design bed mix in Table 6b-1 on the next page.

3. **Key features and and bed/bank features**
   a. Do you expect to add grade controls or bedforms to the design profile? If yes, what type of grade control structures (bedforms) should be constructed in the stream simulation design bed? Describe the dimensions (depth, width, and length) and spacing of these features. Summarize those data from the reference reach and for the design bed in Table 6b-1 on the next page.

   b. Other than the grade controls or bedforms, what other large roughness elements from the reference reach need to be considered in the stream simulation design bed? To help answer this question review the photographs of the channel bed/banks, channel descriptions, the longitudinal profile, and geomorphic map. Summarize those data from the reference reach and for the design bed in Table 6b-1 on the next page.

   c. Determine the initial size (d95, d84, d50, d16), particle shape, and roundness of the key pieces required to construct the grade control structures and other large roughness elements in the design channel (Hint: Refer to the key piece information provided on page 14-16). Summarize those data from the reference reach and for the design bed in Table 6b-1 on the next page.

4. **Important characteristics**
   a. Based on the site information, photographs, and channel characteristics, what are the most important characteristics and features that you would emphasize to the engineer to consider during the design phase?

Table 6b-1. Summary of bed material and key pieces in the reference channel and the design channel.

Particle sizes and other bed/bank features	Reference channel		Stream simulation channel	
	Channel bed	Key pieces	Design bed mix	Key pieces
Bed d95 (mm)				
Bed d84 (mm)				
Bed d50 (mm)				
Bed d30 (mm)		not applicable		not applicable
Bed d16 (mm)			not applicable	
Bed d10 (mm)		not applicable		not applicable
Bed d5 (mm)		not applicable		not applicable
Bedforms				
Wood				
Banklines				
Colluvium				

Exercise 7. Structure type selection

1. Provide two or three preliminary structure widths to consider for the replacement road-stream crossing. Discuss the rationale and criteria used for selecting the different structure widths.

2. What geomorphic, ecological, and engineering factors were considered for the different structure width selections? List the pros and cons (i.e., from a geomorphology, ecology, and engineering perspective) for each of the structure widths selected.

3. Place the culvert acetate overlays (**see instructors for handouts**) over the reference reach cross section and design channel cross section to see how well each structure fits over the channel. Use the criteria listed below along with the structure information provided on page 14-17 to choose one or more preferred structures for the tributary to Schafer Creek road-stream crossing:
   a. Overall Fit
      - Adequate cover height
      - Adequate embedment depth for the channel to adjust and maintain a stable bed/banks
      - Adequate span and rise to construct a channel bed
   b. Constructability of the stream simulation bed, banks, and bedforms
   c. Debris passage
   d. Costs of structure and excavation
   e. Durability

4. List the structures selected along with the rationale and criteria used for selecting the structures.

Choice A
Choice B

5. List those structures that were not feasible choices at the site. Explain why those structures were not feasible choices at the site.

Exercise 9. Bed stability/mobility analysis

1. **Determining which equation to use in the analyses**
   a. Based on your understanding of site characteristics, discuss which equation (unit discharge approach, shear stress approach, or both) appears to be most appropriate for predicting particle mobility and stability at the site.

2. **Reference reach: Flow hydraulics. Choose a cross section representative of your reference reach. For the purpose of this exercise assume that your reference reach cross section is represented by either XS4 or XS10.**
   a. Based on the information provided on page 14-19 or on page 14-20 and the data obtained from the previous exercises, calculate the total boundary shear stress, channel boundary shear stress, total unit discharge, and channel unit discharge for bankfull discharge (4 m^3/s) at the reference reach cross section selected by the group.

   b. Briefly describe how total and channel boundary shear stress and total and channel unit discharge changes with discharge.

3. **Reference reach: Particle MOBILITY, modified critical shear stress**
   a. Based on the information provided on page 14-19 or page 14-20 and the data obtained from the previous exercises, calculate the threshold critical shear stress (τ_{ci}) to entrain the d84 particle size at the reference reach cross section selected by the group.

   b. Using the information provided on page 14-19 or 14-20, determine the discharge the d84 particle size is mobilized in the reference reach channel.

4. **Stream simulation design channel: Flow hydraulics**
   a. Based on the design channel dimensions and structure type selected by the group, calculate the total boundary shear stress, channel boundary shear stress, total unit discharge, and channel unit discharge for the design channel at different flood stages (**see instructor to obtain the appropriate handouts to answer this question**).

5. **Stream simulation design channel: Particle MOBILITY, modified critical shear stress**
   a. Based on the hydraulic information provided in the handouts for the design channel and the data obtained from the previous exercises, calculate the threshold critical shear stress (τ_{ci}) to entrain the d84 particle size in the design channel.

   b. Using the hydraulic information provided in the handouts, determine the discharge the d84 particle size is mobilized in the design channel?

   c. Do the particles in the design channel need to be adjusted to achieve similar particle mobility as in the reference reach? If yes, by how much?

6. **Stream simulation design channel: Discussion**
   a. What other adjustments could be made to the design channel so that the mobility of the d84 particle size is similar to that in the reference reach?

   b. Based on the results from the bed mobility analyses, are you still satisfied with your reference reach selection?

7. Reference reach: Particle STABILITY, modified critical shear stress

a. Based on the information provided on page 14-19 or page 14-20 and the data obtained from the previous exercises, calculate the threshold critical shear stress (τ_{ci}) to entrain the key piece d84 particle size at the reference reach cross section selected by the group.

b. Using the information provided on page 14-19 or 14-20, determine the discharge the d84 particle size is no longer stable in the reference reach channel.

8. Stream simulation design channel: Assessing particle STABILITY

a. Estimate a reasonable starting size of key pieces for the stream simulation design channel.

b. Determine the design flood at which you want the key pieces to be stable (see page 14-18). Remember, you expect the key pieces to be stable/immobile during the design flood.

c. Prior to performing any analyses, do you think it will be necessary to increase the size of the key piece particle sizes? Why?

d. Based on the hydraulic information provided in the handouts for the design channel and the data obtained from the previous exercises, determine when the key piece d84 particle size in the design channel is entrained. Use the critical shear stress approach to perform the analysis.

e. Using the hydraulic information provided in the handouts, determine the discharge the d84 particle size is no longer stable in the design channel. Compare the stability of the key piece d84 particle size in the design channel to the reference reach channel.

f. Does the key piece d84 particle size need to be increased to be stable at the design flood? If yes, by how much? Is the increase in the d84 particle size reasonable and acceptable?

Exercise 10. Bed-material specifications

1. Design-bed mix

a. Using the particle-size distribution curve and the sediment summary tables based on the results from the bed-mobility analysis for the group selected reference reach (**see instructor to obtain the appropriate handouts for this exercise**) develop a gradation specification for the design bed mixture in the table below (Table 10-1) using five different sieve sizes. Obtain the sediment sizes at reasonable percentile intervals directly off the plots to complete the table.

Table 10-1. Summary of gradation specifications for the design-bed mixture.

Sieve size (mm)	Sieve size (inches)	Percent passing
512	20	
305	12	
230	9	
150	6	
100	4	
75	3	
50	2	
25	1	
19	0.75	
4.8	#4 (0.187)	
2.4	#8 (0.937)	
1.2	#16(0.018)	

b. Based on your answers from question 1a, use the table below (Table 10-2) to develop a second gradation that quantifies the percent volume of material for the specified particle-size intervals. For example: 15 percent of the volume of material is between 230 mm and 305 mm, 25 percent of the volume of material is between 100 mm and 230 mm, etc. The total percent volume specified should sum to 100 percent.

Table 10-2. Summary of material volume for different particle size intervals.

Particle size range (mm)	Particle size range (in)	Percent volume
< 2.4	< 0.937	10
	Total percent	100

2. Key Pieces

a. Based on the bed stability analysis for the key pieces in the design channel, was it necessary to adjust the sizes of the key pieces?

b. Are there other site conditions to consider when determining or adjusting the size of the key pieces? Refer back to the key piece information provided on page 14-16 and in table 6b-1 to help answer this question.

c. Determine the gradation of the key pieces for the design channel using the table below (Table 10-3).

Table 10-3. Gradation requirement for fish rest stop (FRS) rock and weir rocks.

FRS Class	Mass (kg)	Approximate average cubic dimension (mm)
FRS-1	1 to 3	100 to 135
FRS-2	4 to 10	150 to 200
FRS-3	15 to 35	230 to 305
FRS-4	35 to 80	305 to 405
FRS-5	80 to 200	405 to 540
FRS-6	160 to 400	510 to 680
FRS-7	280 to 700	610 to 815
FRS-8	550 to 1300	760 to 1015
FRS-9	960 to 2300	915 to 1220
FRS-10	1500 to 3700	1070 to 1430

Group Presentation: Structure Type/Dimensions, Design Channel Characteristics, Site Risk

1. **Reference Reach and Design Gradient**
   a. Reference reach slope segment, gradient, and length.
   b. Type and spacing of bedforms in reference reach.
   c. Design gradient through replacement structure.

2. **Structure**
   a. Type, dimensions, and gradient of structure.
   b. Embedment depth and cover depth of structure.

3. **Design Profile Diagram**
   a. Draw design bed longitudinal profile through the road-stream crossing that ties into the upstream channel and the downstream channel. Be sure to extend the design bed longitudinal profile to the natural channel to show geomorphic continuity between the natural channel and the design channel.
   b. Describe the spacing of bedforms and channel units in the design channel.
   c. The following features need to be displayed on the profile:
      1) Upstream and downstream elevation control points.
      2) Extent and embedment depth of replacement structure.
      3) The location of design bedforms and natural bedforms along the profile.
      4) Delineate the lower and upper vertical adjustment potential line on the profile.
      5) Show and describe what is being done with the sediment wedge and plunge pool.

4. **Design Planform Diagram**
   a. Draw design planform diagram through the road-stream crossing that ties into the upstream channel and the downstream channel. Show and/or describe how transitions between the structure and the adjacent channel are accommodated.
   b. The following features need to be displayed on the diagram:
      1) Upstream and downstream elevation control points.
      2) Extent and orientation of replacement structure with respect to the channel.
      3) The location of design bedforms and natural bedforms along the planform diagram.
      4) Delineate the banklines through the structure and tie them into the banks of the natural channel. Show and describe how the existing banklines will be changed at the outlet and inlet transition areas after the structure is replaced.

5. **Design Cross Section(s)**
   a. Draw at least three representative cross sections (delineate the cross sections on the planform diagram):
      1) Inlet (aggradation, sediment wedge).
      2) Outlet (plunge pool).
      3) Within the replacement structure.
   b. The following features need to be displayed on the cross sections:
      1) Upper and lower vertical adjustment potential lines.
      2) For the cross section through the structure, include a diagram of the structure selected.
      3) For the inlet and outlet cross sections, show and describe what is being done with the sediment wedge and plunge pool.

6. **Design Bed Material**
   a. Design bed, gradation specifications.
   b. Key pieces, gradation specifications.

7. **Risk Assessment**
   a. List the short-term and long-term risks at the site.
   b. Discuss how the short-term and long-term risks were addressed in the design.