TFW-16E-90-004

STREAM AMBIENT MONITORING FIELD MANUAL

Version 2.0

MAY 1990

TFW-16E-90-004

TIMBER / FISH / WILDLIFE

STREAM AMBIENT MONITORING FIELD MANUAL

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May, 1990

MEMORANDUM

Date: June 13, 1990

To: Participants at TFW Field Monitoring Training
Pack Forest June 6-7- 8, 1990.

From: Steve Ralph, Monitoring Project Coordinator

Subject: Errata and comments to monitoring field methods and data sheets.

This memo is being sent to all of those attending the recent field methods training session in the hopes of clarifying the instructions and correcting errors in the field forms and instruction manual. Also enclosed are the following items that should aid in understanding the methods more thoroughly:

1. Figures from Dunne and Leopold (1978) to illustrate bankfull width and channel cross sections;
2. Figure 1 and Figure 2 of simulated stream showing habitat units, unit categorization, and horizontal control survey showing distances and azimuth.
3. Horizontal Control Survey data sheet (Form #2) filled out to match simulated stream in Fig. 1 & 2;
4. Synopsis and summary table for diagnostic features of valley segments and the detail of combinations of these features to distinguish among the 18 valley segment types;
5. A sheet showing TFW Affiliation Codes for use with the data sheet Form 1;
6. Revised pebble size categories with "mm" corrected to read "cm".
7. Revised code sheet for habitat unit codes.

Specific comments and changes are referenced to the corresponding form and section in the manual, as follows.

FORM 1. VALLEY SEGMENT SUMMARY

1. Write the specific details to locate the beginning and ending turning points in the block provided on Form 1. Give at least two (at best, three) references to these so that they can be relocated in the future.

2. The "discharge" is entered here from that measurement done at the beginning of the habitat unit survey. You only need to do a new discharge measurement everyday of the habitat unit survey when it has rained since you began the survey or when the survey takes more than five days to complete.

FORM 2. HORIZONTAL CONTROL SURVEY

1. Percent Gradient - This is only measured at those locations where bankfull width/depth measurements are made, usually within a riffle. In these cases, gradient is taken for only the unit occurring at the bankfull location, not the minimum 100 feet upstream and downstream as suggested in the manual.

2. Bankfull Width/Depth Measurements - Take a minimum of three such measurements per segment, even if the segment is less than a mile in length. As a rule of thumb, we need at least three such measurements per mile of stream surveyed. More than three would be nice. The reason the data sheet contains a bankfull width/depth entry for every turning point is that we want to know the turning

points encompassing the bankfull measurement, when it is made. So, in practice most of the spaces for bankfull width/depth associated with turning points will be left blank, and will only be filled in when a suitable site is located.

3. Bankfull Channel Definitions

   The confusion regarding where to observe and take a bankfull measurement is largely a function of the variety of conditions seen in the field. The attached figures (Dunn and Leopold 1978) should help to clarify the determination of bankfull width. Their definition for bankfull condition is when the water fills the channel completely or is at bankfull stage, its surface is level with the floodplain.

   Richards (1982) in Rivers: Form and Function - defines the bankfull condition ... which is normally defined up to the level at which overbank flow occurs - the "bankfull" section. Keep in mind that you may have to be selective where you choose to measure bankfull width/depth - so use your judgement.

4. Turning Points - Please note a typographical error on Form 2 in regards to the numbering of turning points and again under the "distance" entry space provided. Ignore all n+i notation on the data forms. Start the horizontal control survey at the beginning of the segment with turning point number "0", and measure distance and compass bearing to turning point number "1". In sequence the turning points should be entered on the same horizontal line on the data sheet as 0 to 1, then 1 to 2, 2 to 3, 3 to 4, ...till you reach the end of the segment. Since it is too late to change the field forms (they are being printed now), just make the mental correction so as not to be confused about this error when it shows up on the official forms.

5. Turning Point Distances - This refers to the distance between one point and the next point established upstream. Again the designation of TP n to TP n + 1, etc. just attempts to refer to the distance between the turning points noted above, and as such should be treated the same (i.e. ignore all n+i notation). It was pointed out during the training, that the spaces provided for entering distance between turning points can be filled out one of two ways: either the distances can be cumulative (that is the distance between two points is added to that between successive pairs of points), or the distance from one point to the next is recorded, with the first box on the data sheet always reading "0". See Figure 2 and examples from attached data sheet. As some of you pointed out, it doesn't really matter which way you do this, all we're interested in is the distances between two points. We will calculate the approximate length of all turning points during the data analysis. But if you find it easier to use the hip chain and keep a cumulative running length between points, that is fine. If the string breaks between points, simply zero it out at the downstream turning point and continue upstream to the next turning point.

6. Azimuth Bearings - These should be made with the compass set at the proper declination (degrees east to compensate for influence of magnetic anomalies) and thus entered as true or adjusted bearings. Refer to corresponding USGS topographic map for correct declination for the area within which you are working.

7. Discharge is entered from Form 4 after it is taken for purposes of the habitat unit survey.

Form 3. Mass Wasting and Substrate

1. Discharge - Again is entered from Form 4.

2. Mass Wasting "length" means height of slope failure.

3. Pebble counts are done at locations where bankfull measurements are taken (usually riffles), and to ensure that we have an adequate number of pebble counts in each segment, are taken again at the first

riffle location upstream of that unit where bankfull measurements were made. If you want to do the second or third riffle (or whatever interval), that is fine as long as the number of different sites where substrate pebble counts are made is at least twice the number of bankfull measurements completed by the end of the segment survey. If you note dramatic changes in substrate sizes within a reach (e.g. from gravel to cobble/boulder), get at least three pebble counts in each part of the segment.

4. Substrate particle size categories listed on page 23 of the manual and in Appendix B are given in both English and metric equivalents. All of the metric equivalents are mislabeled as "mm" (millimeters). They should read "cm" (centimeters), e.g. large cobble at 25 to 50 inches = 64 to 128 cm.

5. Embeddedness - Only give one embeddedness rating per entire riffle site at which pebble counts are made. Do this after the pebble count is completed because by then you should have a pretty good idea of the % embeddedness that appears for the whole unit, on the average.

Forms 4A and 4B - Habitat Unit Survey

1. Unit Number - Enter a sequential number for every habitat unit encountered. This is simply a way of numbering the units found within a segment as you progress upstream during your survey. If, for example the first unit you encounter is a low gradient riffle. This is unit number 1 (one). Simply enter one in the space provided under unit number and darken in the circle below that corresponding to that number. Four spaces are provided in case you exceed 1000 units during your segment survey. The second unit may be a slip face cascade. This is entered at unit number 2 (two). See the accompanying data sheet sample filled out.

2. Habitat Unit Dimensions

   a. Habitat Width - Estimate (or measure) average width of a unit by dividing the unit along its long axis into three imaginary sections, and approximate (or measure) the unit width at these locations. Determine the average of these three widths and record on the data sheet.

   b. Habitat Depth - Determine average depth for all units except cascades and rapids. This is done similarly to width above, but more measurements may be needed at larger units. Enter average depth in category marked "Depth (1)" on Forms 4A and 4B. For pools, the crest or outlet depth of pools is entered under "Depth (1)", and the maximum depth of the pool is entered under "Depth (2)".

3. Obstructions - Note that a change should be made under the choices for obstructions to allow for "root wads" acting as obstructions within the channel that act to form pools. On the Habitat Unit Code sheet (attached revised version) note the change in code #8 from "other" to "root wad", with #9 added to account for "other".

4. Unit Category - There was some confusion about when to use the "side channel" category. This is when a branching occurs off of the main channel, which carries less than half of the entire flow. Note all units that occur within this side channel, but don't bother to distinguish between those units occupying either > 50% or < 50% of the wetted width of the channel (i.e. ignore the fact that they may be linked or nested; see Figure 1). For our purposes, islands only occur in 7th order and larger (i.e. really big) rivers. Therefore, don't worry about whether you have islands or side channels; they will all be coded as side channels in these surveys.

5. Habitat Unit Type

   a. Eliminate SDC or Secondary Channel as a habitat type because it is redundant to the unit category discussed above.

   b. Add SSF to refer to subsurface flow or dry channels

6. Substrate Particle Size Codes have been changed to correct the earlier error regarding the metric equivalents.

7. Large Woody Debris

   a. Size classes - two size classes will be used again this year in distinguishing among woody debris. "Small" woody debris ranges in size from a minimum of 8 to 20 inches diameter, while "large" woody debris is greater than 20 inches in diameter. A minimum length of 10 feet must be met before a piece can be counted.
   b. Log jams - Since a separate category is not provided for log jams, we ask that you estimate the number and size of pieces of woody debris within a jam.

8. Seral Stage - Note that a "young" seral stage has been added (coded as #5) to account for stands intermediate to "pole" and "mature timber" stages. The code number for these stages changes to 6 and 7, respectively.

APPENDIX B. Version 2.0, May 1990

HABITAT UNIT CODES

UNIT CATEGORY
1) > OR = 50% WETTED WIDTH
2) UNIT < 50% WETTED WIDTH
3) OCCURS IN SIDE CHANNEL

UNIT TYPE
1) CASCADE
RPD = RAPID
SPC = STEP-POOL CASCADE
SFC = SLIP-FACE CASCADE

2) RIFFLES
PKW = POCKETWATER
GLD = GLIDE
RUN = OBVIOUS!
LGR - LOW GRADIENT RIFFLE

3) POOLS
DMP = DAMMED POOLS
EDP = EDDY POOL
PLP = PLUNGE POOL
SCP = SCOUR POOL
SCH = SCOUR HOLE

4) BEAVER PONDS
BVP = BEAVER PONDS

5) DRY CHANNEL = SSF
SUBSURFACE FLOW

OBSTRUCTIONS (FOR POOLS):

1 - LOG(S)
2 - WOODY DEBRIS JAM
3 - STANDING TREE
4 - BOULDER (S)
5 - BEDROCK
6 - ROOT PROTECTED BANKS
7 - BEDFORM
8 - ROOT WAD
9 - OTHER*
(* EXPLAIN IN COMMENTS SECTION)

SUBSTRATE PARTICLE SIZE CODE:

CODE	SEDIMENT SIZE	
10	BOULDER	>50"
9	LG. COBBLE	25-50"
8	MED. COBBLE	12-25"
7	SM. COBBLE	6-12"
6	COARSE GRAVEL	3-6"
5	MED. GRAVEL	1.6-3"
4	SM. GRAVEL	0.8-1.6"
3	PEA GRAVEL	1-2CM
2	COARSE SAND	0.5-1.0CM
1	MED. SAND	0.25-0.50CM
0	FINE SAND	0.125-0.250CM

WOODY DEBRIS LOCATION:
A = NOT WITHIN WETTED AREA
B = PARITALLY WITHIN UNIT
C = COMPLETELY WITHIN UNIT
D = BRIDGED

SERAL STAGE:
1 = CLEAR CUT
2 = GRASS/FORB
3 = SHRUB
4 = POLE
5 = YOUNG
6 = MATURE
7 = OLD GROWTH

VEGETATIVE TYPE: (WOODY)
1 = DECIDUOUS
2 = CONFEROUS
3 = MIXED

LAND USE:
1 = AGRICULTURE
2 = LIVESTOCK GRAZING
3 = TIMBER
4 = RESIDENTIAL
5 = RIGHT OF WAY
6 = MINING
7 = RMZ
8 = WETLAND
9 = OTHER (EXPLAIN)

EMBEDDEDNESS:
1 = > 75%
2 = 50 - 75%
3 = 25 - 25%
4 = 5 - 25%
5 = < 5%

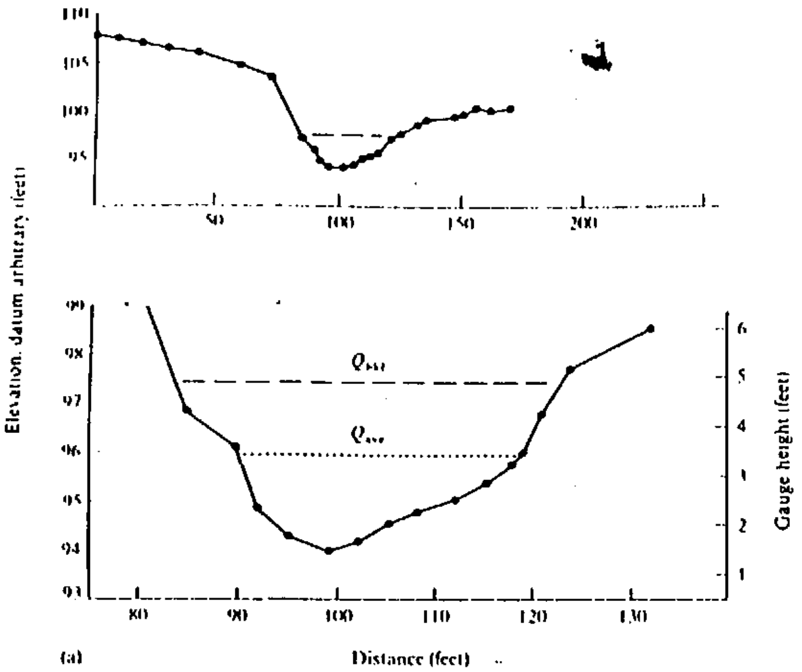
TABLE 2. CLASSIFICATION OF STREAM BEDLOAD (SUBSTRATE) BY PARTICLE SIZE.

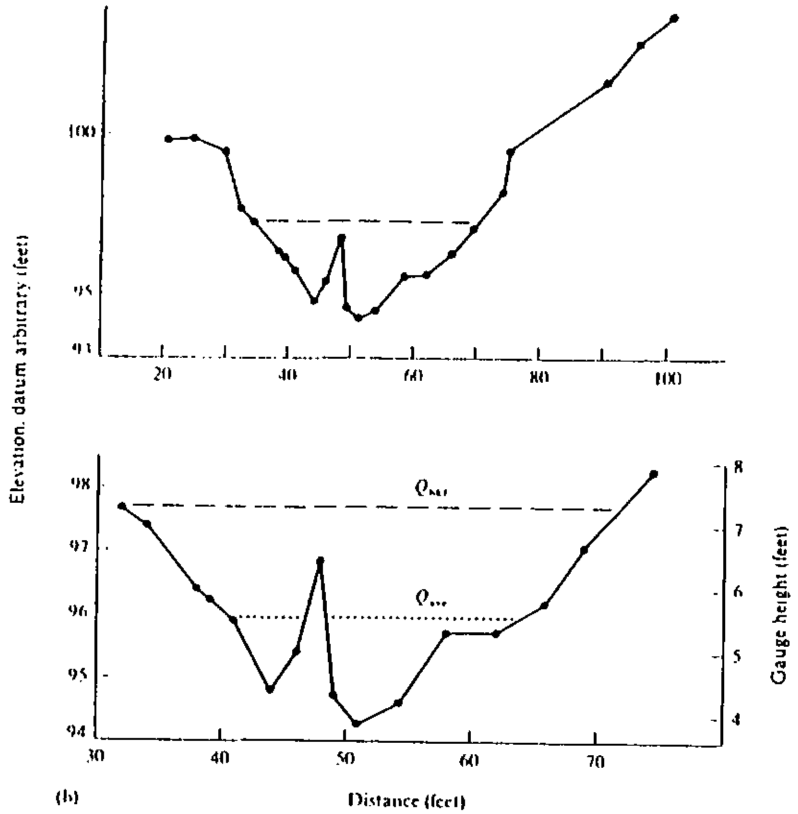
PARTICLE DIAMETER SIZE	SEDIMENT	CODE
> 50 inches (128cm)	boulder	10
25 to 50 in. (64-128cm)	large cobble	9
12 to 25 in. (32-64cm)	medium cobble	8
6 to 12 in. (16-32cm)	small cobble	7
3 to 6 in. (8-16cm)	coarse gravel	6
1.6 to 3 in. (4-8cm)	medium gravel	5
0.8 to 1.6 in. (2-4cm)	small gravel	4
0.4 to 0.8 in. (1-2cm)	pea gravel	3
0.2 to 0.4 in. (0.5-1cm)	coarse sand	2
0.1 to 0.2 in. (0.25-0.5cm)	medium sand	1
0.05 to 0.1 in. (0.125 to 0.25 cm)	fine sand	0

B. Gravel Embeddedness

Embeddedness rates the degree that the larger particles (boulder, rubble, or gravel) are surrounded or covered by fine sediment. The rating is a measurement of how much of the surface area of the larger size particles is covered by fine sediment (silt or sand). We have not included an additional rating that would describe the nature of the embedding material (sand or silt) at this time, but may include this in subsequent years. An embeddedness rating should allow for some qualitative evaluation of the channel substrate suitability for spawning, egg incubation, and habitats for aquatic invertebrates, and young overwintering fish. The rearing quality of the instream cover provided by the substrate can be evaluated also. As the percent of embeddedness increases, the biotic productivity is also thought to decrease.

This estimate of embeddedness will be done at the riffle locations selected for the characterization of the bed material, as described above. To enhance one's judgement in making this rating, remove a particle of bed material and try to estimate as a % how much of the vertical dimension of the particle was embedded by sand or silt. Usually, a distinct line can be seen on the surface where the portion not embedded was exposed to flowing water. Classify the percent embeddedness according to the following rating, and mark the data sheet accordingly:





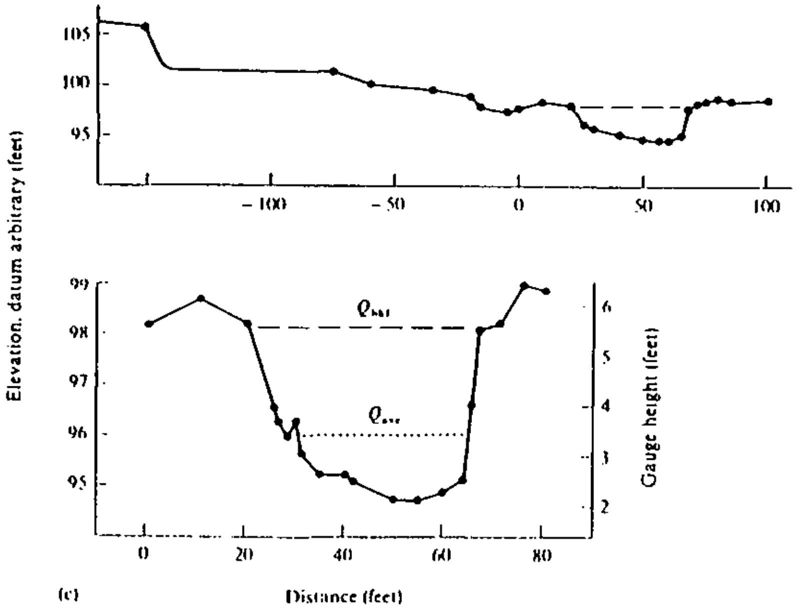


Figure 16-7 (a) New Fork River below New Fork Lake: drainage area 36.2 sq mi; slope .0051; bed material D_{50} 52 mm; $Q_{1.5}$ 355 cfs; Q_{bkf} 340 cfs; Q_{ave} 50.5 cfs.
(b) Fall Creek near Pinedale, Wyoming: drainage area 37.2 sq mi; slope .040; bed material D_{50} 210 mm. $Q_{1.5}$ 350 cfs; Q_{bkf} 315 cfs; Q_{ave} 39.4 cfs.
(c) Silver Creek near Big Sandy, Wyoming: drainage area 45.4 sq mi; slope .004; bed material D_{50} 45 mm; $Q_{1.5}$ 600 cfs; Q_{bkf} 390 cfs; Q_{ave} 43 cfs.

The Floodplain and Bankfull Stage

The cross sections of Figure 16-7, as well as general observation, illustrate the fact that most river channels are bordered by a relatively flat area or valley floor. When the water fills the channel completely or is at bankfull stage, its surface is level with the floodplain. This is a word of great importance to the environmental planner as well as to the geomorphologist, and its definition must be understood in terms of river morphology as well as in terms of flood potential. It is defined as follows*:

The floodplain is the flat area adjoining a river channel constructed by the river in the present climate and overflowed at times of high discharge. Each part of this definition is important and will be elaborated.

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*Refer also to the footnote on p. 428 on this term as used by engineers and other specialists concerned with water resources and land-use planning.

from: Dunne, T. and L. B. Leopold. Water in Environmental Planning. 1978. W.H. Freeman and Co. pp 600-605

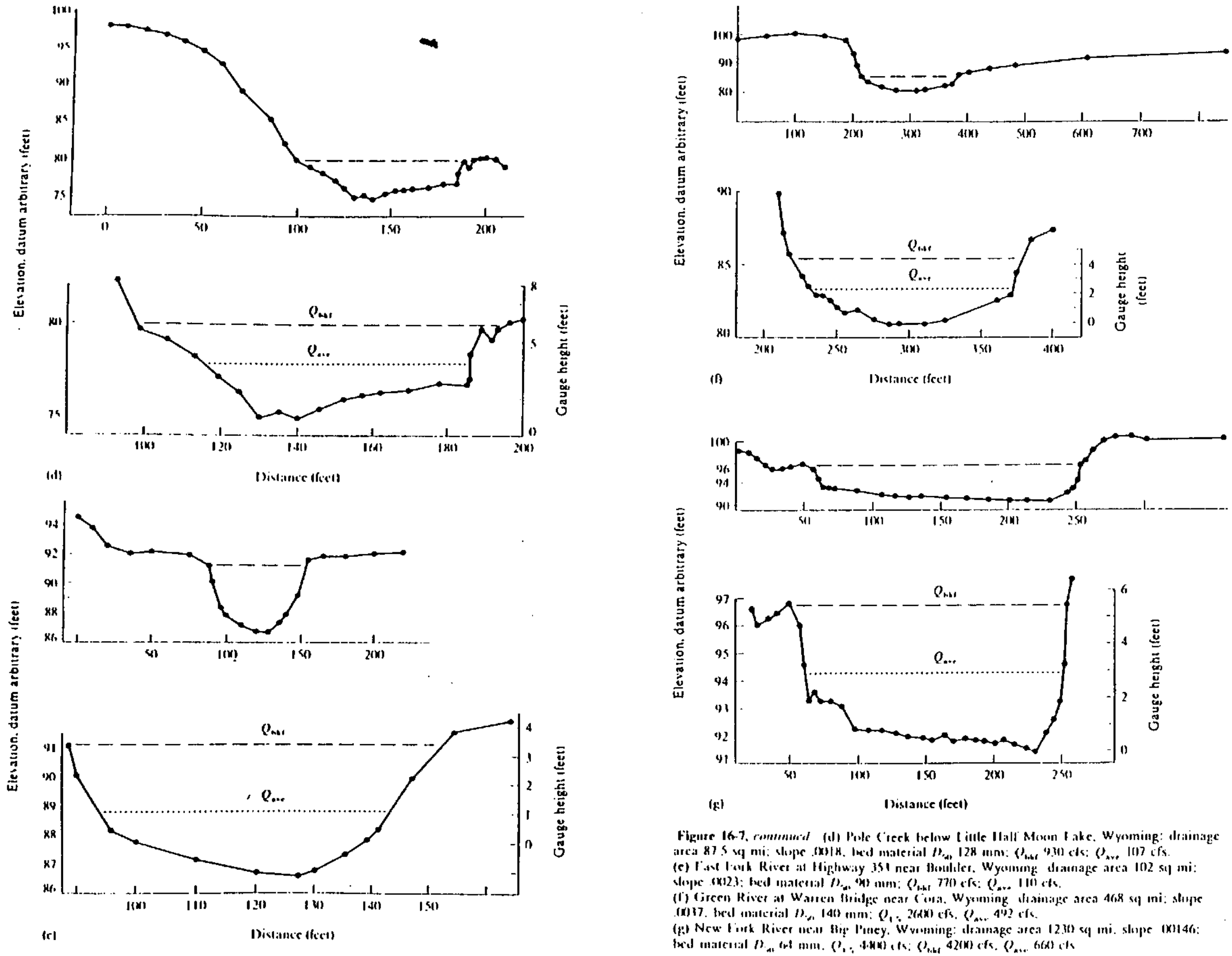


Figure 16-7, *continued* (d) Pole Creek below Little Half Moon Lake, Wyoming: drainage area 87.5 sq mi; slope .0018, bed material D_{50} 128 mm; Q_{bkf} 930 cfs; Q_{ave} 107 cfs.
(e) East Fork River at Highway 353 near Boulder, Wyoming: drainage area 102 sq mi; slope .0023; bed material D_{50} 90 mm; Q_{bkf} 770 cfs; Q_{ave} 110 cfs.
(f) Green River at Warren Bridge near Cora, Wyoming: drainage area 468 sq mi; slope .0037, bed material D_{50} 140 mm; $Q_{1.5}$ 2600 cfs, Q_{ave} 492 cfs.
(g) New Fork River near Big Piney, Wyoming: drainage area 1230 sq mi, slope .00146; bed material D_{50} 64 mm, $Q_{1.5}$ 4400 cfs; Q_{bkf} 4200 cfs, Q_{ave} 660 cfs.

FIGURE1. HYPOTHETICAL STREAM : HABITAT UNITS AND CATEGORIES

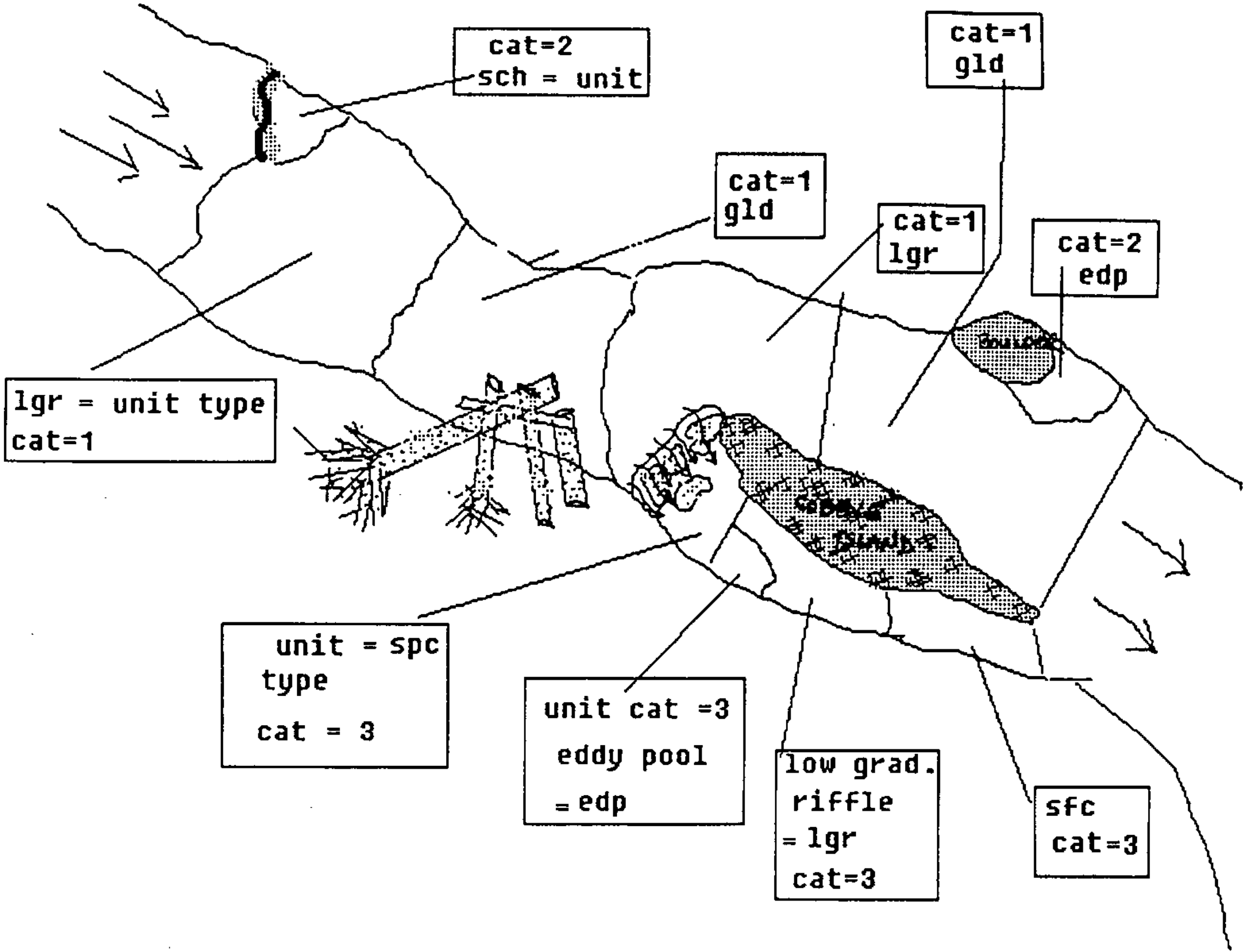
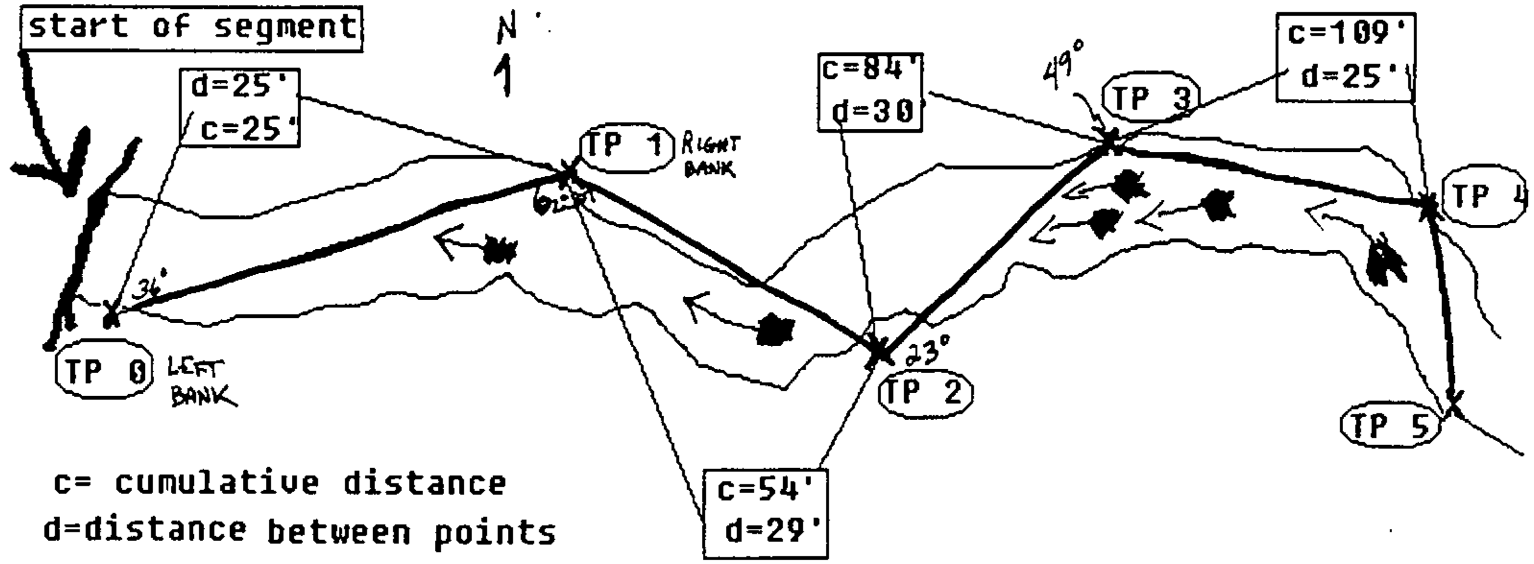


FIGURE 2. HORIZONTAL CONTROL SURVEY SIMULATION



HORIZONTAL CONTROL SURVEY

and Substrate data (FORM 3) before starting habitat unit survey (FORM 4's)
2 Complete written header
3 Refer to code reference sheet and field manual for codes and procedures

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page 1 of 2

STREAM NAME (CIRCLE ONE)	DATE MO. DAY YR.	VALLEY SEGMENT	W.R.I.A. NUMBER	UNITS (CIRCLE ONE)	DISCHARGE (CIRCLE ONE)
NO NAME [✓ CREEK] RIVER	06 15 90	V2	16.1726 ○ UNLISTED	[✓ FEET] METERS	16.10 [✓ MEAS] EST

TURNING POINTS ~~n~~ 0	TURNING POINTS ~~n+1~~ 1	AZIMUTH (0-359)	GRADIENT (%)	PHOTOGRAPHS ROLL	PHOTOGRAPHS FRAME	DISTANCE TP 0	DISTANCE TP ~~n+1~~ 1	BANKFULL WIDTH	BANKFULL DEPTH
0 ● LEFT BANK ○ RIGHT BANK	1 ○ LEFT BANK ● RIGHT BANK	36 ○ MAGNETIC ● TRUE	. ○ < 5	1	1	0	85	.	.

TURNING POINTS 1 ~~n+2~~	TURNING POINTS 2 ~~n+3~~	AZIMUTH (0-359)	GRADIENT (%)	PHOTOGRAPHS ROLL	PHOTOGRAPHS FRAME	DISTANCE TP ~~n+2~~ 1	DISTANCE TP ~~n+3~~ 2	BANKFULL WIDTH	BANKFULL DEPTH
1 ○ LEFT BANK ● RIGHT BANK	2 ● LEFT BANK ○ RIGHT BANK	82 ○ MAGNETIC ● TRUE	. ○ < 5	1	2	25	54	.	.

re 4/90

Continue on back of form.

TURNING POINTS

"n + 4" 2 ● LEFT BANK ○ RIGHT BANK

"n + 5" 3 ○ LEFT BANK ● RIGHT BANK

AZIMUTH (0-359)

23 ○ MAGNETIC ● TRUE

GRADIENT (%)

. ○ <.5

PHOTOGRAPHS

ROLL 1 FRAME 3

DISTANCE

~~TP n + 4~~ TP 2 ~~TP n + 5~~ TP 3

0 30

BANKFULL

WIDTH . DEP

TURNING POINTS

"n + 6" 3 ○ LEFT BANK ● RIGHT BANK

"n + 7" 4 ○ LEFT BANK ● RIGHT BANK

AZIMUTH (0-359)

49 ○ MAGNETIC ● TRUE

GRADIENT (%)

1.5 ○ <.5

PHOTOGRAPHS

ROLL 1 FRAME 4

DISTANCE

~~TP n + 6~~ 3 ~~TP n + 7~~ 4

0 25

BANKFULL

WIDTH 32.7 DEP 5

TURNING POINTS

"n + 8" 4 ○ LEFT BANK ● RIGHT BANK

"n + 9" 5 ● LEFT BANK ○ RIGHT BANK

AZIMUTH (0-359)

○ MAGNETIC ○ TRUE

GRADIENT (%)

. ○ <.5

PHOTOGRAPHS

ROLL 1 FRAME 5

DISTANCE

TP n + 8 TP n + 9

BANKFULL

WIDTH . DEP

VALLEY SEGMENT DIAGNOSTIC FEATURES KEY

Mapping symbol:

Alphanumeric code used to delineate valley segment on maps

VALLEY BOTTOM SLOPE:	roughly corresponds to valley bottom longitudinal gradient measured in lengths of at least 40 times the active channel, or bankfull width; initially measured from topographic maps and then field verified
SIDESLOPE GRADIENT:	describes the cross sectional profile of stream and valley corridor; gradients are measured for the initial 100 vertical meters and/or the initial 300 meters slope distance; distinct breaks in gradient are not averaged, but instead are qualitatively addressed in descriptions
VALLEY BOTTOM WIDTH:	ratio of valley bottom width to active channel width (bankfull width); valley bottom is defined as the essentially flat area adjacent to the stream channel
CHANNEL PATTERN:	describes overall amount of channel constraint, degree of sinuosity, and braiding characteristic of channel
CHANNEL ADJACENT GEOMORPHIC SURFACES:	brief listing of commonly associated geomorphic surfaces; these are not considered definitive criteria to identify valley segments, but are provided for stream managers with this type of information available
GENERAL DESCRIPTIONS:	a brief narrative on landform, general position in the watershed, keys to easy identification, and keys to separate from similar segment types

Table 1. Valley bottom and sideslope geomorphic characteristics used to identify 18 valley segment types in forested lands of Washington. **Valley bottom gradient** is measured in lengths oF 1000 ft. or more. **Sideslope gradient** characterizes the hillslopes within 1000 horizontal and 300 vertical ft. distance from the active channel. **Valley bottom width** is a ratio of the valley bottom width to active channel width. **Stream order** as defined by Strahler (1957). Valley segment type name include alphanumeric mapping codes in boldface.

Valley Segment Type	Valley Bottom Gradient	Side-Slope Gradient	Valley Bottom Width	Channel Pattern	Stream Order	Landform and Geomorphic Features
F1 - Estuarine Delta	≤ .5%	< 5%	> 5X	unconstrained; highly sinuous; often braided	any	occur at mouth of streams on estuarine flats in and just above zone of tidal influence
F2 - Alluviated Lowlands	≤ 1%	> 5%	> 5X	unconstrained; highly sinous	any	wide floodplains typically formed by present or historic large rivers within flat to gently rolling lowland landforms; sloughs, oxbows, and abandoned channels commonly associated with mainstem rivers
F3 - Wide Mainstem Valley	≤ 2%	< 5%	> 5X	unconstrained moderate to high sinuosity; braids common	any	wide valley floors bounded by mountain slopes; generally associated with mainstem rivers and the tributary streams flowing through the valley floor; sloughs and abandoned channels common
F4 - Alluvial/ Colluvial Fan	1%-3%	≤ 10%	> 3X	variable; generally unconstrained	1-4	generally occur where tributary streams enter low gradient valley floors; ancient or active alluvial / colluvial fan deposition overlying floodplains of larger, low gradient stream segments; stream may actively downcut through deep alluvial fan deposition

Table 1 continued. Valley bottom and sideslope geomorphic characteristics of 18 valley segment types.

Valley Segment Type	**Valley Bottom Gradient**	**Side-Slope Gradient**	**Valley Bottom Width**	**Channel Pattern**	**Stream Order**	**Landform and Geomorphic Features**
F5 - Gently Sloping Plateaus and Terraces	≤ 2%	< 10%	1-2X	moderately constrained; low to moderate sinuosity	1-3	drainage ways shallowly incised into flat to gently sloping landscape; narrow active floodplains; typically associated with small streams in lowlands, cryic uplands or volcanic flanks
M1 - Moderate Slope Bound	2%-5%	10%-30%	< 2X	constrained; infrequent meanders	1-4	constrained, narrow floodplains bounded by moderate gradient sideslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks
M2 - Alluviated, Moderate Slope Bound	≤ 2	< 5%, gradually increase to 30%	2-4X	unconstrained; moderate to high sinuosity	1-4	active floodplains and alluvial terraces bounded by moderate gradient hillslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks
V1 - V-Shaped, Moderate Gradient Bottom	2%-6%	30%-70%	< 2X	constrained	≥2	deeply incised drainage ways with steep competent sideslopes; very common in uplifted mountainous topography; less commonly associated with marine or glacial outwash terraces in lowlands and foothills
V2 - V-Shaped, High Gradient Bottom	6%-11%	30%-70%	< 2X	constrained	≥ 2	same as above, but valley bottom longitudinal profile steep with pronounced stairstep characteristics

Table 1 continued. Valley bottom and sideslope geomorphic characteristics of 18 valley segment types.

Valley Segment Type	**Valley Bottom Gradient**	**Side-Slope Gradient**	**Valley Bottom Width**	**Channel Pattern**	**Stream Order**	**Landform and Geomorphic Features**
U3 - Incised U-Shaped Valley, High Gradient Bottom	6%-11%	steep channel adjacent slopes, decreases to < 30%, then increases to > 30%	< 2X	moderately constrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	channel downcuts through deep valley bottom glacial till, colluvium or coarse glacio fluvial deposits; cross sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate sideslopes composed of unconsolidated and often unsorted coarse grained deposits
U4 - Active Glacial Outwash Valley	1%-7%	initially < 5%, increasing to > 60%	< 4X	unconstrained; highly sinuous and braided	1-3	stream corridors directly below active alpine glaciers; channel braiding and shifting common; active channel nearly as wide as valley bottom
H1 - Moderate Gradient Valley Wall / Headwater	3%-6%	> 30%	< 2X	constrained	1-2	small drainage ways with channels slightly to moderately entrenched into mountain toeslopes or headwater basins.
H2 - High Gradient Valley Wall / Headwater	6%-11%	> 30%	< 2X	constrained; stairstepped	1-2	small drainageways with channels moderately entrenched into high gradient mountainslopes or headwater basins; bedrock exposures and outcrops common; localized alluvial/colluvial terrace deposition
H3 - Very High Gradient, Valley Wall / Headwater	11%+	> 60%	< 2X	constrained; stairstepped	1-2	small drainage ways with channels moderately entrenched into very steep mountainslopes or headwater basins; bedrock exposures and outcrops frequent

TFW Ambient Monitoring

AFFILIATION CODES

78	UNDEFINED
54	AMSC
59	AMSC-U.W./CSS
02	Chehalis
03	Chinook
58	CMER S.C., Other
04	Colville
05	Cowlitz
69	DNR
70	DOE
06	Duwamish
66	EPA
55	Fish St. Comm.
07	Hoh
52	Hoh-Clw. Exp For
08	Lower Elwha
09	Lummi
10	Makah
~~42~~	~~Makah T.C.~~
43	Medicine Cr T.C.
11	Muckleshoot
12	Nez Perce
13	Nisqually
51	Nisqually RMP
14	Nooksack
01	NWIFC
41	Point Elliot
40	Point No Point
15	Port Gamble
63	Public Coop.
16	Puyallup
17	Quileute
18	Quinalt
44	Quinalt T.C
53	RMP, other
19	Samish
20	Sauk-Suiattle
56	SHAM
21	Shoalwater
45	Skagit Sy. Coop.
22	Skokomish
~~23~~	[redacted]
24	Snohomish
25	Snoqualmie
46	Spokane
28	Squamish
26	Squaxin Island
27	Steilacoom
36	Stillaguamish
29	Swinomish
30	Swinomish - Ab.
62	TFW Cooperator
31	Tulalip
47	UCUT
32	Umatilla
33	Upper Skagit
64	USFS
67	USFWS
65	USGS
68	U.S. Govt, Other
60	U.W./CSS
34	Warm Springs
71	WDF
61	Weyerhaeuser
57	WQSC
35	Yakima
50	Yakima RMP

ev. 4/90

TFW Ambient Monitoring

VALLEY SEGMENT SUMMARY

1. Use this form once for each valley segment.
2. Note Access points in block provided.
3. Date indicates initial survey start date.
4. Refer to code reference sheet and field manual for codes and procedures.

FORM 1

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks. Page ___ of ___.

STREAM NAME

○ CREEK ○ RIVER

Each of the 14 columns: Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ Ⓙ Ⓚ Ⓛ Ⓜ Ⓝ Ⓞ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ

DATE

DAY: ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑰ ⑱ ⑲ ⑳ ㉑ ㉒ ㉓ ㉔ ㉕ ㉖ ㉗ ㉘ ㉙ ㉚ ㉛

MONTH: ○ MAY ○ JUNE ○ JULY ○ AUG ○ SEPT ○ OCT ○ NOV

YEAR: ○ 90 ○ 91 ○ 92 ○ 93

VALLEY SEGMENT

N

Column 1: Ⓦ Ⓥ Ⓗ Ⓤ Ⓕ

Column 2: ⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

OFFICE USE ONLY: ⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

W.R.I.A NUMBER

○ UNLISTED

Columns 1–2: ⓪ ① ② ③ ④ ⑤ ⑥

Columns 3–6: ⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Column 7: ⓐ ⓑ ⓒ ⓓ ⓔ ⓕ ⓖ ⓗ ⓘ ⓙ

STREAM ORDER

① ② ③ ④ ⑤ ⑥ ⑦

SURVEYORS/AFFILIATIONS

CALLER

S1 A1 S2 A2 S3 A3

S1, S2, S3 (two columns each): Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ Ⓙ Ⓚ Ⓛ Ⓜ Ⓝ Ⓞ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ

A1, A2, A3 (two columns each): ⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

DESCRIPTION OF ACCESS AND REFERENCE TO TURNING POINTS:

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Printed in U S A

rev 4/90

Please complete back of form.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

LOWER BOUNDARY LOCATION

TOWN			RNG			SEC		¼ OF ¼			
0	0	N	0	0	E	0	0	N	E	N	E
1	1	S	1	1	W	1	1	S	W	S	W
2	2		2	2		2	2				
3	3		3	3		3	3				
4	4		4	4			4				
	5			5			5				
	6			6			6				
	7			7							
	8			8							
	9			9							

ELEVATION

○ FEET
○ METERS

0	0	0	0	0
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9

PHOTOGRAPHS

YR		AFF		C	.	ROLL		
0	0	0	0	0		0	0	0
1	1	1	1	1		1	1	1
2	2	2	2	2		2	2	2
3	3	3	3	3		3	3	3
4	4	4	4	4		4	4	4
5	5	5	5	5		5	5	5
6	6	6	6	6		6	6	6
7	7	7	7	7		7	7	7
8	8	8	8	8		8	8	8
9	9	9	9	9		9	9	9

TURNING POINT

0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

LOWER (NEXT) VALLEY SEG.

		OFFICE USE ONLY
W	0	0
V	1	1
H	2	2
U	3	3
F	4	4
	5	5
	6	6
	7	7
	8	8
	9	9

UPPER BOUNDARY LOCATION

TOWN			RNG			SEC		¼ OF ¼			
0	0	N	0	0	E	0	0	N	E	N	E
1	1	S	1	1	W	1	1	S	W	S	W
2	2		2	2		2	2				
3	3		3	3		3	3				
4	4		4	4			4				
	5			5			5				
	6			6			6				
	7			7							
	8			8							
	9			9							

ELEVATION

○ FEET
○ METERS

0	0	0	0	0
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9

PHOTOGRAPHS

YR		AFF		C	.	ROLL		
0	0	0	0	0		0	0	0
1	1	1	1	1		1	1	1
2	2	2	2	2		2	2	2
3	3	3	3	3		3	3	3
4	4	4	4	4		4	4	4
5	5	5	5	5		5	5	5
6	6	6	6	6		6	6	6
7	7	7	7	7		7	7	7
8	8	8	8	8		8	8	8
9	9	9	9	9		9	9	9

TURNING POINT

0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

UPPER (NEXT) VALLEY SEG.

		OFFICE USE ONLY
W	0	0
V	1	1
H	2	2
U	3	3
F	4	4
	5	5
	6	6
	7	7
	8	8
	9	9

NOTES:

TFW Ambient Monitoring

HORIZONTAL CONTROL SURVEY

FORM 2

1. Complete horizontal control survey (this form) and provide Mass Wasting and Substrate data (FORM 3) before starting habitat unit survey (FORM 4's)
2. Complete written header.
3. Refer to code reference sheet and field manual for codes and procedures.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page 1 of 2

STREAM NAME (CIRCLE ONE ↓)	NO NAME [✓ CREEK] RIVER
DATE MO. DAY YR.	06 15 90
VALLEY SEGMENT	V2
W.R.I.A. NUMBER	16.1726 ○ UNLISTED
UNITS (CIRCLE ONE)	[✓ FEET] METERS
DISCHARGE (CIRCLE ONE ↓)	16.10 [✓ MEAS] EST

TURNING POINTS		AZIMUTH (0-359)	GRADIENT (%)	PHOTOGRAPHS ROLL	PHOTOGRAPHS FRAME	DISTANCE TP 0	DISTANCE TP 1	BANKFULL WIDTH	BANKFULL DEPTH
~~"n"~~ 0: 0 ● LEFT BANK ○ RIGHT BANK	~~"n+1"~~ 1: 1 ○ LEFT BANK ● RIGHT BANK	36 ○ MAGNETIC ● TRUE	. ○ .5	1	1	0	85	.	.

TURNING POINTS		AZIMUTH (0-359)	GRADIENT (%)	PHOTOGRAPHS ROLL	PHOTOGRAPHS FRAME	DISTANCE TP 1	DISTANCE TP 2	BANKFULL WIDTH	BANKFULL DEPTH
~~"n+2"~~ 1: 1 ○ LEFT BANK ● RIGHT BANK	~~"n+3"~~ 2: 2 ● LEFT BANK ○ RIGHT BANK	82 ○ MAGNETIC ● TRUE	. ○ .5	1	2	25	54	.	.

A5200

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Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

— STRING BROKE —

TURNING POINTS

~~"n + 4"~~ 2 ● LEFT BANK ○ RIGHT BANK

~~"n + 5"~~ 3 ○ LEFT BANK ● RIGHT BANK

AZIMUTH (0-359)

23 ○ MAGNETIC ● TRUE

GRADIENT (%)

. ○ < .5

PHOTOGRAPHS

ROLL 1 FRAME 3

DISTANCE

~~TP n + 4~~ TP 2 ~~TP n + 5~~ TP 3

0 | 30

BANKFULL

WIDTH . DEPTH .

TURNING POINTS

~~"n + 6"~~ 3 ○ LEFT BANK ● RIGHT BANK

~~"n + 7"~~ 4 ○ LEFT BANK ● RIGHT BANK

AZIMUTH (0-359)

49 ○ MAGNETIC ● TRUE

GRADIENT (%)

1.5 ○ < .5

PHOTOGRAPHS

ROLL 1 FRAME 4

DISTANCE

~~TP n + 6~~ 3 ~~TP n + 7~~ 4

0 | 25

BANKFULL

WIDTH 32.7 DEPTH 5.7

TURNING POINTS

~~"n + 8"~~ 4 ○ LEFT BANK ● RIGHT BANK

~~"n + 9"~~ 5 ● LEFT BANK ○ RIGHT BANK

AZIMUTH (0-359)

○ MAGNETIC ○ TRUE

GRADIENT (%)

. ○ < .5

PHOTOGRAPHS

ROLL 1 FRAME 5

DISTANCE

TP n + 8 TP n + 9

BANKFULL

WIDTH . DEPTH .

TFW Ambient Monitoring

FORM 3

MASS WASTING AND SUBSTRATE

1. Indicate Turning Points adjacent to each Mass Wasting site or Bank Cutting site
2. Refer to code reference sheet and field manual for codes and procedures
3. Continue on additional FORM 3's as needed.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page ____ of ____.

STREAM NAME (CIRCLE ONE ↓) CREEK RIVER

DATE MO. DAY YR.

VALLEY SEGMENT

W.R.I.A. NUMBER ○ UNLISTED

UNITS (CIRCLE ONE) FEET METERS

DISCHARGE (CIRCLE ONE ↓) MEAS EST

MASS WASTING

TURNING POINTS								LENGTH				WIDTH			
DOWNST.				UPST.											
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

TURNING POINTS								LENGTH				WIDTH			
DOWNST.				UPST.											
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

TURNING POINTS								LENGTH				WIDTH			
DOWNST.				UPST.											
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

STREAM BANK CUTTING

TURNING POINTS								LENGTH			
DOWNST.				UPST.							
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

TURNING POINTS								LENGTH			
DOWNST.				UPST.							
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

TURNING POINTS								LENGTH			
DOWNST.				UPST.							
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

TURNING POINTS								LENGTH			
DOWNST.				UPST.							
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪
①	①	①	①	①	①	①	①	①	①	①	①
②	②	②	②	②	②	②	②	②	②	②	②
③	③	③	③	③	③	③	③	③	③	③	③
④	④	④	④	④	④	④	④	④	④	④	④
⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥	⑥
⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦	⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨

Continue on back of form

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1. Conduct Pebble Count only in riffle class units and at intervals described in field manual
2. Particle class codes are described on code reference sheet
3. Use mid point, or B axes, for particle class assignment
4. Refer to code reference sheet and field manual for codes and procedures

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

TURNING POINTS

DOWNST.				UPST			
0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9

SUBSTRATE CHARACTERIZATION (PEBBLE COUNT — 100 PARTICLES)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

RIFFLE EMBED.

○ < 5%
○ 5-25%
○ 25-50%
○ 50-75%
○ > 75%

51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

NOTES (Mass wasting, etc.):

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	WOOD LOCATION B	WOOD LOCATION C	WOOD LOCATION D	SERAL ST. LB	SERAL ST. RB	LAND USE LB	LAND USE RB	% CANOPY CLOSURE	VEG TYP
0 0 0 0	B C C	1	0 0 0 0 0	0 0 0 0	0 0 0	0 0 0 0	0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0	0	0	0	0 0	○ DEC
1 1 1 1	D D D	2	1 1 1 1 1	1 1 1 1	1 1 1	1 1 1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1	1	1	1	1 1	○ CON
2 2 2 2	E F F	3	2 2 2 2 2	2 2 2 2	2 2 2	2 2 2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	○ MIX
3 3 3 3	G G H		3 3 3 3 3	3 3 3 3	3 3 3	3 3 3 3	3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3	3	3	3	3 3	
4 4 4 4	L K P	○ MEAS.	4 4 4 4 4	4 4 4 4	4 4 4	4 4 4	4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	4	4	4	4	4 4	
5 5 5 5	P L R		5 5 5 5 5	5 5 5 5	5 5 5	5 5 5	5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5	5	5	5	5 5	
6 6 6 6	R M W		6 6 6 6 6	6 6 6 6	6 6 6	6 6 6	6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6	6	6	6	6 6	
7 7 7 7	S S	○ EST.	7 7 7 7 7	7 7 7 7	7 7 7	7 7 7	7	7 7	7 7	7 7	7 7	7 7	7 7	7 7	7	7	7	7	7 7	
8 8 8 8	Y		8 8 8 8 8	8 8 8 8	8 8 8	8 8 8	8	8 8	8 8	8 8	8 8	8 8	8 8	8 8	8	8	8	8	8 8	
9 9 9 9			9 9 9 9 9	9 9 9 9	9 9 9	9 9 9	9	9 9	9 9	9 9	9 9	9 9	9 9	9 9	9	9	9	9	9 9	

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	WOOD LOCATION B	WOOD LOCATION C	WOOD LOCATION D	SERAL ST LB	SERAL ST RB	LAND USE LB	LAND USE RB	% CANOPY CLOSURE	VEG TYPI
0 0 0 0	B C C	1	0 0 0 0 0	0 0 0 0	0 0 0	0 0 0 0	0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0	0	0	0	0 0	○ DEC
1 1 1 1	D D D	2	1 1 1 1 1	1 1 1 1	1 1 1	1 1 1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1	1	1	1	1 1	○ CON
2 2 2 2	E F F	3	2 2 2 2 2	2 2 2 2	2 2 2	2 2 2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	○ MIX
3 3 3 3	G G H		3 3 3 3 3	3 3 3 3	3 3 3	3 3 3 3	3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3	3	3	3	3 3	
4 4 4 4	L K P	○ MEAS.	4 4 4 4 4	4 4 4 4	4 4 4	4 4 4	4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	4	4	4	4	4 4	
5 5 5 5	P L R		5 5 5 5 5	5 5 5 5	5 5 5	5 5 5	5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5	5	5	5	5 5	
6 6 6 6	R M W		6 6 6 6 6	6 6 6 6	6 6 6	6 6 6	6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6	6	6	6	6 6	
7 7 7 7	S S	○ EST.	7 7 7 7 7	7 7 7 7	7 7 7	7 7 7	7	7 7	7 7	7 7	7 7	7 7	7 7	7 7	7	7	7	7	7 7	
8 8 8 8	Y		8 8 8 8 8	8 8 8 8	8 8 8	8 8 8	8	8 8	8 8	8 8	8 8	8 8	8 8	8 8	8	8	8	8	8 8	
9 9 9 9			9 9 9 9 9	9 9 9 9	9 9 9	9 9 9	9	9 9	9 9	9 9	9 9	9 9	9 9	9 9	9	9	9	9	9 9	

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	WOOD LOCATION B	WOOD LOCATION C	WOOD LOCATION D	SERAL ST. LB	SERAL ST. RB	LAND USE LB	LAND USE RB	% CANOPY CLOSURE	VEG. TYPE
0 0 0 0	B C C	1	0 0 0 0 0	0 0 0 0	0 0 0	0 0 0 0	0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0	0	0	0	0 0	○ DEC.
1 1 1 1	D D D	2	1 1 1 1 1	1 1 1 1	1 1 1	1 1 1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1	1	1	1	1 1	○ CON
2 2 2 2	E F F	3	2 2 2 2 2	2 2 2 2	2 2 2	2 2 2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	○ MIX
3 3 3 3	G G H		3 3 3 3 3	3 3 3 3	3 3 3	3 3 3 3	3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3	3	3	3	3 3	
4 4 4 4	L K P	○ MEAS.	4 4 4 4 4	4 4 4 4	4 4 4	4 4 4	4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	4	4	4	4	4 4	
5 5 5 5	P L R		5 5 5 5 5	5 5 5 5	5 5 5	5 5 5	5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5	5	5	5	5 5	
6 6 6 6	R M W		6 6 6 6 6	6 6 6 6	6 6 6	6 6 6	6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6	6	6	6	6 6	
7 7 7 7	S S	○ EST.	7 7 7 7 7	7 7 7 7	7 7 7	7 7 7	7	7 7	7 7	7 7	7 7	7 7	7 7	7 7	7	7	7	7	7 7	
8 8 8 8	Y		8 8 8 8 8	8 8 8 8	8 8 8	8 8 8	8	8 8	8 8	8 8	8 8	8 8	8 8	8 8	8	8	8	8	8 8	
9 9 9 9			9 9 9 9 9	9 9 9 9	9 9 9	9 9 9	9	9 9	9 9	9 9	9 9	9 9	9 9	9 9	9	9	9	9	9 9	

TFW Ambient Monitoring

HABITAT UNIT DATA

FORM 4A

1. Use th when beginning a survey of a new valley segment OR as the first form each day to complete the survey of the valley segment
2. Assign new date each day
3. Continue recording habitat unit data on FORM 4B
4. Measure depths to nearest 0.1 feet or 0.01 meters
5. For paired units, the second record is used for actual measurements
6. Refer to code reference sheet and field manual for codes and procedures

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page ____ of ____

STREAM NAME

☐☐☐☐☐☐☐☐☐☐☐☐

DATE — **SEE NOTE ABOVE**

DAY
○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10 ○11 ○12 ○13 ○14 ○15 ○16 ○17 ○18 ○19 ○20 ○21 ○22 ○23 ○24 ○25 ○26 ○27 ○28 ○29 ○30 ○31

MONTH
○ MAY
○ JUNE
○ JULY
○ AUG
○ SEPT
○ OCT
○ NOV

YEAR
○ 90
○ 91
○ 92
○ 93

VALLEY SEGMENT
○W ○V ○H ○U ○F
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

OFFICE USE ONLY
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

W.R.I.A. NUMBER
○ UNLISTED
☐☐.☐☐☐☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

UNITS
○ FEET
○ METERS

DISCHARGE
○ MEASURED
○ ESTIMATED
☐☐☐.☐☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

TURNING POINTS
DOWNST. ☐☐☐☐ — UPST. ☐☐☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

UNIT NUMBER
☐☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

UNIT TYPE
☐☐☐
○B ○D ○E ○G ○L ○P ○R ○S
○C ○D ○F ○G ○K ○L ○M ○S ○V
○C ○D ○F ○H ○P ○R ○W

UNIT CAT.
○1 ○2 ○3
○ MEAS
○ EST.

LENGTH
☐☐☐☐.☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

WIDTH
☐☐☐.☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

DEPTH (1)
☐.☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

DEPTH (2)
☐☐.☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

OBS.
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

LOGS
SM. ☐☐ — LG. ☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

ROOT WADS
☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

WOOD LOCATION
A ☐☐ — B ☐☐ — C ☐☐ — D ☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

SERAL ST.
LB ☐ — RB ☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

LAND USE
LB ☐ — RB ☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

% CANOPY CLOSURE
☐☐
○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

VEG. TYPE
○ DEC.
○ CON.
○ MIX

A5200

Mark Reflex® by NCS MP83530 321

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Continue on back of form

NW Indian Fisheries Commission

TFW Ambient Monitoring

HABITAT UNIT DATA (CONT'D)

FORM 4B

1. Date is carried from FORM 4A
2. Measure depths to nearest 0.1 feet or 0.01 meters.
3. For paired units, the second record is used for actual measurements.
4. Refer to code reference sheet and field manual for codes and procedures.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page ____ of ____

STREAM NAME (CIRCLE ONE ↓) CREEK RIVER

DATE MO. DAY YR.

VALLEY SEGMENT

W.R.I.A. NUMBER ○ UNLISTED

UNITS (CIRCLE ONE) FEET METERS

DISCHARGE (CIRCLE ONE ↓) MEAS EST

TURNING POINTS DOWNST. UPST.

UNIT NUMBER: 3 columns, each ○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

UNIT TYPE: ○B ○D ○E ○G ○L ○P ○R ○S | ○C ○D ○F ○G ○K ○L ○M ○S ○V | ○C ○D ○F ○H ○P ○R ○W

UNIT CAT.: ○1 ○2 ○3 ○ MEAS. ○ EST.

LENGTH: 5 columns, each ○0–○9

WIDTH: 4 columns, each ○0–○9

DEPTH (1): 3 columns, each ○0–○9

DEPTH (2): 4 columns, ○0–○9 (first column ○0–○3)

OBS.: ○0–○9

LOGS SM. LG: 4 columns, each ○0–○9

ROOT WADS: 2 columns, each ○0–○9

WOOD LOCATION A B C D: 8 columns, each ○0–○9

SERAL ST. LB RB: 2 columns, each ○0–○9

LAND USE LB RB: 2 columns, each ○0–○9

% CANOPY CLOSURE: 2 columns, each ○0–○9

VEG. TYPE: ○DEC ○CON ○MIX

UNIT NUMBER: 3 columns, each ○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

UNIT TYPE: ○B ○D ○E ○G ○L ○P ○R ○S | ○C ○D ○F ○G ○K ○L ○M ○S ○V | ○C ○D ○F ○H ○P ○R ○W

UNIT CAT.: ○1 ○2 ○3 ○ MEAS. ○ EST.

LENGTH: 5 columns, each ○0–○9

WIDTH: 4 columns, each ○0–○9

DEPTH (1): 3 columns, each ○0–○9

DEPTH (2): 4 columns, ○0–○9 (first column ○0–○3)

OBS.: ○0–○9

LOGS SM. LG.: 4 columns, each ○0–○9

ROOT WADS: 2 columns, each ○0–○9

WOOD LOCATION A B C D: 8 columns, each ○0–○9

SERAL ST LB RB: 2 columns, each ○0–○9

LAND USE LB RB: 2 columns, each ○0–○9

% CANOPY CLOSURE: 2 columns, each ○0–○9

VEG. TYPE: ○DEC. ○CON ○MIX.

rev 4/90

Continue on back of form.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM	LOGS LG.	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB RB	LAND USE LB RB	% CANOPY CLOSURE	VEG. TYPE
0 0 0 0	B C C	1	0 0 0 0 0	0 0 0 0	0 0 0	0 0 0 0	0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	○DEC.
1 1 1 1	D D D	2	1 1 1 1 1	1 1 1 1	1 1 1	1 1 1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	○CON.
2 2 2 2	E F F	3	2 2 2 2 2	2 2 2 2	2 2 2	2 2 2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	○MIX.
3 3 3 3	G G H		3 3 3 3 3	3 3 3 3	3 3 3	3 3 3 3	3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	
4 4 4 4	L K P	○	4 4 4 4 4	4 4 4 4	4 4 4	4 4 4	4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	4 4	
5 5 5 5	P L R	MEAS	5 5 5 5 5	5 5 5 5	5 5 5	5 5 5	5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	
6 6 6 6	R M W		6 6 6 6 6	6 6 6 6	6 6 6	6 6 6	6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	
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UNIT NUMBER	UNIT TYPE	UNIT CAT	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM	LOGS LG	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB RB	LAND USE LB RB	% CANOPY CLOSURE	VEG. TYPE
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TFW-16E-90-004

TIMBER / FISH / WILDLIFE

STREAM AMBIENT MONITORING FIELD MANUAL

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May, 1990

TRAINING IN THE TFW STREAM AMBIENT MONITORING FIELD PROGRAM

Field Methods Westside

June 6 - 8, 1990
or
June 20 - 22, 1990

Pack Forest Conference Center
Eatonville, Washington

Center for Streamside Studies
College of Forest Resources
University of Washington, AR-10
Seattle, WA 98195

FORWARD

This is version 2.0 of the Ambient Monitoring Field Techniques Manual, prepared for the 1990 field season. It contains important changes in the standardized field procedures to be used in the Timber, Fish and Wildlife statewide monitoring project, now in its second year of field testing. These changes are intended to enhance the reliability in the field procedures and their resultant data. The most significant changes have been made in the treatment of inchannel bottom sediment, and in the sequence in which certain data is collected. Information on sediment, channel geometric dimensions, and bank and slope stability are collected during the horizontal control survey. Habitat specific data are collected in a subsequent pass through the segment to be surveyed. An additional change has to do with the field forms used to record data. These have been completely redesigned to allow for the data to be optically scanned rather than manual transcribed.

The project objectives and rationale are detailed in a document entitled Ambient Monitoring Steering Committee Extensive Stream Survey Project Study Plan, which is available upon request. The valley segment classification system alluded to in the document is more thoroughly described in a separate manual, also available upon request. The valley segment serves as the basis for selection of distinct reaches of streams within which the field methods described herein are performed.

ACKNOWLEDGEMENTS

Both Mike Patron (Northwest Indian Fisheries Commission) and Tim Beechie (Graduate Student, CSS) contributed their insight and expertise to refinement of the field methods, and deserve special recognition. H. Morgan Hicks of the Center for Streamside Studies lent his able design skills to the layout and production of the manual. Tamre Cardoso (Graduate Student, Center for Quantitative Studies) provided editorial comments that have enhanced the document. Mike Patron (NWIFC) and Nana Lowell (Office of Educational Assessment, U.W.) provided great insight into the design of the optically scannable field forms used in recording the field data.

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TABLE OF CONTENTS

I. INTRODUCTION

This manual describes the specific field methods to be used in this the second year pilot project for the implementation of a Timber, Fish & Wildlife (TFW) statewide stream monitoring program. The Ambient Monitoring Field Project is essential for successfully meeting many of the goals of the TFW agreement, primarily by providing reliable, consistent information on the status and trends for aquatic fisheries habitat associated with forested streams within Washington State. The ambient monitoring field project has been designed with the intention that it will ultimately provide this essential information to the process of adaptive management. Reliable, up to date data on resource condition across the state will be interpreted and the results applied to the management situation. This information will provide a direct link to evaluating the overall effect of the new forest practice regulations - a perspective needed for the judicious application of "adaptive management". Adaptive management is the process that allows us to make changes in land management actions based upon an growing understanding of the relationship between land-use activities and renewable public resources supported within streams and forests.

A. Content of this Manual

This field manual is written for use by field personnel, affiliated staff and interested cooperators that will be applying these methods in the field. We have included background information on key variables to be measured as well as their methods. Many of these methods have been adapted from existing literature in the hopes of providing reliable ways in which comparable data on key riparian parameters can be collected in a consistent fashion. Some methods have been modified from those presented in the first year, as these changes were felt necessary to further the reliability of the resulting data.

B. General Strategy

The Ambient Monitoring Steering Committee (AMSC) Extensive Field Monitoring Workplan (March 1990), provides the rationale and general approach to our statewide stream monitoring field efforts and stream segment classification scheme. Two important objectives have been identified:

> to implement a broad-brush extensive survey of key physical habitat features within streams and rivers. These variables are of particular concern because they manifest the in-channel response to natural or man-induced disturbances occurring within the watershed; and

> to test the usefulness of delineating streams into their component valley segments based on recognizable combinations of key attributes. Stream segments delineated by virtue of their

five diagnostic attributes allows for an understanding of the processes that shape the character of the stream, and thus its in-channel habitat. These segments are the most easily identified large scale features of streams (Frissell and Liss 1986).

The field sampling design includes selecting streams from within the state's component ecoregions (Omernik and Gallant 1986) and delineating them by virtue of their component valley segments. The working hypothesis is that through classification, an understanding of the character of instream fisheries habitat and how it responds to land use activities and impacts (from our field surveys) can be extrapolated from one stream segment to a similar stream segment. Key to meeting this objective is a sampling effort to inventory the status of important physical features of streams on a statewide basis.

Instruction in the methods and criteria for site selection, i.e., determining "valley segment types", was the subject of a separate training exercise. A guide to identifying valley segment types by C. E. Cupp, is available from the Ambient Monitoring Program Coordinator at (206) 543-3507. A listing of the description and alphanumeric codes (revised from 1989) is included in Appendix A.

C. Background Information on Watershed Condition

By design, our level of focus in this initial sampling effort is at the stream "segment" level. Our understanding and future interpretation of the relationship between what we measure within the stream segment, the natural landscape processes at work, and ongoing land use practices, is largely dependent upon our knowledge of the unique combination of attributes and history of disturbance within a particular watershed. A separate but related project will characterize key attributes of major basins within which our sampling is occurring. These include important resources and activities conducted on the scale of watersheds, such as the following:

> basin hydrology and annual flow hydrograph,
> distribution and character of soils within the watershed,
> geologic history and geomorphic features,
> vegetation,
> the disturbance history of the basin including the pattern of forest fires, road construction and timber harvesting, evidence of mass soil failures, debris slides or other such events, and
> basin area.

Rivers and their component segment types within a watershed drainage system will be shaped to varying degrees by these features and the complex processes that account for them. Knowledge of the context within which a system resides will undoubtedly aid in our ability to interpret linkages between basin processes and changes manifested within the stream channel.

D. Field Data Collection Forms

The field data collection forms designed for the first year of this study have been modified substantially. This year, field forms have been designed that will be optically scanned to automatically transcribe the data into a computer format. By doing so, we hope to significantly reduce the need to edit the data entered on the forms, allow for more consistency in data entry, and for summary reports of collected data to be produced during the current field season. Specific instructions on filling out the corresponding field forms is included at the end of the discussion on each of the methods that follow. The field forms are not included in this section because they are still being printed at time of publication. Copies will be available by June 1990.

1. **Form 1** - Valley Segment Summary Form - The front side contains entries for name and location of stream valley segment, date of survey, WRIA number, stream order, surveyors identity and affiliation. The back side contains entries for beginning and end points that define distinct valley segments, Township and Range information, elevation, photographs, and turning points.
2. **Form 2** - Horizontal Control Survey Form - The front side contains entries for the segment location header information, distances between turning points and corresponding compass bearings, gradient, and bankfull width and depth information. The back side has additional space for recording turning point information.
3. **Form 3** - Mass Wasting/Bank Cutting and Substrate Form - The front side contains entries for recording occurrences of mass wasting or slope failures and below that are spaces for recording lengths of bank cutting. The corresponding turning points are also recorded to bracket the position associated with the entry. The back side contains entries for recording the pebble counts at selected riffles and percent embeddedness. This will be done every 300 meters at rifles such as at the nearest riffle to the points where bankfull width and depth measurements are made.
4. **Form 4A** - Habitat Unit Data Form - This form is to be used at the onset of the actual habitat unit survey. If a valley segment survey takes more than one day to complete, each successive day of the survey will start with a Form 4A. Data for a particular day's survey is continued on Form 4B (see below). Stream location information is repeated in the heading of each form; discharge or flow measurement are to be made and entered at the start of the habitat unit survey. In addition to length, width and depth (both estimated and measured) of individual units, other parameters are recorded that include obstructions, large woody debris

(LWD), seral stage of riparian vegetation, land use by bank, and percent canopy closure (measured). The back side is a continuation.

5. **Form 4B** - Habitat Unit Data Form (Continued) - This form is a continuation of Form 4A, with locational information recorded at top of each individual sheet. The back side continues the field entries for habitat unit data.

II. SUMMARY DESCRIPTION OF FIELD PROCEDURES FOR EXTENSIVE SURVEYS

This field season, several important changes have been made in the way and in the sequence in which certain methods are completed in the field. The stream course will be walked by the crew two separate times: the first pass through involves the horizontal control survey and associated measurements of substrate and channel geometry, while the second pass through involves an inventory of the individual habitat units found within the wetted area of the channel (these sampling methods involve the visual estimation techniques refined by Hankin and Reeves (1988), described later). For the field data collection effort, we will be conducting an extensive level that has two key components.

A. Horizontal Control Survey

Fields approximate stream course length by establishing "turning points" and corresponding bearings throughout the length of the valley segment; characterize substrate; channel width and depth measurements; and occurrences of bank cutting and hillslope failures (referred to here as mass wasting).

After consulting the appropriate maps, locate access to the segment and note this on Form 1. Reference the beginning and end points of the segment to some permanent feature so that they may be relocated in the future.

1. **Reference Points** - The beginning and end reference points of each surveyed segment will be marked with a rebar stake and compass bearings and distances to two fixed points will be made. This is important for baseline horizontal distance coordinates that will help locate key features of the aquatic habitat.
2. **Channel gradient** - Gradient will be verified during the horizontal control survey by shooting a gradient upstream and downstream of the locations chosen for bankfull width and depth measurements.
3. **Substrate** - Substrate will be characterized at select transects using the pebble count method (Wentworth Substrate Particle Size Classification) at uniform riffles selected every 300 meters and associated with channel width and depth measurements (see channel geometry section).
4. **Bankfull Width and Depth** - Width and depth (averaged across the channel) will be measured at a minimum of three sites per mile of stream within a segment.
5. **Channel Condition/Slope Stability** - The area (length and width) of mass failures and length of bank cutting between turning points will be noted on the data sheet provided.

6. **Photos Points** - Established during the horizontal control survey along the stream course, photos will be taken at each turning point that crosses the stream, facing upstream, whenever possible.

B. Habitat Unit Survey

This survey keys in on the occurrence and dimensions of instream habitat units; in-channel obstructions, woody debris and riparian vegetation.

1. **Discharge** - The instantaneous rate of flow past a given cross section of the channel will be measured at the beginning of a segment survey. This measurement will be taken at cross-channel transects located in uniform glides or riffles to give flow as a function of depth, velocity and wetted perimeter.
2. **Habitat Unit Identification** - Each habitat unit within a segment will be classified according to those found in the modified Bisson channel habitat units (see key to Habitat Unit Types found in Appendix E).
3. **Obstructions** - When the habitat unit encountered is a pool, choose one of eight coded categories (see code reference sheet in Appendix B) to indicate the feature that is forming that pool.
4. **Habitat Unit Dimensions** - The length and width of all units will be visually estimated. The mean depth of riffle units and the crest depth and maximum depth of pool units will be measured. In addition, a fraction of the habitat unit dimensions will be both estimated and measured to generate a correction factor for this sampling scheme that calibrates the estimated with the measured dimensions.
5. **Woody Debris** - At every habitat unit woody debris (LWD) will be counted, categorized as logs, root wads, or debris jams, and tallied in the appropriate size and location categories. Pieces of LWD that span more than one unit will only be counted once, even though they occur within subsequent units.
6. **Riparian Condition** - For every measured unit of a particular habitat type, a canopy closure measurement will be made; at every habitat unit, a gross characterization of the adjacent riparian plant community seral stage will be recorded and the apparent land use by bank will be noted.

III. VALLEY SEGMENT SUMMARY - FORM 1

This form is completed only once per valley segment to compile the important information regarding stream name, location, segment type, order, unique identifier, and upper/lower boundaries as delineated by corresponding turning points. Some of the entries cannot reasonably be filled in until the segment survey itself has been completed (for example the turning point and photo log). Most field entries are self explanatory, and the discussion below focuses only on those that need some explanation.

A. Stream Name

Write in the name and fill in bubbles corresponding to the letters of the name for the stream or river as it appears on the USGS Quad Map.

B. Valley Segment Type

The segment type should have been determined prior to initiating the survey. Initial designations may be in error and should be brought to the attention of the local tribal contact, or project coordinator.

C. WRIA Number

This number must be filled out for each stream. Contact tribal coordinator for help if needed.

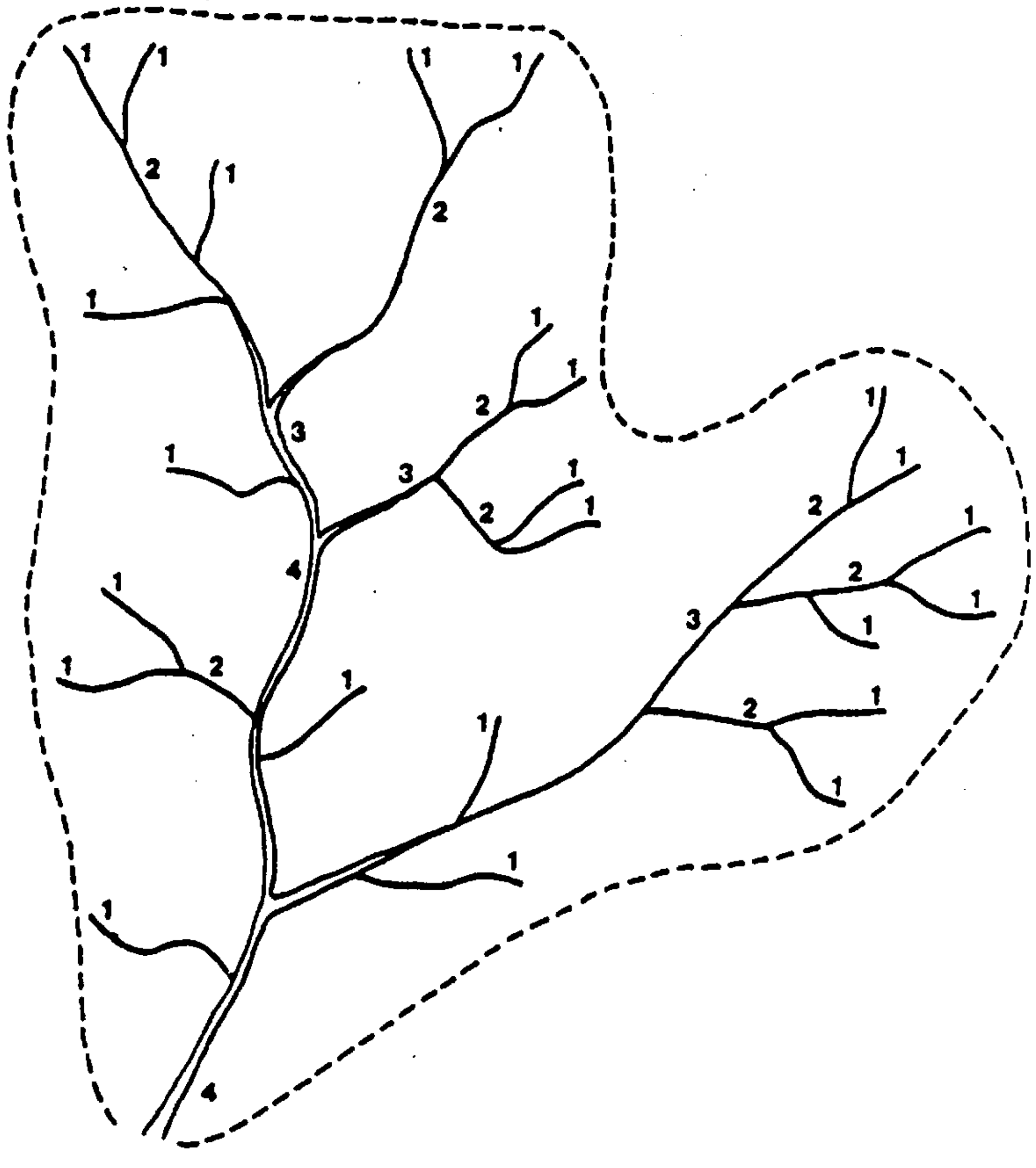
D. Stream Order

Record stream order from the Quad map when determining segment type. The stream order numbering system is a means of numbering streams as part of a drainage basin (Figure 1), where tributaries that have no branches are designated first-order streams, second-order streams are formed when two first-order streams join, third-order streams are formed by the joining of two second-order streams, and so on. Some valley segment types may be found in streams of a variety of different orders.

E. Surveyors/Affiliations

Both surveyors initials and affiliation are entered. The team member doing the estimating for a particular segment is entered as Surveyor #1.

Figure 1. Hierarchy of stream ordering. Numbers indicate ordering of respective segments. The watershed is fourth-order.



F. Reference Points

Relocation of the surveyed segments in future years is critical to meeting the objectives of this monitoring program. The term "referencing" means to measure the distance and compass bearing to at least two fixed objects. The beginning and end points of a segment are permanently marked with rebar, and triangulated to fixed features such as a boulder or large tree above the high water mark. Write the description of the reference points, distances and compass bearings in the space provided for "access points".

G. Township, Range and Section

Refer to your USGS topographic maps to get the delineation.

H. WRIA Number

The Water Resource Inventory Area numbering system is to be used as the unique identifier for the stream within which the segment survey is completed. The State of Washington WRIA map provides the 2-digit watershed code while the stream catalogue provides a more precise 4-digit location code (note that in some areas a letter designation appears at the end of the four digit numeric code). Once the valley segment code has been determined for the segment to be surveyed, it will be paired with the WRIA number to give a unique identifying code to the stream segment.

I. Channel Elevation

Although channel elevation can be useful in fixing our point on the stream, we are only using it for relative location. Channel elevations can be determined within +/- 40 ft (12.0 m) from U.S. Geological Survey topographic quadrangle maps with 40-ft (12.0 m) contours. Be sure to note either feet or meters as the unit of measurement from the map.

J. Adjacent Valley Segment Types

Note the valley segment type both below and above the segment under survey, if known.

IV. HORIZONTAL CONTROL SURVEY - FORM 2

A. Horizontal Control Survey

Essential to the success of the monitoring project is a way of relocating sampled segments within the stream, so that they may be resampled in subsequent years. This is done by establishing control points along our survey path. The following discusses a method for measuring horizontal distance between upstream and downstream points along the bank following the general course of the stream channel. In this way a longitudinal profile of the stream can be developed and key features noted in the survey can be relocated in future years.

As the crew progresses upstream, pick a line of sight along the stream course. One team member walks as far as possible upstream but staying within sight of his/her partner at the beginning point. The distance between these two points is measured, and a compass bearing is taken to the turning point established by the team member farthest upstream. Record the turning point station at the edge of the stream or bank to mark this transition. Turning points are numbered sequentially as one progresses upstream. Distances and bearings between the points are recorded on the Horizontal Control Survey Form. Photos of the stream channel are shot facing upstream from each turning point. In some situations a downstream photo may also be necessary to portray the channel. Photo roll and frame numbers are also recorded on the Horizontal Control Survey Form. (See Fig. 2.)

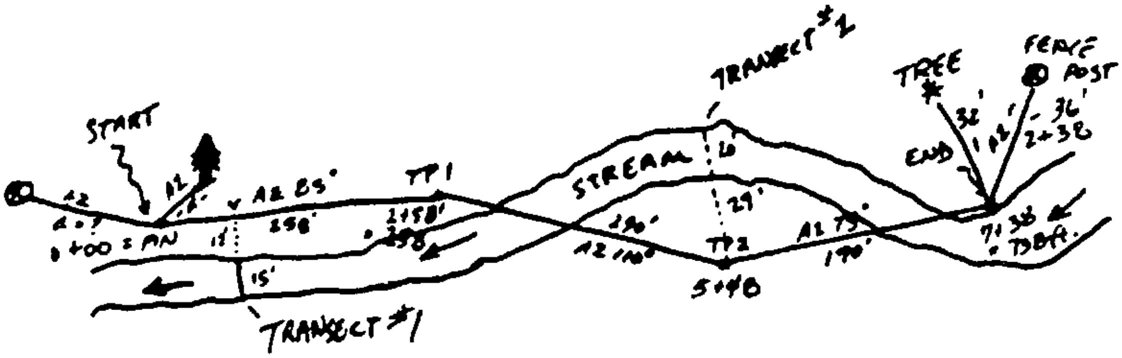


Figure 2. Diagram of stream from horizontal control survey.

B. Channel Morphology

1. **Channel Gradient** - Channel gradient is viewed by many to be the most important variable regulating stream velocity and therefore is a concern for aquatic environment studies. Channel gradient is defined as the change in static water surface elevation per unit length of channel. The channel and valley sideslope gradient are important attributes in our valley segment classification scheme. During the horizontal control survey of a segment, gradient will be measured with a clinometer at those same locations chosen for bankfull width and depth measurements. At those locations, we measure the difference in water surface elevation between points located equal distances (no less than 100 feet) both upstream and downstream from each channel cross section. The intent is to measure the average channel gradient at the same locations chosen for bankfull width and depth measurements, not the gradient at an individual unit.

   The clinometer recommended as part of the survey equipment allows slope angles expressed as % slope, to be read directly from the scale viewed through the sighting hole. Field personnel should practice taking gradient measurements with a clinometer, and then repeat using an engineering transit, if possible, to help calibrate their eye. Hand level or clinometer readings may provide a gross but acceptable gradient measurement for the extensive level survey we are attempting here, within 1/2 % of accuracy. Clinometer readings of gradient generally work better for gradients in excess of 3 %, while their accuracy decreases when the gradient is less than 1 %.

   The stream surveyor measuring gradient should use a reference mark on a stadia rod or determine where their eye level falls on their partner, then send the partner upstream to act as a "sighting mark". The surveyor then sights through the clinometer and lines up the hairline with eye level on the upstream partner. Gradient is read in the window where the hairline crosses the graduated scale. Gradient is best measured when both surveyors are standing in riffles.

2. **Channel and Riparian Features** - The riparian zone is composed of two dominate features, the flood plain and channel. The channel is further subdivided into banks and channel bed or bottom. All of these features represent the interaction between the flow regime for the stream, the quantity and character of sediment movement past the channel section of interest, and the character of the materials making up the bed and banks of the stream.

   Channels are shaped by impacts created by flowing ice, water and debris; so it is logical that some relatively frequent flows dominate the channel-forming process. On the average, flows that recur about every 2 years or less can be contained within the stream channel, whereas greater flows may spread out onto the flood plains (depending on channel shape). The flow that is just large enough to completely fill the channel, or so called bankfull flow, is the dominant flow shaping stream channels. The physical appearance (i.e. morphology) of the channel and flood plain are all referenced to this flow level. For purposes of aquatic environment inventory, the flood plain and components of the channel are defined as follows:

Channel - The channel refers to that feature containing the stream that is distinct from the surrounding area due to breaks in the general slope of the land, lack of terrestrial vegetation, and changes in the composition of the substrate materials. The channel is made up of stream banks and stream bottom. In this survey, use the convention of referring to the right bank or left bank facing in the downstream direction.

The bankfull width is the width of flowing water during the channel forming flood flows (the high flows which occur every 1 to 2 years). Bankfull width can be measured by examining a riffle type habitat unit where the flow is confined within a fairly straight stretch of channel and the channel flows through alluvial (stream-deposited) material. A slight berm of material, deposited by the receding floodwaters, indicates the edge of the bankfull channel width. Bankfull width is measured from berm to berm on either side of the channel, and average bankfull depth is measured by stretching a line or tape from bank to bank and averaging the measured vertical distances from this point to the stream bottom at obvious slope breaks across the channel.

Banks - The portion of the channel cross section that tend to restrict lateral movement of water. The bank often has a gradient steeper than 45% depending on bank materials and exhibits a distinct break in slope from the stream bottom. Also, an obvious change in substrate materials may be a reliable delineation of the bank.

Stream Bottom - The portion of the channel cross section not classified as bank. The bottom is usually composed of stream sediments or water-transported debris and may be covered by rooted or clinging aquatic vegetation. In some geologic situations, the stream bottom may consist of bedrock rather than sediments.

Flood plain - The area adjacent to the channel that is occasionally submerged under water. Usually the flood plain is a low gradient area well covered by various types of riparian vegetation.

The following cross sectional profiles (Figs. 3a, 3b, 3c, from Platts et al. 1987) collected on Frenchman Creek in the mountains of southern Idaho illustrate the terminology. The cross sections are plotted using the same horizontal and vertical scales to avoid exaggeration of channel features. Figure 3a shows a well-defined channel with obvious breaks between the channel and the flood plain. The tops of both banks are usually close to the same elevation and are distinct from the flood plain because of breaks in bank gradient as shown in this example. The bottom of the left bank is very well defined compared to the

Figure 3a. A well-defined stream channel (downstream view).

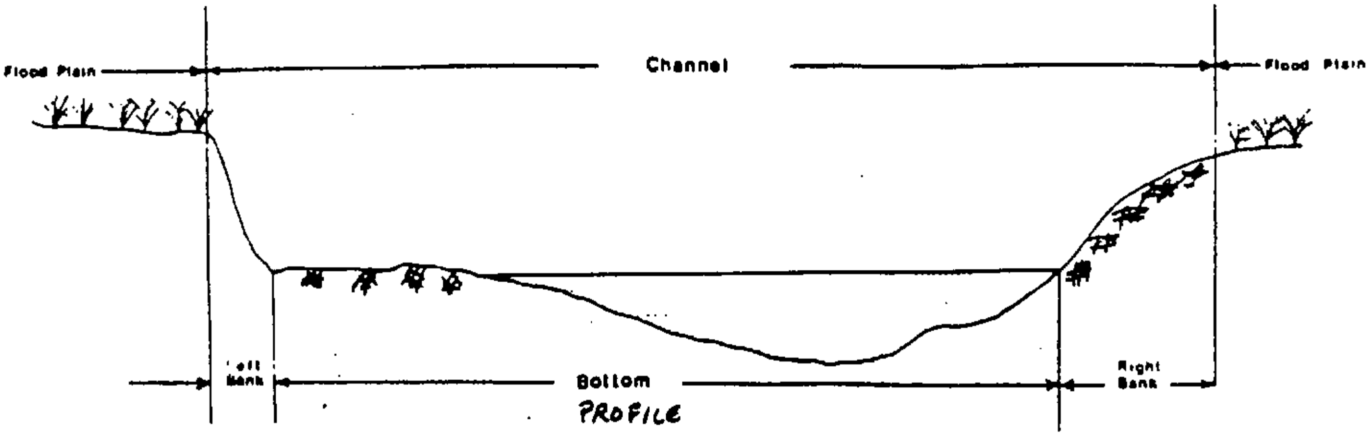


Figure 3b. A well-defined stream channel with concentrated low flows and exposed bottom (downstream view).

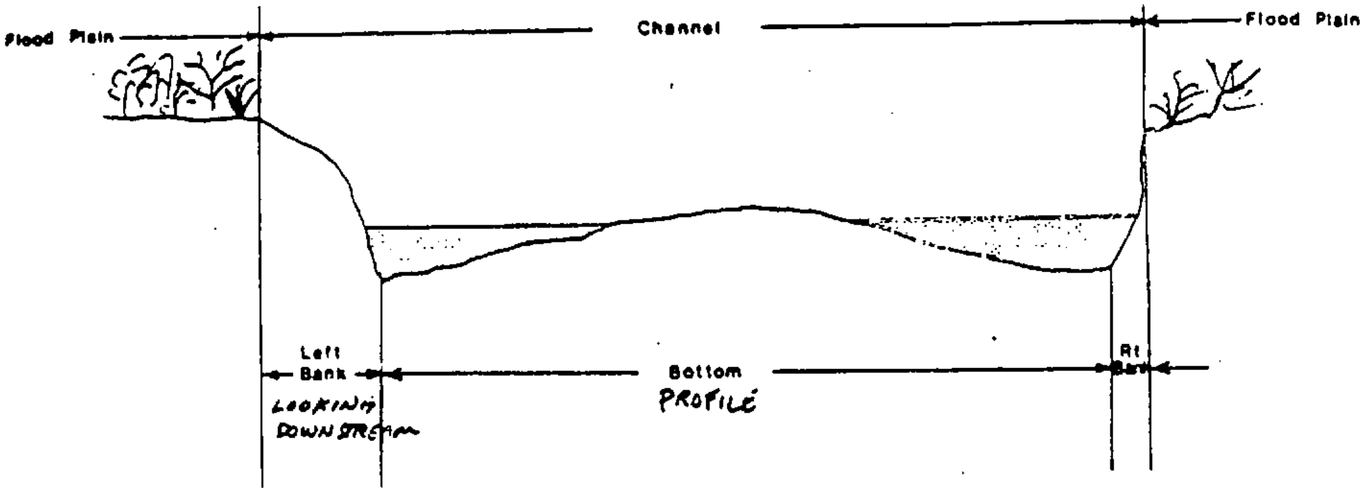
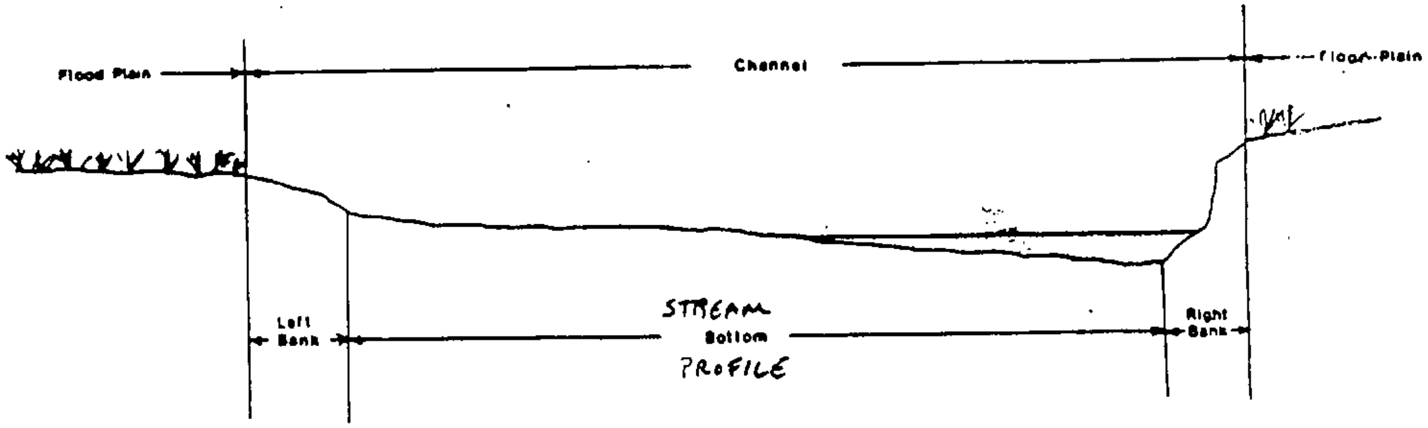


Figure 3c. Stream channel cross channel section on a bend in a stream.



right bank suggesting a possible change in the composition of the substrate material at this point. Field examination showed a very definite transition from bottom sediments to fine-textured, organic bank materials at this point.

Figure 3b shows a well-defined channel and banks with low flows concentrated on both sides of the bottom and an exposed bottom in the middle.

Figure 3c illustrates a common situation found when a cross section site falls on a bend in the stream. In these cases, the inside of the bend is a zone of sediment deposition and the outside is a zone of erosion from the banks. The result is an asymmetrical cross section as shown.

Often, it is difficult to delineate the bank, especially the bottom edge, on the inside of the bend because of sediment deposition. The left bank shown in the figure was delineated on the basis of a break in grade and vegetation growth at the top of the bank and a change from rock sediments to organic materials, plus a small grade change at the bottom of the bank. Figure 3c also illustrates another situation that occurs with some cross sections, especially where the bank and bottom channel on one side have a different appearance than the opposite side, i.e. where friction forces near the bank cause erosion. However, the top of the bank is stabilized by vegetation roots allowing the bank to undercut. Bank undercutting is most common along the outside of bends in the channel, but is not restricted to bends . It can, and commonly does, occur on straight channel reaches as well. Sometimes, the undercut bank collapses, causing a stair-step appearance at the bottom of the bank as shown on the bottom of right bank in Fig. 3c. This is true where bottom materials have a high silt or clay content, not in gravel/sand mixtures.

3. Channel Geometry Measurements (Fig. 4)

a. **Bankfull Width** - Bankfull width and depth measurements will be made where bankfull width can be clearly seen. The bankfull width is that area of the channel that is typically flooded about every 2 years. Bankfull width and depth measurements are important for determining the size of these channel forming flows as well as the width/depth ratio and relative stability of the channel.

Bankfull width is best measured where the stream flow is fairly straight (such as at riffles) and the channel is bounded by alluvial (stream deposited) material. A berm of material deposited by the receding floodwaters identifies the edge of the bankfull channel. The berm may be obscured by leaves and vegetation.

b. **Bankfull Depth** - If the channel profile is uniform, one or two measurements of depth are usually sufficient to determine average depth. Where the channel profile is not uniform, the idea is to take a sufficient number of depth readings to characterize the average width of the channel. For a general rule of thumb, take one depth reading at the deepest portion of the channel (this is usually synonymous with the thalweg). Then take two more measurements at locations either side of this deep point, at positions 1/3 and 2/3 of the remaining distance across to each bank. When these numbers are averaged, add one more depth of 0 to account for the starting point on one shore, where the water surface and the bank or the channel meet.

V. MASS WASTING AND CHANNEL BANK CUTTING - FORM 3, FRONT SIDE

The length of bank cutting and instances of hillslope failures (i.e. mass wasting events) are recorded on Form 3. This is done concurrently with the horizontal control survey. During this survey, team members should note the physical characteristics described below, estimate the area of mass slope failures and length of bank cutting as they progress upstream.

The channel is divided into three vertical components, as shown in Fig. 4: the upper banks include that portion of the topographic cross section from the break in the general slope of the surrounding land to the normal high water line; the lower banks include the intermittently submerged portion of the channel cross section from the normal high water line to the water's edge during the summer low flow period; and the bottom includes the submerged portion of the channel cross section.

A. Mass Wasting or Slope Failures

Mass wasting includes landslides from adjacent hillslopes that reach the stream channel, as well as mass soil movement adjacent to the channel. The difference between mass wasting and bank cutting is that mass wasting affects the upper banks while bank cutting affects the lower banks. Figure 5 illustrates different types of mass failures.

Estimate the length and width associated with each mass wasting event, and note the upstream and downstream turning points that bracket the length traversed. The estimated length (or height) and width of failures is recorded in the space provided.

B. Bank Cutting Frequency

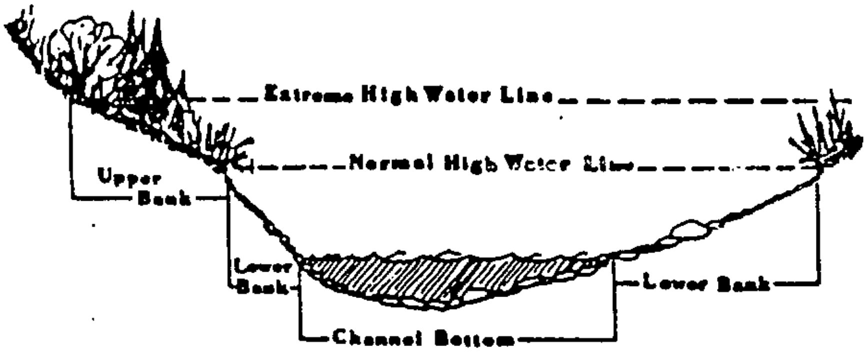
Bank cutting occurs along many channels as a response to several processes that may be acting in concert. Flows associated with large storm events, increased sediment loads that decrease channel flood flow carrying capacity, dam break floods, and even animal grazing. Our intent is to document the approximate length of bank cutting seen along the stream. Since right and left bank areas are recorded separately, be sure to note the turning points that encompass the upper and lower boundary of the cut bank.

Figure 4. Channel Cross Section.

Upper Bank - That portion of the topographic cross section from the break in the general slope of the surrounding land to the normal high water line. Terrestrial plants and animals normally inhabit this area.

Lower Banks - The intermittently submerged portion of the channel cross section from the normal high water line to the water's edge during the summer low flow period.

Channel Bottom - The submerged portion of the channel cross section which is totally an aquatic environment.



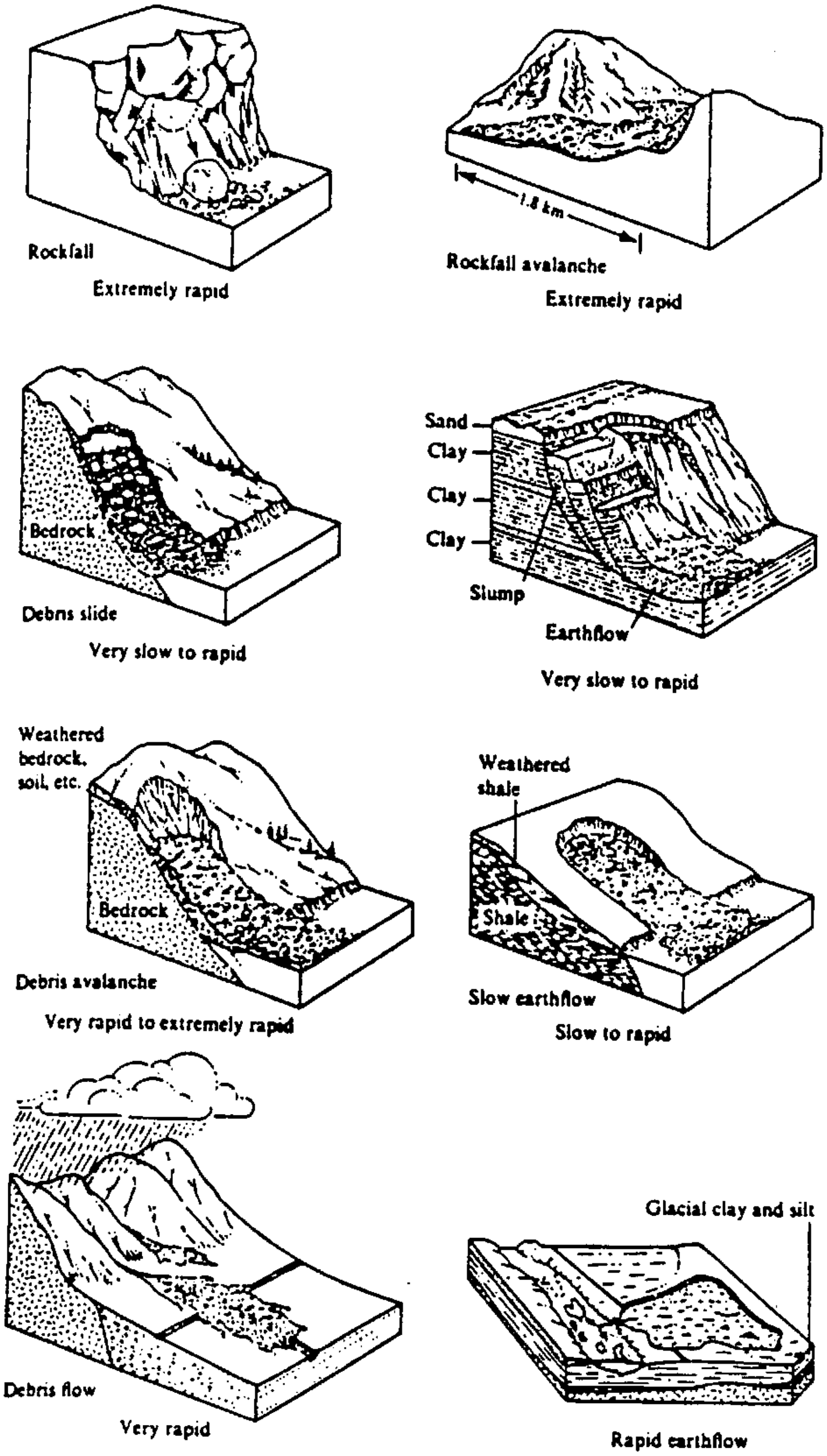


Figure 5. Types of mass wasting (from Dunne and Leopold, 1979).

VI. STREAM CHANNEL SUBSTRATE - FORM 3, BACK SIDE

This important physical habitat component is accounted for by conducting a pebble count (Wolman 1954) at selected riffle units during the horizontal control survey. This is a departure from the visual estimation of dominant and subdominant particle sizes done during the first year of this pilot project. The pebble count will yield information about coarse particle size distribution within selected riffles that is more reliable and easily analyzed. The bed material that characterizes the channel bottom is an important determinant of fish spawning and wintering habitat quality. This method is designed for coarse sized particles and is therefore bias against very small and very large particles. A relative index of gravel embeddedness is included to serve as an empirical assessment of the percent of fine materials surrounding bed material.

- Boulders are stratified into two size classes.
- Cobble stabilizes the stream bottom, provides habitat for fish rearing, and is the substrate where much of the food for fish is produced. Cobble is divided into three size classes.
- Gravel is important for spawning, incubation of embryos, and as substrate for some aquatic invertebrates. Gravel is distributed among four particle sizes.
- Sand (Fines) Fine sediment is separated into three classes consisting of sand (coarse, medium and fine sediment). The reason for the separation is that the larger particle can trap alevins in the redds, and the small fine particles decrease water flow through spawning gravels.

The pebble count procedure involves selecting 100 substrate particles within a riffle, measuring their intermediate axis diameter size and recording it in a corresponding size category as seen below. The procedure is to randomly wander over the unit and at every second step reach down without looking and place your index finger on the particle directly beneath the toe of your boot. This particle is removed and the middle axis is measured with a metric ruler. The actual measurement is used to place the particle in a size category based upon a modification of the Wentworth Substrate Particle Size Classification as noted below.

A. Particle Sizes of Bottom Substrate

The sediment particle size categories are shown in the table below; the interpretations of boulder, rubble, gravel, and fine sediments are based on this classification. The corresponding size code is entered onto the back side of Form 3.

TABLE 2. CLASSIFICATION OF STREAM BEDLOAD (SUBSTRATE) BY PARTICLE SIZE.

PARTICLE DIAMETER SIZE	SEDIMENT	CODE
> 50 inches (128mm)	boulder	10
25 to 50 in. (64-128mm)	large cobble	9
12 to 25 in. (32-64mm)	medium cobble	8
6 to 12 in. (16-32mm)	small cobble	7
3 to 6 in. (8-16mm)	coarse gravel	6
1.6 to 3 in. (4-8mm)	medium gravel	5
0.8 to 1.6 in. (2-4mm)	small gravel	4
0.4 to 0.8 in. (1-2mm)	pea gravel	3
0.2 to 0.4 in. (0.5-1mm)	coarse sand	2
0.1 to 0.2 in. (0.25-0.5mm)	medium sand	1
0.05 to 0.1 in. (0.125 to 0.25 mm)	fine sand	0

B. Gravel Embeddedness

Embeddedness rates the degree that the larger particles (boulder, rubble, or gravel) are surrounded or covered by fine sediment. The rating is a measurement of how much of the surface area of the larger size particles is covered by fine sediment (silt or sand). We have not included an additional rating that would describe the nature of the embedding material (sand or silt) at this time, but may include this in subsequent years. An embeddedness rating should allow for some qualitative evaluation of the channel substrate suitability for spawning, egg incubation, and habitats for aquatic invertebrates, and young overwintering fish. The rearing quality of the instream cover provided by the substrate can be evaluated also. As the percent of embeddedness increases, the biotic productivity is also thought to decrease.

This estimate of embeddedness will be done at the riffle locations selected for the characterization of the bed material, as described above. To enhance one's judgement in making this rating, remove a particle of bed material and try to estimate as a % how much of the vertical dimension of the particle was embedded by sand or silt. Usually, a distinct line can be seen on the surface where the portion not embedded was exposed to flowing water. Classify the percent embeddedness according to the following rating, and mark the data sheet accordingly:

TABLE 3. RATING AND CODE FOR EMBEDDEDNESS.

RATING	DESCRIPTION
5	Gravel, rubble, and boulder particles having less than 5% of their surface covered by fine sediment.
4	Gravel, rubble, and boulder particles having between 5 and 25% of their surface covered by fine sediment.
3	Gravel, rubble, and boulder particles having between 25 and 50% of their surface covered by fine sediment.
2	Gravel, rubble, and boulder particles having between 50 and 75% of their surface covered by fine sediment.
1	Gravel, rubble and boulder particles having more than 75% of their surface covered by fine sediment.

VII. STREAM HABITAT UNIT DATA - FORMS 4A & 4B

The depth and velocity of the flowing water (and the habitat available for fish and other aquatic organisms) is affected by the stream banks, channel gradient, channel form, stream bottom composition, and discharge, i.e. the rate of water flowing in the channel expressed as cubic feet (USGS convention) or cubic meters per second. This is why a measurement of discharge is taken at the beginning of a habitat unit survey.

A. Stream Flow Measurement

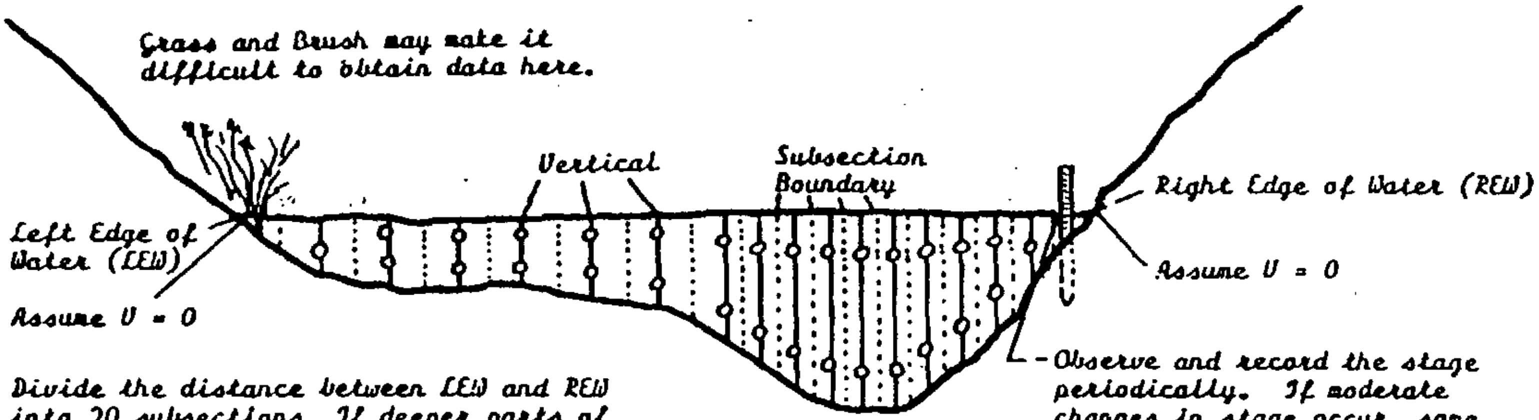
The water and surrounding channel comprise a complex and dynamic hydraulic geometry system where variable water flows and associated changes in width, depth, and velocity interact with such factors as sediment transport, channel shape, bank cutting, and size of bottom materials. Fish can respond in a number of ways to variations in these factors, depending on species, age, and time of year.

As an independent variable driving the system, flow is an important concern for any stream environment study. The three dimensional movement pattern of water flowing in a stream channel in addition to daily and seasonal fluctuations makes stream flow difficult to measure and describe.

1. **Frequency of Measurement** - We will be measuring stream flow (discharge) at the beginning of a habitat unit survey. The width and depth of all habitat units (riffles and side channels especially) is intimately tied to flow levels at the time of the survey. As you progress upstream and encounter smaller tributary streams flowing into your segment, these should be written on the survey form in the space for notes. These should be correlated with the horizontal control stations, where possible. Note the discharge on Form 2, as well as Forms 4A & 4B.

Additionally, if it is raining during the survey, the crew may want to drive a stake into the bank when you take your discharge measurement, mark where the water level is on the stake and recheck the level of the flow at the end of the day to see how much the stage or water surface elevation has increased. If a USGS flow gauge is located within the stream system, this should be noted on the survey form.

2. **Flow** - Flow (Q) is expressed as the rate of a volume of water moving past a given stream cross section per area of water (A) in square feet times flow velocity (V) in feet per second to give the traditional units of cubic feet per second. Because flow velocity varies greatly within and across a channel with both depth and width, it is not possible to measure stream flow with a single measurement of velocity. Rather, the channel must be broken into a number of partial sections (Fig. 6) to account for variations in velocity and depth. Appendix A contains details on determining depth, velocity and discharge. The following is a summary.



- Observe and record the stage periodically. If moderate changes in stage occur, some adjustments must be made in reducing the data.

Divide the distance between LEW and REW into 20 subsections. If deeper parts of the stream are encountered, subdivisions are again subdivided. No more than 10% of the total discharge should occur in any subdivision.

The depth of water is measured at the vertical and the observation depth of the meter is decided. If the depth is less than 2.5feet(0.6 meter), the meter is set at .6 of the depth from the surface. When depths are greater than 2.5feet, the average of the measurements at .2 and .8 of the depth from the surface is the mean velocity.

Count the number of revolutions for either a period of 50 or 100 seconds for ease of data reduction.

Keep the current meter clean. Moss and algae should not be allowed to wrap around the spindle or hub of propeller. Spin test before and after making a stream gaging to check for excessive friction in the bearings.

Not to scale

Figure 6. Measuring Stream Discharge in a Typical Cross Section (from Schulz 1978).

The total discharge or flow calculation is based on the sum of the flows for individual partial sections as follows:

$$Q = \sum_{i=1}^{n} \left(\frac{W_{i+1} - W_{i-1}}{2} \right) d_i \left(\frac{V_{i_1} + V_{i_2}}{2} \right)$$

where:

n = the total number of individual sections,

w_i = horizontal distance from the initial point,

d_i = water depths for each section, and

v_i = measured velocity for each section.

The flow for each partial section is calculated and then summed to get the total discharge. The number of sections used in any flow measurement depends on the variability of velocities within the channel. Usually, at least 15-20 measurement points should be used unless the channel is extremely regular in both bottom elevation and velocity distribution. Measurement points are taken at all breaks in the gradient of the stream bottom and where any obvious changes in flow velocity occur within the channel. It is advisable to space the partial sections so that no partial section has more than 10 percent of the total flow contained in it. Cells of equal width across the entire cross section are not recommended unless the channel cross section is extremely uniform.

3. **Depth at Which Velocity Is Measured** - Velocity variations with depth are accounted for by measuring flow at depths where velocity is equal to the average velocity for the water column passing that point. Velocity at the bottom is zero and reaches a maximum near the surface of the water. The proper depths to measure the average velocity vary with water depth as follows: If the depth is less than 2.5 ft., take the velocity measurement at 0.6 of the depth; and if it is greater than 2.5 ft., take the velocity reading at both 0.2 and 0.8 of the depth, and average the two readings. All depth measurements are referenced to the water surface. Velocity is measured with a current meter attached to a rod or cable for measuring depth. The rod is adjustable and can be set at the proper measurement depth.

B. Terms Used To Describe Fish Habitat

To quantify and describe the distribution and arrangement of habitat units (pools, riffles, side channels, and the like) we use unit descriptions which are modified versions of those developed by

Bisson et al. (1982, Appendix D), paired with a sampling scheme and estimation technique developed by Hankin and Reeves (1987).

Fish habitats within streams are classified into four broad categories according to location within the channel, pattern of water flow, and nature of flow-controlling structures. The key to distinguishing these features and unit descriptions are included in Appendix E and Fig. 7..

1. **Riffles** - These units are divided into six habitat types: glides or runs, pocket water, low gradient riffles, step pool cascades, slip face cascades, and rapids (according to increasing velocity, and size of bed materials.
2. **Pools** - Pools are divided into five types: dammed pools, eddy pools, plunge pools, scour pools, and scour holes
3. **Side Channels** - These include water flowing in channels separated from the main channel. Wall-based channels and side channels that may provide fish habitat are important features to note.
4. **Beaver Ponds** - A somewhat anomalous category, but because of their importance to fish, have been given their separate listing.

C. Position Within the Channel of Habitat Units

Individual habitat units within a given length of stream will occupy all or only part of the wetted width, i.e. units may not only occur in series, but in parallel or even nested within each other. This feature is accounted for by filling in the "unit category" block on Form 4A & 4B. An entry of "1" indicates that the unit occupies more than 50% of the wetted width of the unit; "2" indicates the unit occupies less than 50% of the wetted width; and "3" indicates the unit occurs within a side channel irrespective of its position in the channel.

D. Estimating Physical Dimensions of Habitat Units

A technique for quickly sampling habitat unit areas within a given stream segment has been developed by Hankin and Reeves (1988). Appendix F gives a more complete description of this method and it's statistical basis (Parton, unpublished). The basic approach to the estimation technique is for members of the crew to "calibrate" their ability to visually estimate distance, by first approximating and then measuring the distance to see how accurate they were. With a little practice, an individual can become quite consistent and refine the precision of their "eye-ball estimate". Systematic estimates are made of habitat unit length and width, using these visual estimation techniques. Depths will always be measured and averaged as this has proven to be easier and more accurate than estimating.

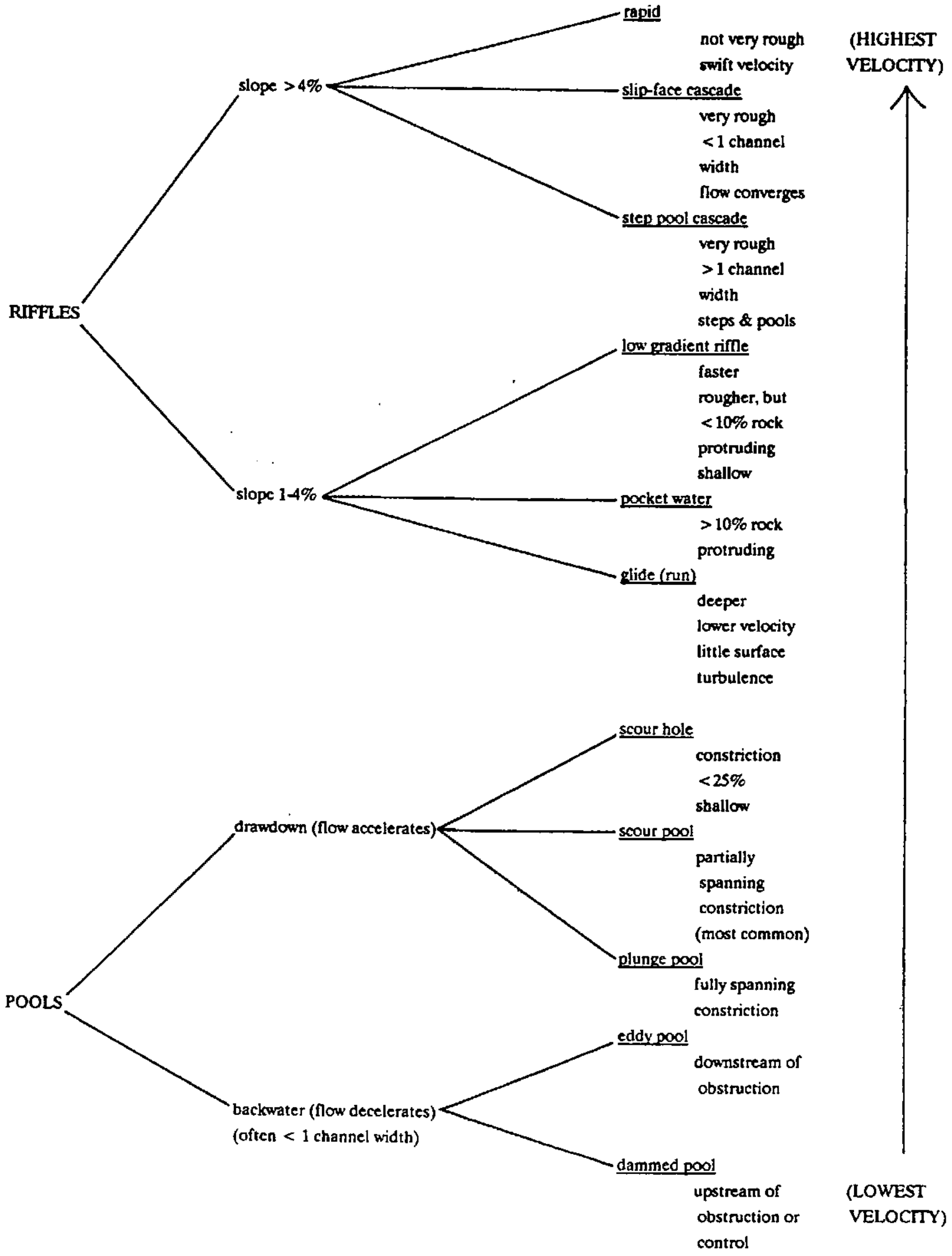


Figure 7. Key to channel units (from Sullivan).

Within a given segment, a team classifies habitat units according to the key provided in Appendix E and estimates the dimensions as they proceed upstream during their inventory. The fraction or interval of the habitat units of a particular type to be measured is based on the frequency of occurrence of that habitat unit (which will be roughly tallied during the horizontal control survey).

In addition, to select the actual unit to begin both estimated and measured dimensions, a random number is selected. For example, frequently occurring units such as low gradient riffles may have a sampling fraction of one-in-ten. If "3" is randomly selected at the starting point, and "10" is the interval of occurrence selected to both estimate and measure, then the third, thirteenth, twenty-third ..., low gradient riffle will be both estimated and measured. Relatively uncommon units, such as dammed pools, may only occur a few times within a surveyed segment. In order to obtain measurements with which to calibrate their corresponding estimates, a lower sampling fraction must be assigned to these less frequently occurring units.

Once the survey begins, one member of the crew is designated as the estimator. S/he will visually estimate and call out the length and width, dimensions for each habitat unit as the crew progresses upstream during the survey. Depths are measured and averaged for the unit. The second member of the team records these estimates on the data sheet, and make the determination of the kind of unit it is.

1. **Calibration** - At every measured habitat unit (i.e. those units selected by the sampling fraction) the second crew member actually measures the above dimensions that were "estimated" by their team partner. Under no circumstances does s/he tell the "estimator" what the actual measured dimensions are. These measured dimensions are recorded on Form 4A or 4B in the row below the estimated dimensions they are paired with. When the data is analyzed, a calibration factor is determined for each surveyor in order to correct the estimated dimensions.
2. **Habitat Unit Width** - Stream width is an important index to measuring the quantity of instream habitat for fish and insects, as well as the proximity of the streamside vegetation. Stream width is the averaged horizontal distance from wetted edge to wetted edge along the existing water surface within a habitat unit. Average stream width across a given channel unit should be visually estimated and measured, as outlined above, and recorded to the nearest 1 foot, or metric equivalent. Total unit area will be automatically calculated as the product of unit length times mean width. To provide consistency in measurement, protruding logs, boulders, stumps, or debris surrounded by water are included in the measurement of the water surface.

Islands are not included in the measurements of habitat unit width. Any solid accumulation of sand, rocks or other sediment protruding above the water and more than 1 ft (0.3 m) in width is considered an island. The stream width measurement ends when, on approaching the shoreline, any material is not completely surrounded by water and water is only pocketing between the material. The wetted width of the unit on each side of the island is summed and recorded as the width of the habitat unit. These guidelines are necessary to obtain measurement consistency from year to year on the same stream.

3. **Habitat Unit Depth** - Stream depth is affected by stream flow, velocity, substrate, and channel geometry. Depth is important in the assessment of potential fish production and biomass per unit volume of water.

Mean channel depths at the channel unit level will be measured for every unit. Habitat unit depth is the vertical height of the water column from the channel bottom to the water surface, recorded to the nearest tenth of a foot, or 0.01 meter. At each pool, two depths will be recorded, one for the crest or pool outlet depth and one for the maximum depth of the pool (Figure 8 and Appendix G). Depths at other unit types are measured using the stadia rod or ruler. Determine stream depth as the average of the measured water depths taken across the channel unit. The stage (or elevation of the water surface at a given discharge), and the width and depth profile of the channel bottom largely determines how many of these measurements are needed.

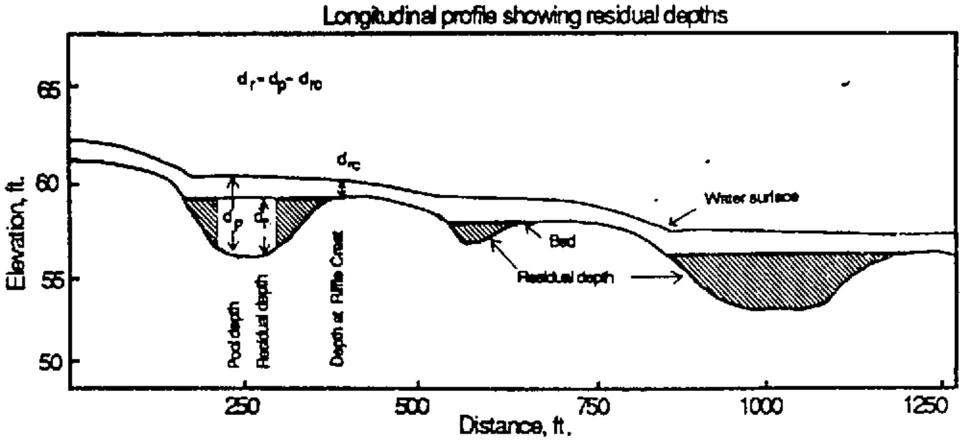


Figure 8. A longitudinal profile of a reach of stream, showing the method for measuring residual depths.

E. Obstructions

The column labeled "obstructions" on Form 4A will account for the in-channel feature that forms pool units only. The list of possible obstructions are listed on the code reference sheet and include log(s), debris jam(s), standing tree, other root protected banks, boulder(s) or bedrock.

F. Large Woody Debris

Trees, logging debris, stumps, root wads and similar large woody debris (LWD) that enters a stream channel play an important role in determining both the physical character of channel units and the suitability of instream habitat for fish and aquatic insects. The size, type and distribution of this material changes over time, and streams of different character can accommodate differing amounts of LWD loading. The objectives of this sampling scheme are to get a count of LWD occurring either singly or in log jams, and how these pieces are distributed within a valley segment. This data is entered on Forms 4a & 4b. This approach to measuring and rating in-channel organic debris is keyed to visual estimation of habitat units. Since we want to get an accurate count of LWD, we only want to count a piece or log jam once. So even though a stump or log may span more than one channel unit, we only want it counted within the first unit where it is encountered.

1. For the first occurrence within a channel unit, count each piece of woody debris within the bankfull channel, or each log jam when three or more pieces occur together. The total number of pieces in the location classes (A - D) should be equal to the total number of logs, root wads and debris jams within any one unit.
2. On the Habitat Unit Data Forms 4A & 4B, record the number of individual logs or root wads indicated on the form. Logs should be > 10 feet long to be counted. This minimum length can be reduced somewhat in smaller streams with less energy to transport debris. Root wads are counted separately, and should be at least two feet in diameter to qualify as root wads.
3. When counting the pieces of woody debris within a channel, record the number of logs or root wads under the appropriate position column where:

A = All or a part of the woody debris occurs within the active channel, but not within the unit.

B = Partially in channel unit, partially outside of unit, and influencing up to 50% of the unit.

C = Lies completely within the channel unit, with the log or stump mostly submerged and anchored, and influences more than 50% of the unit.

D = Spanning or bridging the channel, but not in contact with the water surface at the time of the survey.

VIII. RIPARIAN VEGETATION - FORMS 4A & 4B

Streamside or riparian vegetation is probably the most critical vegetation on the landscape relative to maintenance of both instream fisheries habitat and water quality. It has a large bearing on many of the physical attributes of a stream, such as bank stability, sediment input, water velocity, and stream temperature. These variables largely determine the character of the instream habitat for fish and aquatic insects. The amount of sunlight reaching the surface of the stream, which is the energy base for aquatic plant growth and stream temperature, is also a function of the surrounding vegetation. In addition, riparian areas are important islands of diversity within extensive forested ecosystems.

Our approach to monitoring riparian vegetation involves measurement of canopy closure and assessment of riparian vegetation seral stage, vegetation type as well as land use within the riparian area.

The measurement of the canopy closure provides an indirect measurement of the degree of shading afforded the stream by the adjacent riparian vegetation. The relative importance of canopy closure is a function of the width of the stream, the slope, the aspect and general character of the riparian vegetation, and the sensitivity to temperature effects, e.g. streams on the east side of the Cascades may be more subject to temperature changes than those on the west side. The method described below has been excerpted from Platts et al., 1987. Measurements of canopy closure need only be made at every measured habitat unit or when obvious changes in adjacent forest stand management are seen, such as in a clear-cut forest.

The second aspect involves characterizing the vegetation along the stream corridor by the apparent seral stage of the plant communities. These visual estimates of seral stage will be made at every habitat unit. In addition, note the apparent land-use of the adjacent area. Fill in the appropriate boxes on the form provided.

A. Canopy Closure

A spherical densiometer is used to estimate canopy closure. Canopy closure is the area of the sky over the stream channel bracketed by vegetation. Canopy density is the amount of the sky blocked within the closure by vegetation. While canopy closure can be constant throughout the season if fast-growing vegetation is not dominant, density can change drastically if the riparian vegetation is deciduous, as is likely the case in many east-side areas subject to intensive land use practices.

Originally, these methods were taken from Platts, et al.. (1987). After some field trial and error, they have been simplified, as indicated below. Those dealing with 5th or greater order rivers should follow the methods in the original manual or consult Platts (1987) for details.

1. For streams less than 40 feet across (wetted width), simply stand in the approximate middle of the channel unit and take four readings using the densiometer as described below; one facing upstream, then downstream, then in turn facing the right and left bank (the order doesn't matter as long as all four directional readings are taken). Generally, one can follow the instructions printed on the cover of the densiometer, although some have found them somewhat confusing.
2. When the channel unit width is greater than 40 feet, two additional readings (one facing upstream and one facing downstream) should be made at both the right and left edges of the channel unit, and the scores added to the total number of readings averaged for the entire cross sectional site. If desired, a line or cord may be stretched across the center of the unit within which the canopy closure measurement will be made. This line serves as the cross channel reference point for placing the densiometer.
3. The densiometer is held in the hand in front of the observer, and above the water surface at approximately waist height. The arm, from the hand to the elbow, is held horizontal to the water surface. The densiometer is held away from the observer in the upstream direction. The observer's head reflection should almost touch the top or bottom of the grid line (depending upon whether you are holding a concave or convex densiometer). Use the level bubble to keep the instrument steady. Points on the grid etched into the reflective surface will show clear sky or vegetation.
4. Notice that there are 24 sectors etched onto the reflective surface of the densiometer (Fig. 9). Imagine that each sector is further subdivided into four quarters, with each quarter section having a possible score of 1, and each etched section having a possible maximum score of 4. It is within these four quarters that your readings are focused. Count the sections that do have vegetation in them, or count the sections that do not. We will explain the procedure for both.
5. If there is a high degree of canopy closure, you might find it easier to count the number of quarter sectors that appear to not have overhead vegetation in them; these are given a score of one. There are a maximum of four points possible within each square. When vegetation appears within the quarter sector, it's score is zero. Assume 4 equally spaced dots in each square on the grid and systematically count dots equivalent to quarter-square canopy openings.

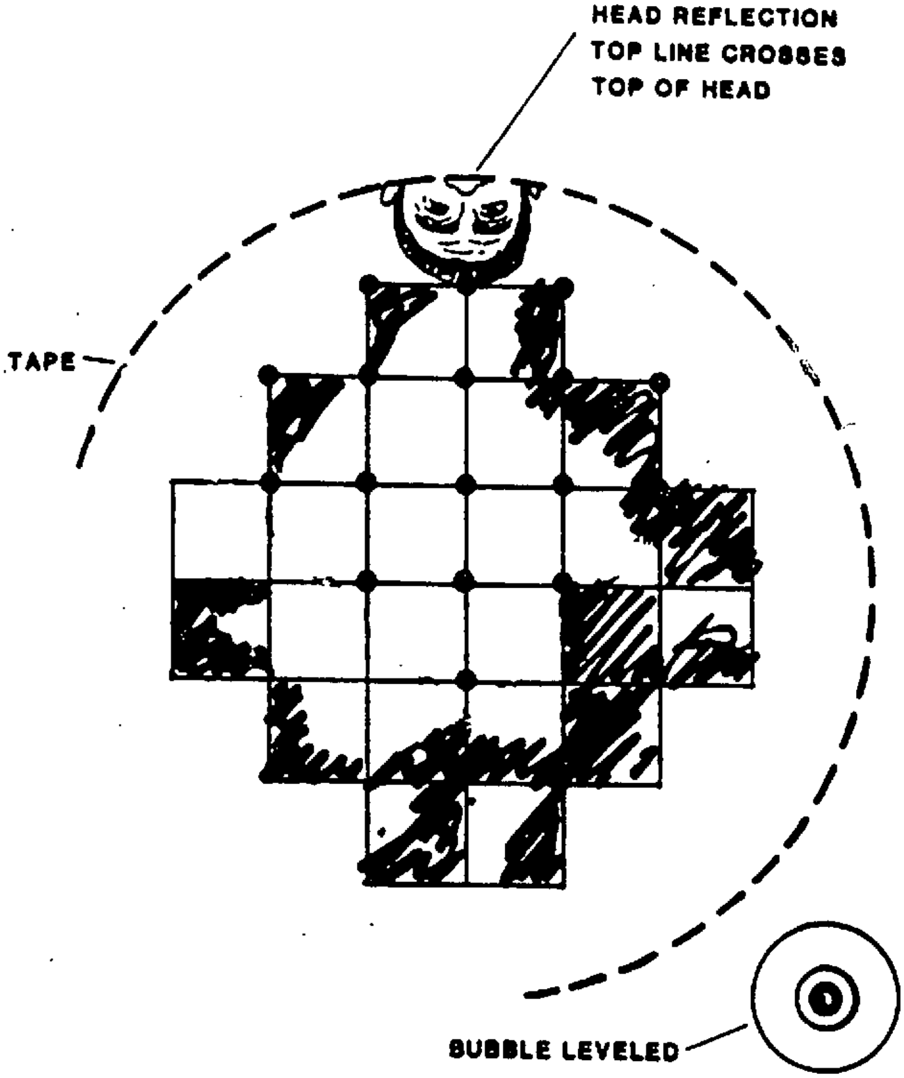


Figure 9. The concave spherical densiometer, showing placement of head reflection and bubble level.

6. Add up all of the scores for each of the four directions together, and divide by four (or by 8 if readings were taken at both banks) to get an average score, and subtract this from 96 to get a closure estimate. Multiply this averaged score by 1.04. This is entered as the percentage of canopy closure. In cases where there is little overhead vegetation, it is easier to simply count the quarter sections that do have vegetation in them. Scores are again averaged and the product multiplied by 1.04 to give the percent of canopy closure.

   An example is given in Fig. 9 that demonstrates this concept. You will notice that in this example, there is some vegetation shown in the reflective surface, but generally it appears to cover less than 50% of the overhead area reflected in the instrument. Imagine that the observer is facing upstream. Counting the quarter sections within each grid mark with vegetation in them gives a score of 39 out of a possible score of 96. Assume that readings were taken in the remaining three directions and the scores recorded are 24, 41 and 22, respectively. Take the average of these four scores, which is = 31.5; then multiply by 1.04 to give a score of 33 (round up). This is the % of canopy closure for the unit.

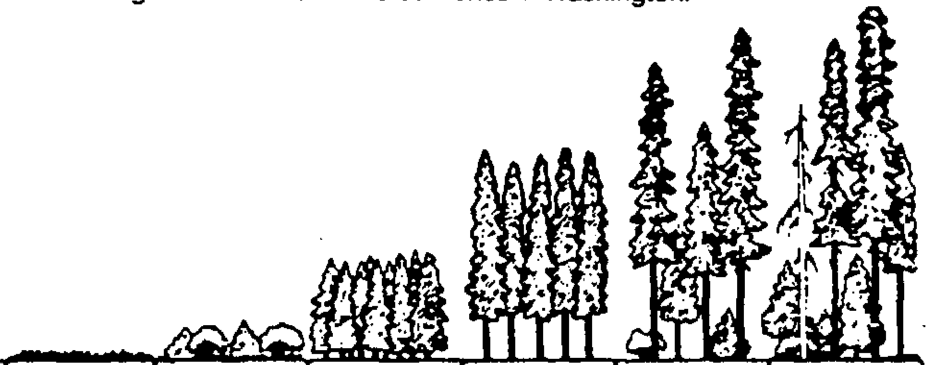
   When the data is processed, we will have the program take the average of all closures or density measurements on all transects on the stream segment being studied. The average percent canopy closure for the cross section is recorded on the Habitat Unit Data Form 4. The largest value for this is 99%.

B. Seral Stage of Streamside Vegetation

Our approach to characterizing the vegetation along the stream corridor is to record the seral or successional stage into which it appears to fit. The attached profiles of successional stages (Fig. 10) give a broad picture of the different kinds of vegetative community profiles that you will likely encounter in the field. The physical appearance of the seral stage may vary somewhat depending upon where you are in the state, but this should provide a basic guide to community structure.

Only the vegetation growing within 25 feet of the streamside edge need be included in the observers frame of reference. The idea here is to give a general indication of the dominant stage of the streamside plant community, be it primarily grasses, shrubs or a young mixed forest of hardwoods and conifers. In the future, we will expand the scope of monitoring within the riparian corridor to answer specific questions.

Figure 10. Successional stages of flora in some forest zones in Washington.



FOREST ZONE	DBH in inches	Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
		0-0.4	0.5-4.9	5-8.9	9-20.9	21+	

WESTERN HEMLOCK	AGE in years	0 - 6	7 - 20	21 - 35	36 - 70	71 - 120	121+
		Douglas-fir →		Western hemlock → western red cedar		Western hemlock (Douglas-fir in seral stands or on dry sites)	

TRUE FIR MOUNTAIN HEMLCOK	AGE in years	0 - 20	21 - 35	36 - 65	66 - 100	101-140	141 +
		Douglas-fir → and/or Noble fir		Western hemlock Pacific silver fir		→ Pacific silver fir	

Successional Stage Definitions [1/]

Grass-forb:	Shrubs and/or tree regeneration less than 40 percent crown cover and less than 5 feet tall; unit may range from largely devoid of vegetation to dominance by herbaceous species.
Shrub-seedling:	Shrubs greater than 40 percent crown canopy; of any height; trees less than 40 percent crown canopy with small diameters.
Pole-sapling:	Tree crown canopy less than 60 percent.
Young:	Crown canopy cover exceeding 60 percent.
Mature:	Crown cover may be less than 100 percent; little decay or defect present;minimal occurrence of understory trees; dead and down material residual from previous stand.
Old growth:	Stands with at least two tree layers (overstory and understory); at least 20 percent of the overstory layer composed of long-lived successional species; standing dead and down material; decay in some trees.

[1/] Adopted from Hall, F. et al. 1982.

1. **Seral Stage Rating** - Record the applicable seral stage rating on the habitat unit form for each unit. Code the seral stage of each bank (facing downstream).

   Codes:

   1 = clear-cut (< or = 5 years since harvest)
   2 = grass/forb
   3 = shrub
   4 = pole stage
   5 = mature timber
   6 = old growth

2. **Land–Use** - In a general sense, note in the land-use column what the dominant land-use of the area by bank, adjacent to the stream appears to be from the following categories:

   Codes:

   1 = agricultural (row crop)
   2 = livestock grazing/pasture
   3 = timber lands
   4 = residential
   5 = right of way (roads, powerlines, etc)
   6 = mining,
   7 = riparian management zone
   8 = wetland
   9 = other (explain in comments)

3. Note on the data sheet in the Vegetation Type field whether the riparian plant community is (1) primarily decidious, (2) primarily coniferous, or (3) a mixture of each (approximately a 50:50 ratio)

LITERATURE CITED

Bisson, P.A., J.L. Nielson, R.A. Palmason, and L.E. Gore. 1981. A system of mapping habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. p. 62-73. In N.B. Armantrout (ed.) Acquisition and utilization of aquatic habitat information. Proceedings of a conference held in Portland, Oregon, 28-30, 1981. Western Division, American Fisheries Society.

Frissell, C.A., Liss, W.J., Warren, C.E. and Hurley, M.D. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management: Vol. 10, No. 2, pp. 199-214.

Hankin, D.G. and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.

Lisle, Thomas E. 1987. Using "Residual Depths" to Monitor Pool Depths Independently of Discharge. USFS Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. Research Note PSW-394.

Omernik, James M. and Gallant, Alisa L. 1986. Ecoregions of the Pacific Northwest. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR. EPA/600/3-86/033.

Pfankuch, Dale J. 1978. Stream Reach Inventory and Channel Stability Evaluation. USDA FS Region 1.

Platts, W.S., et al., 1987. Methods for evaluating riparian habitats with applications to management. General Technical Report INT-221. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 177 p.

Schulz, 1978. Problems in Applied Hydrology. Water Resources Publications, Fort Collins, CO.

Wolman, Gordon M., 1954. A method of sampling coarse river-bed material. Transactions, American Geophysical Union, Vol. 35, Number 6.

APPENDICES

VALLEY SEGMENT TYPES USED IN TFW CLASSIFICATION

VALLEY SEGMENT TYPE DESCRIPTOR	NEW SYMBOL	OLD SYMBOL	1989 #/survey
ESTUARINE DELTA	F1	A1	0
WIDE ALLUVIATED LOWLAND PLAINS	F2	B1	0
WIDE, MAINSTEM VALLEY aka. wide alluviated valley floor	F3	B2	7
ALLUVIAL/COLLUVIAL FAN	F4	B3	4
GENTLY SLOPING PLATEAUS & TERRACES rolling plains & plateau	F5	C1/C3	0
MODERATE SLOPE BOUND VALLEY	M1	C2	8
ALLUVIATED, MODERATE SB VALLEY	M2	C4	6
INCISED U-SHAPED, MODERATE GRADIENT BOTTOM incised colluvium/till, moderate gradient channel valley	U2	D1	1
INCISED U-SHAPED HIGH GRADIENT BOTTOM incised colluvium/till, high gradient	U3	D2	1
V-SHAPED,MODERATE GRADIENT BOTTOM	V1	E1	10
V-SHAPED, STEEP GRADIENT BOTTOM	V2	E2	11
BEDROCK CANYON	V3		
ALLUVIATED MOUNTAIN VALLEY	V4	E3	7
U-SHAPED VALLEY	U1	F1	0
U-SHAPED, ACTIVE GLACIAL OUTWASH VALLEY	U4	F2	0
VALLEY WALL/HEADWATER, MOD.GRAD.BOTTOM	H1	G1	0
VALLEY WALL/HEADWATER, HIGHGRAD.BOTTOM	H2	G2	2
VALLEY WALL/HEADWATER, VERY HIGH GRAD. BOT.	H3	G3	1

APPENDIX B. Version 2.0, May 1990

HABITAT UNIT CODES

UNIT CATEGORY
1) > OR = 50% WETTED WIDTH
2) UNIT < 50% WETTED WIDTH
3) OCCURS IN SIDE CHANNEL

UNIT TYPE
1) CASCADE
RPD = RAPID
SPC = STEP-POOL CASCADE
SFC = SLIP-FACE CASCADE

2) RIFFLES
PKW = POCKETWATER
GLD = GLIDE
RUN = OBVIOUS!
LGR - LOW GRADIENT RIFFLE

3) POOLS
DMP = DAMMED POOLS
EDP = EDDY POOL
PLP = PLUNGE POOL
SCP = SCOUR POOL
SCH = SCOUR HOLE

4) SECONDARY CHANNEL
SDC = SECONDARY CHANNEL

5) BEAVER PONDS
BMP = BEAVER PONDS

OBSTRUCTIONS (FOR POOLS):

1 - LOG(S)
2 - WOODY DEBRIS JAM
3 - STANDING TREE
4 - BOULDER (S)
5 - BEDROCK
6 - ROOT PROTECTED BANKS
7 - BEDFORM
8 - OTHER*
(* EXPLAIN IN COMMENTS SECTION)

SUBSTRATE PARTICLE SIZE CODE:

CODE	SEDIMENT SIZE	
10	BOULDER	>50"
9	LG. COBBLE	25-50"
8	MED. COBBLE	12-25"
7	SM. COBBLE	6-12"
6	COARSE GRAVEL	3-6"
5	MED. GRAVEL	1.6-3"
4	SM. GRAVEL	0.8-1.6"
3	PEA GRAVEL	1-2MM
2	COARSE SAND	0.5-1.0MM
1	MED. SAND	0.25-0.50MM
0	FINE SAND	0.125-0.250MM

WOODY DEBRIS LOCATION:
A = NOT WITHIN WETTED AREA
B = PARITALLY WITHIN UNIT
C = COMPLETELY WITHIN UNIT
D = BRIDGED

SERAL STAGE:
1 = CLEAR CUT
2 = GRASS/FORB
3 = SHRUB
4 = POLE
5 = MATURE
6 = OLD GROWTH

VEGETATIVE TYPE: (WOODY)
1 = DECIDUOUS
2 = CONFEROUS
3 = MIXED

LAND USE:
1 = AGRICULTURE
2 = LIVESTOCK GRAZING
3 = TIMBER
4 = RESIDENTIAL
5 = RIGHT OF WAY
6 = MINING
7 = RMZ
8 = WETLAND
9 = OTHER (EXPLAIN)

EMBEDDEDNESS:
1 = > 75%
2 = 50 - 75%
3 = 25 - 25%
4 = 5 - 25%
5 = < 5%

FROM: HAMILTON, K., and BERGERSEN, E.P. METHODS TO ESTIMATE AQUATIC HABITAT VARIABLES. 1983 COLORADO COOPERATIVE Fishery RESEARCH UNIT AND COLORADO STATE UN. FORT Collins, Co.

CHAPTER 4. ~~DISCHARGE~~

4.1 General Considerations

Discharge (rate of flow, flow) is the volume of water that flows past a given point per unit time [e.g., cubic feet per second (cfs)]. It is the product of the cross-sectional area of flowing water and its velocity.

The discharge in some rivers and locations may be obtained directly from the U.S. Geological Survey. Information requested on Form 9-207 from the U.S. Geological Survey for any station will include date, width, area, mean velocity, gage height, and discharge. Many stations are now monitored by satellite, so that this information is available sooner than published records. Contact the National Oceanic and Atmospheric Administration (NOAA). This information should be related to the study site only if the gage house is nearby and if you can be relatively certain that the flow in the study area is the same as at the gage (i.e., no significant inflow or outflow between the gage and the study area).

If access to a stream gage is not possible or the stream flow is not known to be the same between the gage and the study area, the discharge must be measured at the study area. Because the accuracy of discharge measurements is greatly influenced by the amount of variation in the cross section, the discharge should be calculated from the cross section with the most uniform dimensions and substrate. For river surveys, velocity measurements are likely to be made at all cross sections, so discharge can be calculated for any of the cross sections. If all cross sections are highly nonuniform, it may be desirable to find one nearby the study area exclusively for discharge measurement. The discharge calculation should have the same number of significant digits, based on the precision of the stream-gaging measurements.

Discharge can also be measured directly using weirs and flumes (Bureau of Reclamation 1967), which is beyond the scope of this manual.

4.2 Channel Geometry Elements Used in Discharge Analysis
(modified from Bovee and Milhous 1978)

The following elements are used to calculate estimated discharge: Bottom slope (S_o) is the change in the average elevations of the bottom between two cross sections, divided by the distance between them. Channel roughness (n) is a coefficient of resistance to flow caused by particle friction and channel features. Cross-sectional area (A) is the area that contains water perpendicular to the direction of flow, computed as width × mean depth of cross section. Depth (d) is the vertical distance from a point on the bottom to the water surface (Fig. 4.1).

APPENDIX C.

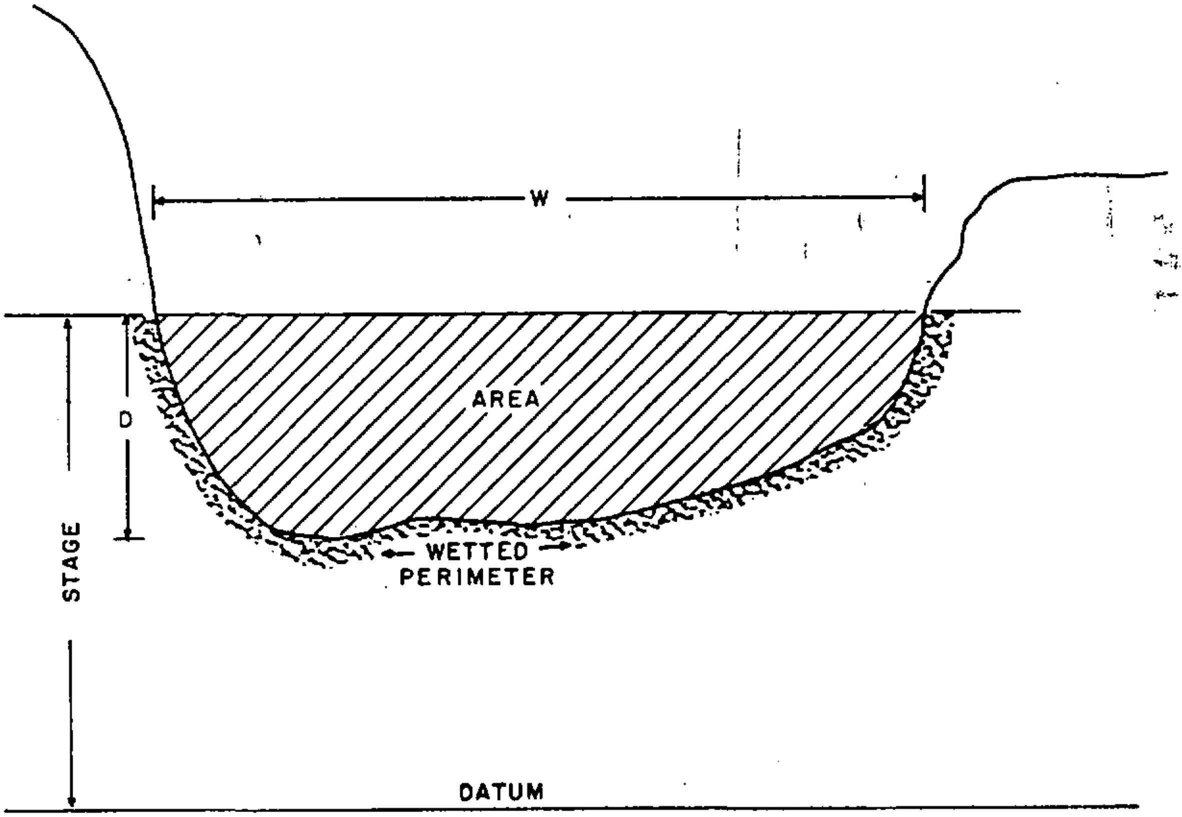


Fig. 4.1. Cross-sectional area of channel is computed as width (W) × mean depth of the cross section. Stage is the elevation of the water surface above a datum (plane of known arbitrary elevation) (from Bovee and Milhous 1978).

Energy slope (S_e) is change in total energy (potential and kinetic) available, divided by the distance between cross sections (Fig. 4.2). The total energy at a channel section is found with the open-channel form of the Bernoulli equation, as follows:

$$H = z + d + V^2/2g \quad , \tag{4.1}$$

where H = total energy head (ft or m)

z = elevation of the bed (ft or m)

d = average depth for section (ft or m)

V = average velocity (ft/sec or m/sec)

g = acceleration of gravity (32.2 ft/sec^2 or 9.8 m/sec^2)

For practical purposes, the terms z + d equal the water surface elevation for a given cross section (Fig. 4.2). Thus, the slope of the energy grade line is

$$S_e = \frac{h2 - h1}{\Delta x} \quad . \qquad (4.2)$$

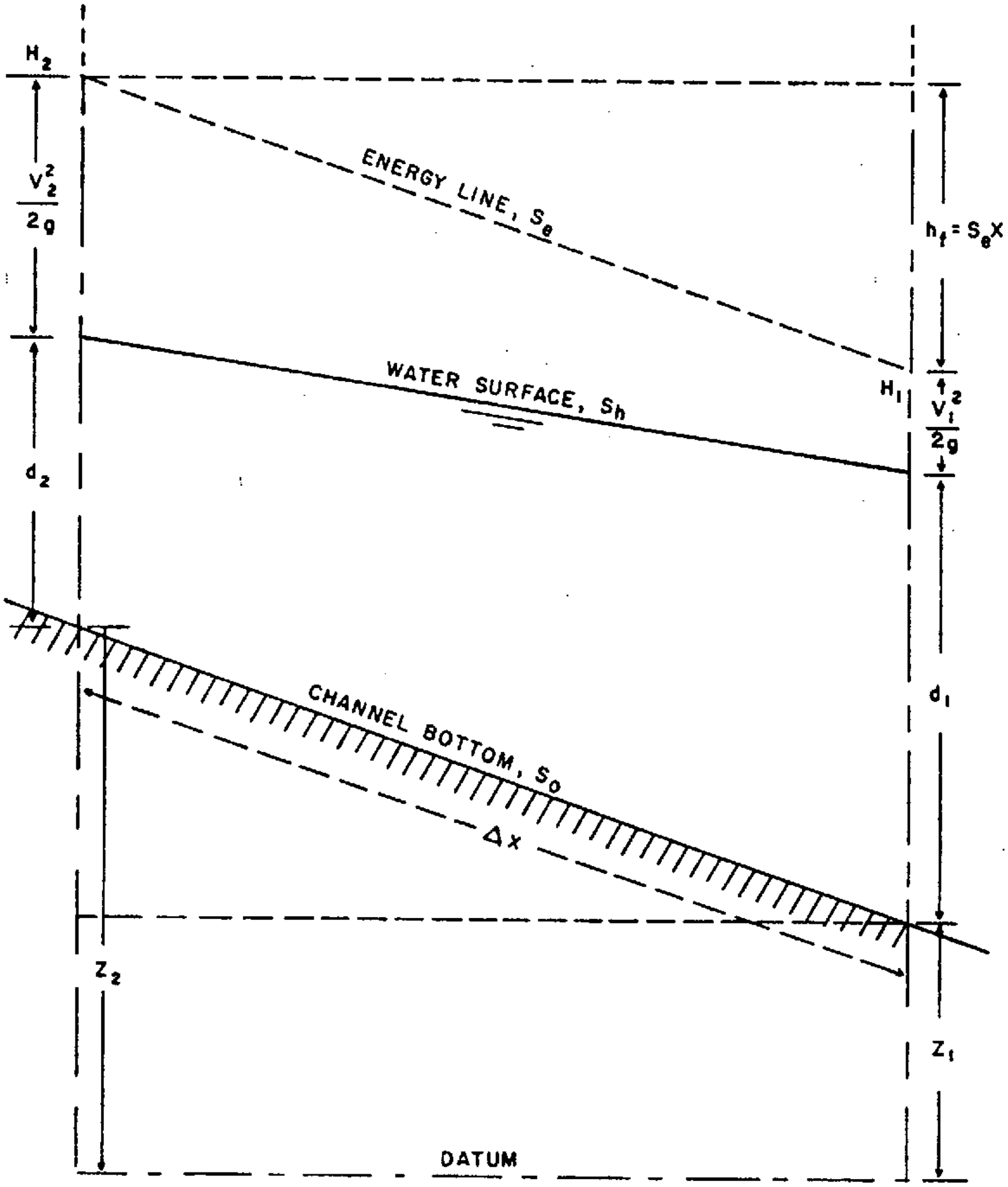


Fig. 4.2. Variables used in the energy analysis of open-channel flow (from Bovee and Milhous 1978)

If the assumption is made that flow in the channel is uniform, then the bed slope, hydraulic slope, and energy slope are considered equal: $S_o = S_h = S_e$.

Hydraulic depth (d) is equivalent to mean depth; d = A/w.

Hydraulic radius (R) is the ratio of the cross-sectional area to the wetted perimeter: R = A/p. For wide, shallow channels, R approximates the hydraulic depth.

Hydraulic slope (S_h) is the change in elevation of the water surface between two cross sections, divided by the distance between the cross sections.

Stage is elevation, or vertical distance, of the water surface above a datum (a plane of known or arbitrary elevation).

Steady flow occurs when the depth of flow in an open channel does not change or can be assumed constant over a specified time interval.

Unsteady flow occurs when the depth changes with time.

Thalweg is the longitudinal line connecting points of minimum bed elevation along the streambed.

Uniform flow occurs when the depth of flow is the same at every section of the channel. Thus, the hydraulic slope, energy slope, and bottom slope are parallel.

Varied flow occurs when the depth of flow changes along the length of the channel. Varied flow is classified as either rapidly or gradually varied, depending on the distance within which the change in depth occurs. Rapidly varied flow is manifest in an abrupt change in depth, resulting in hydraulic jumps, hydraulic drops, and related phenomena. The criterion for uniform or varied flow is change in depth with respect to space.

4.3 Commonly Used Equations For Analysis of Open Channel Flows

The water surface elevation in a stream defines the cross-sectional area of flow. If the velocity is also known, the discharge can be calculated using the equation of continuity:

$$Q = AV \quad , \tag{4.3}$$

Q = discharge (ft^3/sec or m^3/sec)

A = area of the cross-section flow (ft^2 or m^2)

V = average velocity of flow through the cross section (ft/sec or m/sec)

In 1889, an Irish engineer, Robert Manning, presented a velocity equation known now as the Manning equation:

$$V = \frac{1.486}{n} R^{2/3} S_e^{1/2} \quad , \tag{4.4}$$

V = mean velocity in the channel (ft/sec)

R = hydraulic radius (ft)

S_e = slope of the energy grade line

n = the coefficient of roughness, referred to as Manning's n.

The version of the Manning equation given as Eq. (4.4) is in English units. If metric measurements are used for R, the term 1.486 is omitted from the equation, and V will be given in metric equivalents to R.

Discharge may be calculated by substituting V from the Manning equation into the continuity equation:

$$Q = \frac{1.486}{n} R^{2/3} S_e^{1/2} A \quad .$$

The cross-sectional area and hydraulic radius are determined by the cross-sectional measurements and the stage. Manning's n may then be computed for the cross section by

$$n = \frac{1.486}{Q} R^{2/3} S_e^{1/2} A \quad .$$

Manning's n is then assumed constant in subsequent calculations when new stages are used for new discharge estimations. Manning's n can also be estimated in the field by experienced personnel in the field. See section 19.5, for further discussion of the estimation of n by observation.

4.4 Determining the Stage-Discharge Relationship

Once the stage has been determined for a certain discharge, its elevation is used to determine future discharges. Knowing the stage, the depth distribution is found for each cross section by subtraction of bed elevations across the channel from the stage. Thus, if the stage and bed elevations are known, the depth may be determined at any location on the cross section.

A. Manning Equation, Assuming Uniform Flows

Assuming a uniform flow, the measured hydraulic slope can be used instead of the energy slope. Flow variations caused by changes in channel geometry are assumed to be negligible. The more uniform the dimensions and substrate of the channel, the more reliable the results will be.

The following elements of channel geometry are measured at two cross sections: (1) water surface elevation (stage); (2) discharge; (3) hydraulic slope; (4) dimensions of the channel cross section, using partial sections (a) width and (b) depth; and (4) cross-sectional area and hydraulic radius calculated from cross-sectional dimensions. Manning's n is then calculated by Eq. (6). To determine discharges at different stages, only stage is measured in the field. All other data can be calculated using the stage measurement, and the Manning's n is assumed to remain constant.

B. Rating Curve

This is the most accurate method of obtaining a relationship between stage and discharge. It requires the determination of several discharges directly from field measurements. Stage is plotted on the abscissa and discharge on the ordinate of log-log paper, or a least-squares equation is calculated from these data pairs. Subsequent estimations of discharge require only a stage measurement, which is used on the plotted curve or in the regression equation to calculate discharge.

4.5 Calculations of Partial Discharge

Methods for obtaining data required for discharge calculations are found under the appropriate chapters in this manual (Depth, Distance, Velocity).

Referring to Fig. 4.3, you will see that data on the total channel cross section is composed of measurements that describe partial sections. Each partial section also has a partial discharge calculated from the field measurements:

a_i = cross-sectional area of partial section, i

w_i = width of partial section, i; the distance halfway to the previous measurement point, n - 1, plus the distance halfway to the next measurement point, n + 1

d_i = depth of partial section, i, measured at the center of the partial section (observation point n)

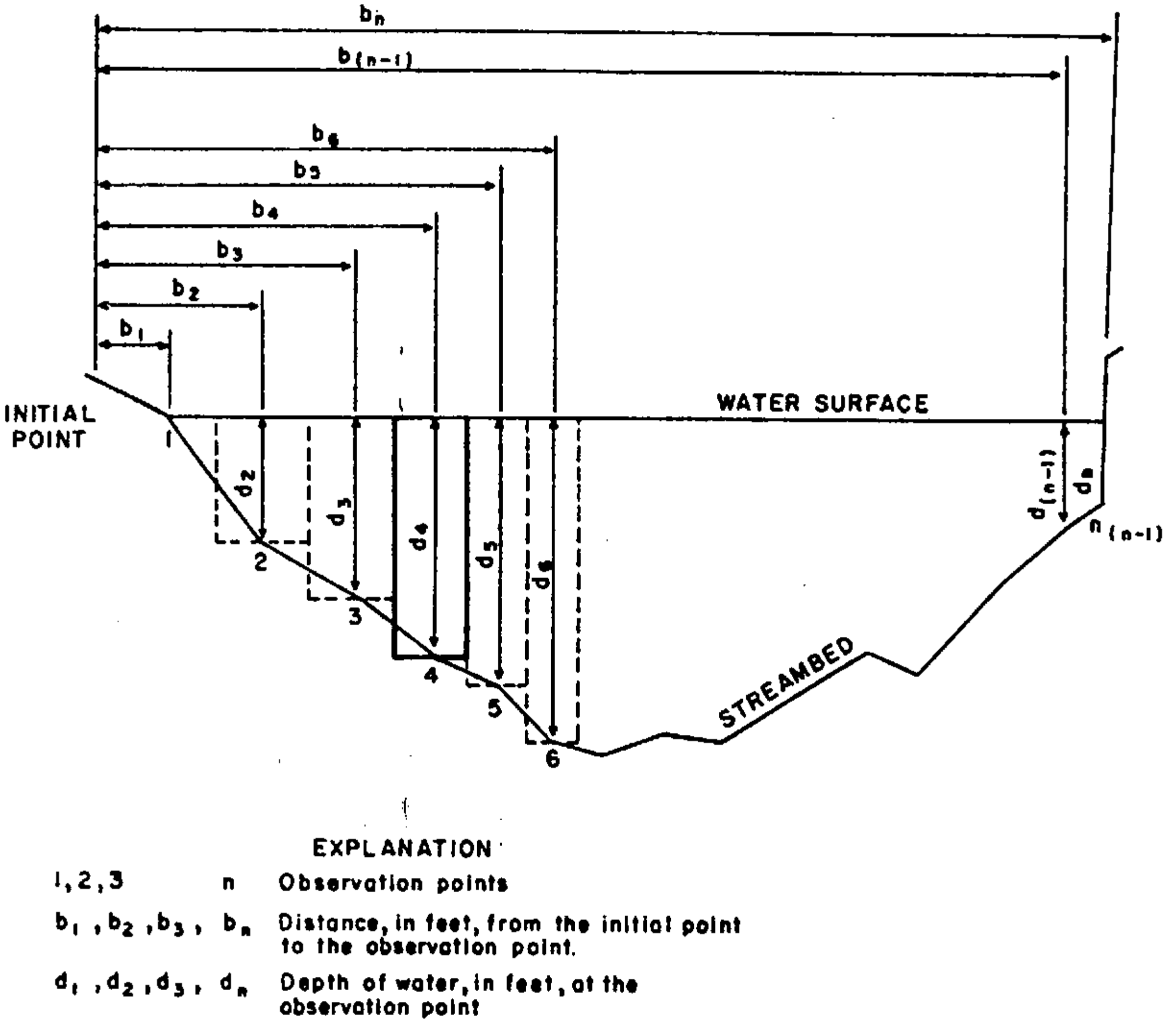


Fig. 4.3. The total channel cross section can be divided into partial sections and a partial discharge calculated from b, d, and the velocity in the partial section. The total discharge is the sum of the partial discharges (from Bovee and Milhous 1978)

v_i = velocity of partial section, i

q_i = discharge through partial section, i

$$a_i = w_i \times d_i$$

$$q_i = a_i \times v_i$$

$$q_i = w_i \times d_i \times v_i \quad .$$

The discharge for the entire transect is the sum of the partial discharges:

$$Q = \Sigma (v_i \times w_i \times d_i) \qquad (4.5)$$

4.6 Accuracy

The accuracy of discharge calculations depends on (1) the accuracy of methods used to measure width, depth, stage, and velocity; (2) the number of partial sections measured; and (3) the accuracy of the estimated Manning's n.

Accuracy of subsequent discharge predictions depends on whether they rely on one set of field measurements (Manning's equation) or on a rating curve constructed from a number of measurements.

The reliability of Manning's equation is limited by the range of flows of interest and the magnitude of extrapolation from the calibrated flow to the unknown flow. Seemingly small differences between the assumed value and the actual value for Manning's n can introduce very large errors into the prediction. Factors that introduce large errors in the rating-curve method include discharge measurements too close together and construction of a curve from only a few measurements. See Bovee and Milhous (1978) for an analysis of error for the different methods of predicting discharge.

4.7 Equipment

Because discharge is estimated by calculation, required equipment for field measurements is listed under the individual variables necessary for calculating the equations. A calculator with memory or access to a computer should be acquired when large amounts of data are expected.

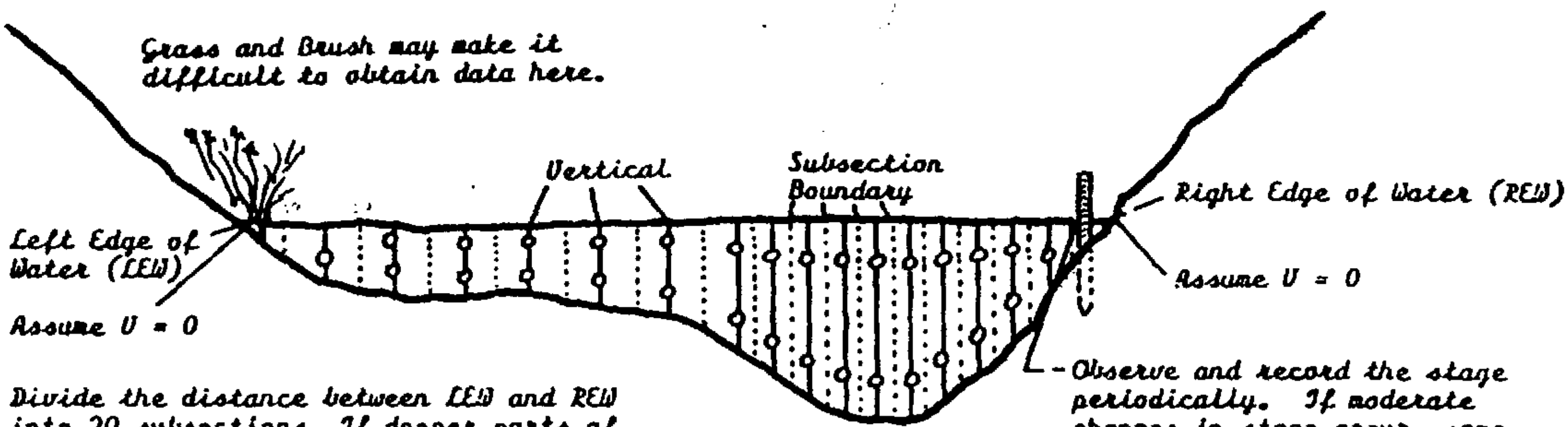
4.8 Training

Measurement of the individual variables requires different training periods and devotion to accuracy. If the field data are on well-planned data sheets from which calculations can be directly made, little time should be required to explain the sequence of calculation. The calculations are simple arithmetic, but they can be tedious if done by hand. Use of a computer package requires experience.

4.9 References

Barnes (1967), Binns (1982), Bovee and Milhous (1978), Dunne and Leopold (1978), Gregory and Walling (1973), Bureau of Reclamation (1967).

MEASURING STREAM DISCHARGE



Divide the distance between LEW and REW into 20 subsections. If deeper parts of the stream are encountered, subdivisions are again subdivided. No more than 10% of the total discharge should occur in any subdivision.

Observe and record the stage periodically. If moderate changes in stage occur, some adjustments must be made in reducing the data.

The depth of water is measured at the vertical and the observation depth of the meter is decided. If the depth is less than 25feet(0.6 meter), the meter is set at .6 of the depth from the surface. When depths are greater than 25feet, the average of the measurements at .2 and .8 of the depth from the surface is the mean velocity.

Count the number of revolutions for either a period of 50 or 100 seconds for ease of data reduction.

Not to scale

Keep the current meter clean. Moss and algae should not be allowed to wrap around the spindle or hub of propeller. Spin test before and after making a stream gaging to check for excessive friction in the bearings.

Fig. Measuring Stream Discharge in a Typical Cross Section (from Schulz 1978)

DATA TABLE

Stream Discharge Data to Accompany Problem 7.1

Stage	Distance from Bank	Width	Depth	Current Meter Depth	Revolutions	Time seconds	RPS	Velocity at Point	Velocity Mean	Subsection Area	Subsection Discharge
(ft)	(ft)	(ft)	(ft)	(ft)		(sec)		(ft/s)	(ft/s)	(sq.ft)	(cfs)
1.25	0		0	—	—	Right	Edge	of	Water	(REW)	—
1.25	1	2.5	0.75	0.42	14	100	.14	0.465	0.465	1.87	0.87
1.25	5	4.5	1.15	0.69	15	100	.15	.487	.487	5.175	2.52
1.25	10	5.0	1.18	0.71	15	100	.15	.487	.487	5.90	2.88
1.26	15	5.0	1.20	0.72	16	100	.16	.510	.510	6.00	3.06
1.25	20	5.0	1.15	0.69	17	100	.17	.532	.532	5.75	3.06
1.24	25	5.0	1.21	0.73	21	100	.21	.622	.622	6.05	3.77
1.23	30	4.0	3.01	0.60 2.41	35 28	50 50	.70 .56	1.725 1.410	1.567	12.040	18.87
1.24	33	3.0	4.60	0.92 3.68	38 31	50 50	.76 .62	1.860 1.545	1.703	13.800	23.49
1.25	36	3.0	6.40	1.28 5.12	39 35	50 50	.78 .70	1.905 1.729	1.815	19.200	34.85
1.26	39	3.0	7.05	1.41 3.53 5.64	48 49 37	50 50 50	.96 .98 .74	2.310 2.355 1.815	2.209	21.180	46.72
1.25	42	3.0	6.80	1.36 3.40 5.44	45 48 31	50 50 50	.90 .96 .62	2.175 2.310 1.545	2.085	20.40	42.53
1.25	45	3.0	4.98	1.00 3.98	43 33	50 50	.86 .66	2.085 1.635	1.860	14.940	27.79
1.25	48	2.5	2.20	0.44 1.76	38 29	50 50	.76 .58	1.860 1.455	1.658	5.50	9.12
1.25	50	1.5	.95	.57	48	100	.48	1.230	1.230	1.425	1.75
1.25	51		0	—	—	Left	Edge	of	Water	(LEW)	—
									Total	139.20	221.28 cfs

Not necessary with meters that give digital readout in feet per second

[illegible]

APPENDIX D.

A SYSTEM OF NAMING HABITAT TYPES IN SMALL STREAMS, WITH EXAMPLES OF HABITAT UTILIZATION BY SALMONIDS DURING LOW STREAMFLOW[1]

Peter A. Bisson, Jennifer L. Nielsen, Ray A. Palmason
and Larry E. Grove[2]

Abstract.--Fish habitat in small streams is classified into a number of types according to location within the channel, pattern of water flow, and nature of flow controlling structures. Riffles are divided into three habitat types: low gradient riffles, rapids, and cascades. Pools are divided into six types: secondary channel pools, backwater pools, trench pools, plunge pools, lateral scour pools, and dammed pools. Glides, the last habitat type, are intermediate in many characteristics between riffles and pools. Habitat utilization by salmonids was studied during summer low streamflow conditions in four western Washington streams. Most age 0+ coho salmon (Oncorhynchus kisutch) reared in pools, particularly backwaters, and preferred cover provided by rootwads. A few large coho occupied riffles and sought the cover of overhanging terrestrial vegetation and undercut banks. Age 0+ steelhead trout (Salmo gairdneri) selected riffles with large wood debris; while age 1+ steelhead preferred plunge, trench, and lateral scour pools with wood debris and undercut banks. The largest individuals of both steelhead age classes were found in swiftly flowing riffle habitats. Age 0+ cutthroat trout (S. clarki) preferred low gradient riffles but switched to glides and plunge pools when steelhead and coho were present, thus suggesting that they had been competitively displaced from a preferred habitat. Age 1+ and 2+ cutthroat preferred backwater pools when coho were absent but avoided them when coho were present. Cutthroat of all age classes generally favored cover provided by wood debris in both pool and riffle habitats.

INTRODUCTION

Identification of the important components of stream habitat is essential if we are to accurately assess environmental change, understand ecological segregation within multispecies communities, or determine the need for stream enhancement projects. Most fishes in small streams are habitat specialists (Gorman and Karr 1978) and utilize specific locations within stream channels throughout their freshwater life cycles in response to different spawning, feeding, and overwintering requirements (Northcote 1978). Within the Salmonidae competition plays a key role in habitat utilization when food is limited (Kalleberg 1958; Keenleyside and Yamamoto 1962; Hartman 1965; Chapman 1966a; Mason 1969; and many others) and such density dependent interactions result in habitat partitioning that facilitates the coexistence of several species as well as multiple age classes (Rosenzweig 1981). Habitat shifts can occur when conditions unsuitable to feeding develop (Hunt 1969; Bustard and Narver 1975a; Mason 1976; Peterson 1980) leading to the breakdown of territories and the aggregation of individuals into protected spaces. Utilization of particular locations within the stream varies greatly in time and space, and although small streams tend to be structurally complex, few if any areas of the channel are not occupied at one time or another.

Fishery biologists have traditionally classified streams into a variety of zones based on channel characteristics (e.g. Platts 1974; Moreau and Legendre 1979), associated biota (e.g., Huet 1959), or a combination of physical, chemical, and biological features (e.g. Binns and Eiserman 1979). Habitat requirements have often been presented as tolerance ranges or preferenda for certain water quality conditions. While tolerance limits for such parameters as

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[1] Paper presented at the symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information (Portland, Ore., October 28-30, 1981).

[2] Present address: Weyerhaeuser Company, Western Forestry Research Center, Centralia, Washington 98531.

dissolved oxygen and temperature have been defined with relative precision for many fish species, lack of a precise language describing the components of the physical environment may limit our ability to predict a stream's productivity for a species of interest. The often-used names 'riffle' and 'pool' convey a notion of relative water depth and current velocity, but beyond this they give little indication of living conditions relative to substrate, flow patterns, and cover. Not surprisingly, considerable variation exists in fish utilization of these general categories within the stream (Allen 1969). The terminology discussed in this paper represents an attempt to classify habitat in greater detail. Results of limited field evaluations indicate that the system can be a useful tool in assessing stream conditions and in describing spatial segregation among coexisting fish populations.

METHODS

Terminology

There appears to be no widely accepted set of habitat definitions for small streams. Although riffles and pools are the basic units of channel morphology and will always develop in natural streams as a mechanism of self-adjustment to the law of least time rate of energy expenditure (Yang 1971), the actual configuration and hydraulic properties of these units are highly variable. The continuous gradation in depth and velocity between pools and riffles has spawned terms such as 'run', which appear frequently in fisheries literature, often without detailed explanation. In attempting to construct a precise and consistent set of descriptive terms we have utilized definitions from the Glossary of Geology (Gary et al. 1974) wherever possible.

Riffles

Three types of riffle habitats were identified. Low gradient riffles (Fig. 1) were shallow (< 20 cm deep) stream reaches with moderate current velocity (20-50 cm/sec) and moderate turbulence. Substrate was usually composed of gravel, pebble, and cobble-sized particles (2-256 mm). An upper gradient limit for this habitat type was arbitarily set at 4%. Rapids (Fig. 2) possessed a gradient greater than 4% with swiftly flowing water (>50 cm/sec)


Figure 1. Low gradient riffle.

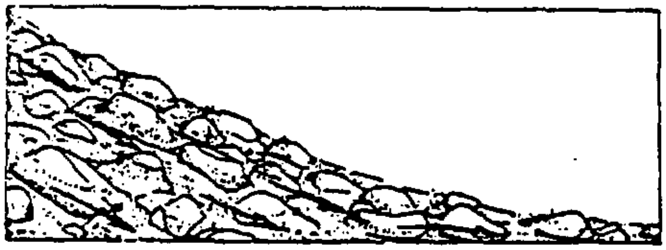


Figure 2. Rapids.


Figure 3. Cascade.

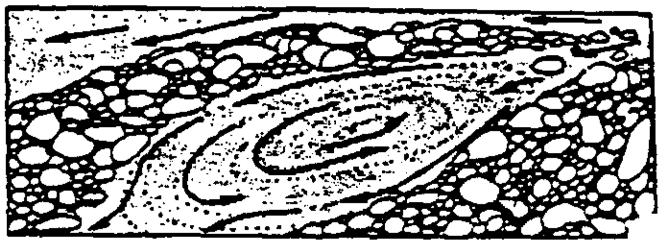


Figure 4. Secondary channel pool.

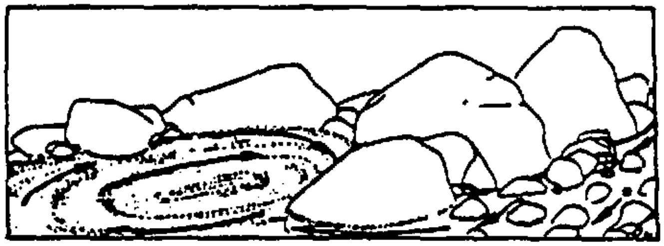


Figure 5. Backwater pool associated with boulders.


Figure 6. Backwater pool associated with rootwad.

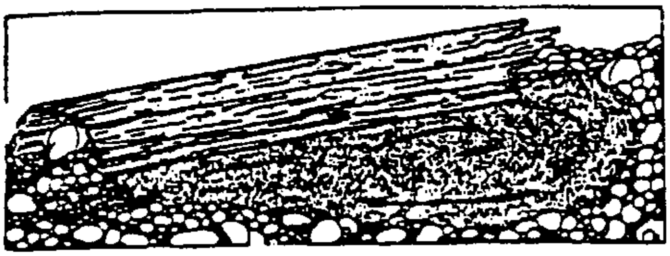


Figure 7. Backwater pool associated with large debris.

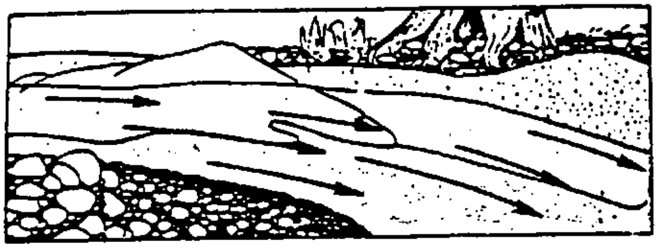


Figure 8. Trench pool associated with bedrock.

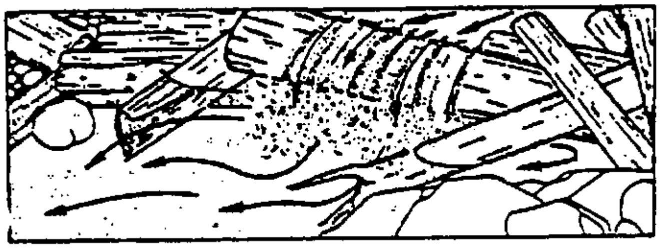


Figure 9. Plunge pool associated with large debris.


Figure 10. Lateral scour pool associated with large debris.

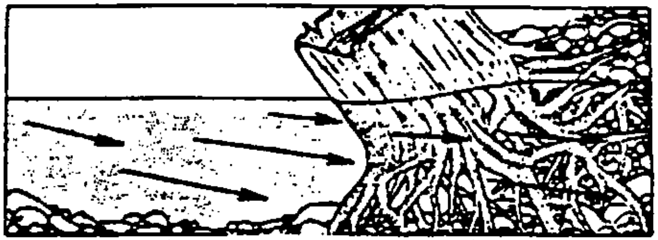


Figure 11. Lateral scour pool associated with rootwad.


Figure 12. Lateral scour pool associated with bedrock.

having considerable turbulence. The substrate of rapids was generally coarser than the substrate of low gradient riffles, and during low streamflow conditions large boulders typically protruded through the surface. Cascades (Fig. 3), the third type of riffle habitat, were the steepest. Unlike rapids, which had an even gradient, cascades consisted of a series of small steps of alternating small waterfalls and shallow pools. The usual substrate of cascades was bedrock or an accumulation of boulders; however, this habitat type was occasionally found on the downstream face of woody debris dams.

Pools

During low streamflow conditions there were six pool types, which were associated with the presence of bedrock outcroppings, large rocks, or large tree stems and rootwads in the channel. Secondary channel pools (Fig. 4) were those that remained within the bankful margins of the stream after freshets. During the survey period (June-September) most of these pools had disappeared, and those remaining had little flow through them. Secondary channel pools were usually associated with gravel bars, but many contained sand and silt substrates. Backwater pools (Figs. 5-7) were found along channel margins and were caused by eddies behind large obstructions such as rootwads or boulders. This pool type was often quite shallow (>30 cm) and tended to be dominated by fine-grained substrates. Like secondary channel pools, backwater pools possessed current velocities that were very low. Trench pools (Fig. 8) were long, generally deep slots in a stable substrate. Channel cross sections were typically U-shaped with a coarse-grained bottom flanked by bedrock walls. Current velocities in trench pools were the swiftest of any pool type and the direction of flow was most uniform. Plunge pools (Fig. 9) occurred where the stream passed over a complete or nearly complete channel obstruction and dropped vertically into the streambed below, scouring out a depression. This pool type was often large, quite deep (>1 m), and possessed a complex flow pattern radiating from the point of water entry. Substrate particle size was also highly variable. Lateral scour pools (Figs. 10-12) differed from plunge pools in that the flow was directed to one side of the stream by a partial channel obstruction. Often an undercut bank was associated with this pool type. Dammed pools

Figure 13. Dammed pool associated with large debris.

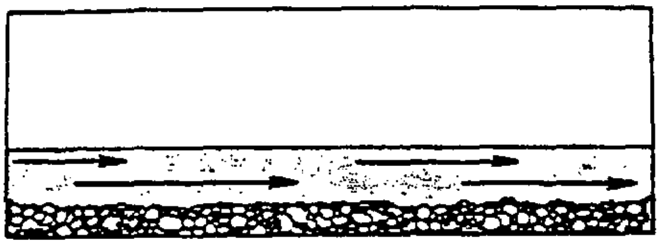


Figure 14. Glide.

(Fig. 13) consisted of water impounded upstream from a complete or nearly complete channel blockage. Typical causes of dammed pools were debris jams, rock landslides, or beaver dams. Depending upon the size of the blockage, dammed pools could be very large. Water velocity in this pool type was characteristically low and substrates tended toward smaller gravels and sand.

Glides

A third general habitat category existed that possessed attributes of both riffles and pools. Glides (Fig. 14) were characterized by moderately shallow water (10-30 cm deep) with an even flow that lacked pronounced turbulence. Although they were most frequently located at the transition between a pool and the head of a riffle, glides were occasionally found in long, low gradient stream reaches with stable banks and no major flow obstructions. The typical substrate was gravel and cobbles. The term 'run' has been applied to this habitat type, but we feel that the designation 'glide' is a more precise descriptor of the habitat conditions. Similar usage of the term has previously been adopted by Cuinat et al. (1975) and Chapman and Knudsen (1980).

Cover

Eight distinct kinds of cover for fishes were identified. These included three kinds of wood debris - rootwads, large debris (tree stems), and small debris (branches, twigs, etc.) - that differed in the amount of overhead cover and flow modifications they provided within the channel. Overhanging terrestrial vegetation and undercut banks were two kinds of cover that wer largely governed by the condition of the riparian zone. Water turbulence acted as cover when the presence of bubbles prevented a clear view of the water beneath (Lewis 1969). Rocks functioned as cover in two ways, by providing overhanging ledges and by providing crevices for hiding. Finally, maximum depth was itself a form of cover from non-diving terrestrial predators (Stewart 1970). We assumed that the primary function of cover during the summer was protection from predation.

Sample Locations and Inventory Techniques

Sample locations were chosen to encompass a wide variety of stream conditions in western Washington. Nineteen sites consisting of channel reaches 0.2 - 1.3 km long were located in four streams. Three of the streams (Newaukum River, Salmon Creek, Thrash Creek) were Chehalis River tributaries; the fourth stream (Fall River) was part of the Willapa Bay drainage system. The sites included 700 individual habitats totaling approximately 7,800 m axial length, 33,600 m^2 wetted surface area, and 8,900 m^3 volume. Channels ranged in size from third to fifth order with 1-8% gradient. Parent rock type was either sandstone or basalt. Streamside vegetation varied according to forest management history; recently clearcut sites were dominated by shrubs second growth forested sites were dominated b red aler (Alnus rubra), and old growth forested sites were dominated by mixed conifers. All sample locations possessed natural populations of salmonids, although some sites were above upstream migration blockages and contained only resident non-migratory cutthroat trout. There was no evidence that any of the sites had been fished by anglers.

Each stream reach was surveyed on foot and the location of different habitat types, as well as significant flow controlling structures, was drawn to scale on a map (Fig. 15). Contour lines based on depth measurements were drawn within pools to enable volume estimation. Wetted surface areas were determined by counting squares on gridded paper that was superimposed on the maps. Axial length was figured as the distance along the thalweg or greatest linear dimension of a habitat unit parallel to the direction of flow. Reach summaries were constructed by summing the lengths, areas, and volumes of each habitat type and expressing each group as a percentage of the total. The amount of cover in each habitat was rated on a relative abundance scale of 0-3, where a score of zero indicated that the particular kind of cover was essentially absent and a score of three indicated a very abundant condition. Substrate was noted as predominant type, i.e., the physical and/o biological type most prevalent within a habita unit.

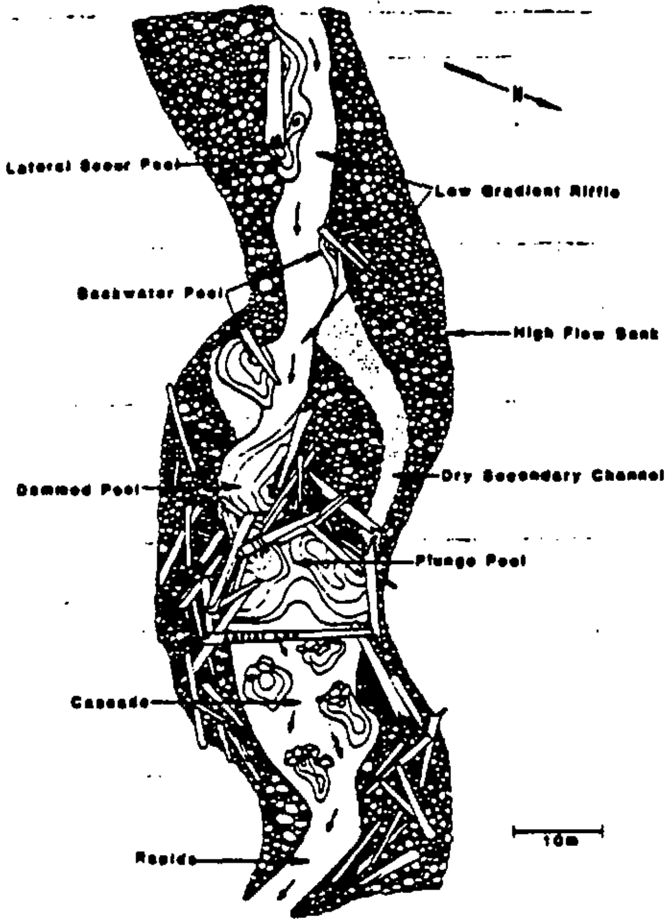


Figure 15. An example of a stream channel map showing locations of various habitat types.

Fish populations were sampled by isolating individual habitat types with blocking nets and electrofishing the habitat three times, retaining separately the fish captured on each pass. Individual biomasses were determined from length-weight relationships (Bisson and Sedell 1982 <u>in press</u>) and age class abundance was figured from size frequency distributions and scale samples. Population density and biomass estimates were based on a removal summation method of calculation (Carle and Strub 1978). Sculpins (*Cottus* spp.) were also captured but their biomasses are not reported in this paper. Approximately 28% of the total number of habitats inventoried were sampled for fish populations, resulting in the capture of 11,385 salmon and trout.

In order to quantify habitat utilization by species and individual age classes it was necessary to relate the fraction of the population found within a particular habitat type to the relative abundance of that habitat type in the stream. The formula used was based on the electivity index of Ivlev (1961):

$$(1)\ \text{Utilization} = \frac{\text{habitat specific density} - \text{average total density}}{\text{average total density}}$$

where

habitat specific density = average density in the habitat type of interest

average total density = average density over the entire stream reach, all habitats combined

Values of this habitat utilization coefficient theoretically range from minus one, indicating total non-use of a habitat type, to positive infinity as a greater proportion of the population resides in the habitat type of interest. A value of zero indicates that the population occurs in the habitat type in proportion to that type's abundance in the stream.

FIELD TRIALS

Habitat Characteristics

Although variation in size and frequency of habitat types was related to stream order, basin geology, and land management history, average dimensions of the different habitats are given in Table 1 for comparison. Overall, glides had the greatest individual length and surface area but pools had the greatest volume. Despite their relatively large size, glides were infrequent and accounted for a small fraction of total stream space. Pools were the dominant habitat category, accounting for about 50% of stream length and almost 80% of stream volume. Lateral scour pools were the most common type and also possessed the greatest surface area. Secondary channel pools, backwater pools, and dammed pools were smallest and least frequent. None of the sample sites contained beaver dams, log jams, or major landslides, thus accounting for the absence of large dammed pools in the reaches that were surveyed. Low gradient riffles were both the largest and most abundant riffles type, while rapids and cascades tended to be small and less frequent. Riffles averaged 40% of stream length but accounted for only 16% of stream volume

Large woody debris, including rootwads, was the most abundant cover in pools, while rocks were the primary cover in riffles. Depth was important cover in pools having large water volumes (lateral scout, plunge, and trench). Turbulence created cover where falling water formed bubbles in plunge pools, rapids, and cascades. In general, cover quantity and diversity was greater in pools than in riffles or glides.

Habitat Utilization

During the summer very few individuals of any fish species occupied secondary channel pools (Table 2). Many of these habitats had become isolated from the main channel and they often possessed high temperatures and dense algal growths. Although it is likely that secondary channel pools are utilized at other times of the year, particularly in large rivers (Sedell et al. 1980), lack of use of these habitats during low streamflow periods by salmonids is similar to the findings of studies of other stream fishes (Tramer 1977; Williams and Coad 1979).

Backwater pools were heavily utilized by age 0+ coho salmon, although coho in backwaters were smaller than average (Table 3). Preferential use of this habitat type by coho may have been related to a dependency on terrestrial food during summer that has been found by other investigators (Chapman 1966b; Mundie 1969). No other species displayed as strong an association with backwater pools as did coho; however, where anadromous forms were absent, yearling and older cutthroat also preferred this habitat type. In general, fish size in backwaters tended to be smaller than average.

Trench pools were selectively utilized by coho and yearling steelhead, and by age 1+ and 2+ cutthroat in anadromous zones. Where coho and steelhead were absent, all cutthroat age classes exhibited a mild avoidance of this pool type. Underyearling cutthroat collected f trench pools were smaller than average. Plunge pools were selected by coho, yearling steelhead, and all cutthroat age classes except age 0+ fish in areas upstream from an anadromous zone. Coho in plunge pools were the largest of those taken in any pool type.

Lateral scour pools were preferred by older age classes of both steelhead and cutthroat. Individuals collected from this pool type were average size, except for age 0+ cutthroat which tended to be slightly smaller than average in non-anadromous areas. Owing to the relative abundance of this habitat type, over 25% of all salmonids occurred in lateral scour pools.

An insufficient number of dammed pools were sampled to yield satisfactory evidence of relative habitat utilization or average fish weight. Flow pattern in this pool type would seem to be favorable to coho and there is ample evidence from other studies (Bustard and Narver 1975b; Nickelson and Hafele 1979; Everest and Meehan 1981) that coho utilize impounded water in streams. Provided there is sufficient depth and cover, dammed pools should also provide favorable habitat for age 1+ steelhead and age 1+ and older cutthroat.

Low gradient riffles were selectively occupied by underyearling steelhead a

Table 1. Average habitat size and percent of total stream (in parenthesis).

Habitat Type	n	Average Habitat Size / % of Total: Length (m)	Area (m²)	Volume (m³)
Pools				
Secondary Channel	26	9 (<1)	34 (<1)	8 (<1)
Backwater	74	8 (10)	29 (7)	8 (7)
Trench	34	15 (8)	70 (8)	26 (10)
Plunge	38	14 (5)	77 (5)	45 (10)
Lateral Scour	146	16 (28)	102 (35)	43 (50)
Dammed	5	7 (<1)	30 (<1)	18 (1)
Riffles				
Low Gradient Riffles	197	11 (26)	51 (25)	7 (12)
Rapids	114	7 (13)	25 (9)	3 (3)
Cascades	21	8 (<1)	30 (<1)	6 (<1)
Glides	43	15 (9)	92 (11)	15 (6)

Table 2. Habitat specific utilization coefficients.

	Anadromous Zone						Above Anadromous Zone		
	Coho	Steelhead		Cutthroat			Cutthroat		
Habitat Type	0+	0+	1+	0+	1+	2+	0+	1+	2+
Pools									
Secondary Channel	-1.00	-0.99	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Backwater	6.74	-0.46	0.21	-1.00	-0.52	-0.75	-0.36	0.42	0.80
Trench	1.07	0.14	1.16	-1.00	0.54	0.99	-0.21	-0.16	-0.23
Plunge	0.93	0.10	2.23	1.41	0.79	0.92	-0.54	1.09	1.61
Lateral Scour	-0.46	0.07	0.89	-0.08	1.14	1.83	0.18	1.04	0.88
Dammed	Insufficient Samples								
Riffles									
Low Gradient	-0.75	0.50	-0.70	0.26	-0.23	-0.71	0.45	-0.73	-0.78
Rapids	-0.99	0.50	0.98	-0.45	-0.67	-0.20	-0.10	-0.83	-0.90
Cascades	-0.97	0.79	0.58	-1.00	0.70	-1.00	-0.24	-0.80	-0.89
Glides	-0.91	0.34	0.86	1.42	-0.77	-0.92	0.00	-0.79	-0.33

Table 3. Size differences among salmonids captured in individual habitat types, expressed as percent deviation from overall average weight. Data for n ≤ 5 are omitted.

	Anadromous Zone						Above Anadromous Zone		
	Coho	Steelhead		Cutthroat			Cutthroat		
Habitat Type	0+	0+	1+	0+	1+	2+	0+	1+	2+
Pools									
Backwater	-12	-11	-2		+4	-9	+27	-2	-21
Trench	-2	0	+5		-1	+3	-21	-5	
Plunge	+14	-1	-2		-4	+2	+8	-2	+3
Lateral Scour	+1	-2	-5		+4	+4	-9	0	+1
Riffles									
Low Gradient	+1	+5	-16		-13	-7	+11	+26	
Rapids	+21	+12	+15		+10		-20	+7	
Cascades		+29	-4		+18		-8	-6	
Glides	+5	-15	-19			-26	+6	-9	

cutthroat, and were not preferentially used by other age classes. Cutthroat in anadromous zones were smaller than average while those in non-anadromous areas were larger than average, thus suggesting that competition with steelhead had reduced cutthroat growth rates in low gradient riffles. Evidence for competitive dominance of underyearling cutthroat by underyearling steelhead was also provided by the reduced utilization of low gradient riffles by cutthroat where steelhead were present compared to sites where steelhead were absent. Platts (1977) found that cutthroat were displaced to secondary habitats in the presence of juvenile chinook salmon and steelhead, but Hartman and Gill (1968) speculated that differences in the distribution of underyearling cutthroat and steelhead were related to microhabitat variation in spawning preferences of adults.

Utilization of rapids and cascades was limited mostly to steelhead. Both habitats were strongly avoided by most coho, yet the few individuals that occurred in rapids were much larger than average. Underyearling and yearling steelhead favored both habitats and seemed to grow well there. Chapman and Bjornn (1969) have also observed that steelhead occupy swifter water as they become larger and these authors felt that preference for faster water was associated with increased exposure to food organisms. However, while steelhead preferred fast water riffles, cutthroat, for the most part, did not.

Glides were selectively utilized only by steelhead and by underyearling cutthroat. Insufficient numbers of age 0+ cutthroat were collected from sites possessing coho and steelhead to permit determination of size variation; however, ages 0+ and 1+ steelhead occurring in glides were the smallest of those found in any habitat type.

Cover Associations

In both pool and riffle habitats the densities of age 1+ and older trout tended to increase in association with increased cover (Table 4) but age 0+ salmon and trout were relatively unaffected by cover conditions, although some positive associations did exist between underyearling densities and certain cover types. Our finding that older trout were more responsive to increased cover agrees with the

Table 4. Average correlations (r^2) between age class density and cover types within habitats.

Cover Type	Coho 0+	Steelhead 0+	Steelhead 1+	Cutthroat 0+	Cutthroat 1+	Cutthroat 2+
	-----	-----	-----	Pools	-----	-----
Rootwad	+0.19	-0.05	+0.34	+0.05	+0.04	+0.13
Large Wood Debris	-0.27	-0.11	+0.23	+0.05	+0.40	+0.25
Small Wood Debris	-0.16	-0.07	+0.18	+0.20	+0.15	+0.17
Terrestrial Vegetation	0.00	+0.12	+0.09	-0.24	+0.04	+0.12
Undercut Bank	0.00	+0.12	+0.26	-0.13	+0.22	+0.37
Turbulence	-0.01	-0.26	-0.04	-0.34	+0.05	+0.21
Underwater Boulders	-0.78	-0.25	-0.54	-0.49	-0.23	-0.09
Maximum Depth	-0.14	-0.29	-0.02	-0.42	+0.03	+0.44
	-----	-----	-----	Riffles	-----	-----
Rootwad	-0.03	-0.21	-0.29	+0.02	-0.16	+0.24
Large Wood Debris	-0.03	+0.31	+0.42	-0.30	+0.46	+0.43
Small Wood Debris	0.00	+0.03	+0.11	+0.40	+0.07	+0.27
Terrestrial Vegetation	+0.80	+0.11	-0.13	-0.04	+0.07	+0.11
Undercut Bank	+0.37	-0.50	-0.42	0.00	+0.35	+0.43
Turbulence	-0.42	-0.27	+0.19	-0.31	+0.40	+0.20
Underwater Boulders	-0.46	-0.08	-0.19	-0.25	+0.43	-0.07
Maximum Depth	-0.51	-0.20	+0.46	-0.45	+0.43	+0.57

stream enhancement results of Saunders and Smith (1962) and Hunt (1978), who noted that cover additions improved the productivity of older trout more than it did underyearlings.

Wood debris proved to be a preferred cover type for age 1+ steelhead and age 1+ and 2+ cutthroat. The strongest associations were observed with large debris pieces, especially in riffle habitats. Preference of yearling steelhead for large debris has been documented by Bustard and Narver (1975a) and both Osborn (1981) and June (1981) have shown that older cutthroat rely heavily on large wood debris for cover. Underyearling steelhead did not respond positively to increased wood debris in pools but utilized large debris in riffles. Underyearling cutthroat showed a slight positive response to increased debris in pools and a definite preference for small debris in riffles. The utilization of small debris by underyearling cutthroat may be similar to the cover preferences of age 0+ brown trout (S. trutta), which have been shown to decline following small debris removal (Mortensen 1977). Age 0+ coho exhibited a mild positive response to increased rootwad abundance in pools, but were unaffected by other kinds of debris. Association of coho with wood debris has been previously demonstrated by Lister and Genoe (1970) and Bustard and Narver (1975a, 1975b).

Overhanging terrestrial vegetation and undercut banks along riffles were strongly preferred by coho, although riffles were inhabited by relatively few individuals of this species (Table 2). Overhead banks and vegetation may have been selected because they provided more terrestrial food, resulting in bigger fish (Table 3). It seems unlikely that coho used these kinds of cover for shade because no obvious preferences for bank cover were observed in pools, and Ruggles (1966) has shown that addition of shade structures to experimental channels actually reduced coho holding capacity. Weak positive responses to increased bank undercuts and overhanging vegetation along riffles were displayed by age 1+ and 2+ cutthroat, which, like coho, were rare there. However, steelhead in riffles did not select overhanging vegetation and actually appeared to avoid riffles with undercut banks. Ages 0+ and 1+ steelhead and ages 1+ and 2+ cutthroat showed mild preferences for bank cover in pools.

Turbulence and underwater boulders were not selected by most species, except yearling cutthroat in riffles. The absence of significant response by steelhead to increased boulder cover was surprising in view of the strong attachment to this cover type shown for steelhead by Hartman (1965) and Facchin and Slaney (1977), and increases in age 1+ steelhead carrying capacity following experimental boulder placement in a Vancouver Island stream (Ward and Slaney 1979). We have no explanation for this disparity in observations except to speculate that increased turbulence and boulder density may have hindered feeding activity by making visual sighting of food organisms more difficult. Within habitats, deeper water was preferentially utilized only by age 1+ and older trout. Underyearlings of all species avoided deep water, preferring instead to reside in shallower areas along habitat margins. Positive associations between increased depth and fish size have been observed in both rainbow trout (Lewis 1969) and cutthroat (Griffith 1972).

APPLICATION OF THE SYSTEM

The system of naming habitat types that is described in this paper proved to be workable during low streamflow conditions. The habitat types became easy to recognize after some practice, and disagreements between independent classifiers were usually few. Approximately 100 m of stream channel could be mapped by one person in a day depending upon channel complexity. However, rapid inventory of the habitat types present in a stream, without dimensional measurements, could proceed much faster.

We were generally less satisfied with the cover evaluations. The majority of disagreements arose over what numerical score was to be assigned to the cover conditions within a particular habitat. In addition, the technique that was employed treated all kinds of cover equally, and it was obvious that a score of 3 (very abundant) for one cover type was not necessarily equivalent, in terms of overhead shading or protection from predation, to a high score for another cover type. For example, the kind of cover provided by wood debris, bank characteristics, or channel morphology was different from one another in nature and did not fit well into an equally weighted scale that was based on relative abundance. Wesche (1980) has discussed the subjectivity involved in measuring cover and has proposed a cover rating that intregrates bank, channel, and substrate characteristics for both small and large streams. Other workers have devised comprehensive numerical indices of habitat conditions that have been used to predict stream carrying capacity, (Bovee and Cochnauer 1977; Binns and Eisermann 1979) but these models do not easily separate fish preference for habitat type from preference for cover type.

We found that within individual habitats certain kinds of cover were preferred to others; however, a more rigorous approach would be to follow population changes after experimentally adding different kinds of cover to streams. For example, Boussu (1954) added small debris (interwoven willow branches) to a Montana stream and recorded large increased in underyearling and yearling rainbow trout and brook char biomasses. More recently, Ward and Slaney (1979) found that logs and boulders placed together in riffle areas of a Vancouver Island stream significantly enhanced ages 1+ and 2+ steelhead, but were not heavily utilized by underyearling coho. The results of our summer field studies indicate that wood debris, especially large stems and rootwads, was the most generally favored cover type and may hold the greatest promise for enhancement projects.

Although the terms 'selected' and 'preferred' have been applied in this paper to habitat and cover utilization by salmon and trout, it is likely that the spatial segregation we observed was an outcome of both physical habitat requirements and biological interactions. What appeared to be a preferred habitat in one stream was not always so in another; cutthroat trout, for example, occurred in different habitats when coho and steelhead were present than when they were the sole salmonid species. Chapman (1966a) has pointed out the importance of interspecific competition in governing habitat selection by salmonids, but behavioral observations have shown that competitive displacment can occur both within a single age class (Mason 1969) and between cohorts of a species (Jenkins 1969). The intensity of territorial defense in certain tropical reef fishes is related to physical habitat conditions, high quality habitats being aggressively defended (Itzkowitz 1979). However, Slaney and Northcote (1974) have shown that when food is abundant territories are small and agression is minimized in underyearling rainbow trout. Thus, the actual location of fishes in a stream channel will be influenced by the presence of competitor and predator species, population density, and food availability, as well as preferences for specific habitat types.

The complex interaction of a fish population with its physical and biological environment usually makes it difficult, if not impossible, to accurately predict either the standing crop or production of a species of interest in a particular stream. What can be determined, however, is the suitability of stream conditions irrespective of a species' presence or absence, which may be due to a variety of factors other than physical habitat. The detailed classification system presented here can be used to assess stream suitability once specific habitat and cover associations are known. We might predict, for example, that underyearling coho will be favored in streams possessing many backwater pools with rootwad cover and terrestrial vegetation overhanging the riffles, whereas yearling and older cutthroat will be favored where there are deep plunge and lateral scour pools with large logs and undercut banks. Although the system worked for the western Washington streams we studied, it is by no means comprehensive. Other habitat types may exist in larger rivers, or in small streams during freshets, and these will require additional description.

ACKNOWLEDGEMENTS

We thank our many friends and colleagues who assisted us in developing the classificat system and in the field trials, including R. Bilby, S.H. Duncan, V.W. Era, J.T. Heffner, J.A. Rochelle, K.O. Sullivan, and J.W. Ward. Helpful comments on an earlier version of the paper were provided by R.J. Behnke and R.L. Beschta. The project originally evolved from discussions with J.R. Sedell, whose thoughtful advice we gratefully acknowledge.

REFERENCES

Allen, K. R. 1969. Limitations on production in salmonid populations in streams. Pages 3-20 *in* T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Binns, N. A., and F. M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108:215-228.

Bisson, P. A., and J. R. Sedell. 1982. Salmonid populations in logged and unlogged stream sections of Western Washington; proceedings of a symposium on old-growth forest -- fisheries relationships. Alaska Distric of the American Institute of Fishe Research Biologists, Juneau, Alaska, US In press.

Boussu, M. F. 1954. Relationship between trout populations and cover a small stream. Journal of Wildlife Management 18:229-239.

Bovee, K. D. and T. Cochnauer. 1977 Development and evaluation of weighted criteria probability of use curves for instream flow assessments: fisheries. Instream Flow Information Paper Number 3. Cooperative Instream Flow Service Group, Fort Collins, Colorado, USA.

Bustard, D. R., and D. W. Narver. 1975a. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 32:667-680.

Bustard, D. R. and D. W. Narver. 1975b. Preferences of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada 32:681-687.

Carle, F. L., and M. R. Strub. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

Chapman, D. W. 1966a. Food and space as regulators of salmonid populations in streams. The American Naturalis 100:345-357.

Chapman, D. W. 1966b. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. Pages 116-130 in K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman, editors. Volume 4, Special Publications of the Pymatuning Laboratory of Ecology, University of Pittsburg, Pittsburg, Pennsylvania, USA.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in Western Washington. Transactions of the American Fisheries Society 109:357-363.

Cuinat, R., J. Dumas, J. A. Timmermans, J. Arrignon, and G. Tuffery. 1957. Ecological diagnosis in salmonid streams: method and example. Technical Paper Number 22. European Inland Fisheries Advisory Commission (EIFAC), Food and Agriculture Organization of the United Nations, Rome, Italy.

Everest, F. H., and W. R. Meehan. 1981. Some effects of debris torrents on habitat of anadromous salmonids; abstracts to presentations at the 1981 west coast regional meeting. Pages 67-74. National Council for Air and Stream Improvement, Portland, Oregon, USA.

Facchin, A., and P. A. Slaney. 1977. Management implications of substrate utilization during summer by juvenile steelhead trout (Salmo gairdneri) in the South Alouette River. Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch, Fisheries Technical Circular Number 32, Victoria, British Columbia, Canada.

Gary, M., R. McAfer, Jr., and C. L. Wolf, editors. 1974. Glossary of geology. American Geological Institute, Washington, District of Columbia, USA.

Gorman, O. T., and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Griffith, J. S., Jr. 1972. Competitive behavior and habitat utilization of brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in northern Idaho. Journal of the Fisheries Research Board of Canada 29:265-273.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon. (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 22:1035-1081.

Hartman, G. F., and C. A. Gill. 1968. Distributions of juvenile steelhead and cutthroat trout (Salmo gairdneri and S. clarki clarki) within streams in southwestern British Columbia. Journal of the Fisheries Research Board of Canada 25:33-48.

Huet, M. 1959. Profiles and biology of western European streams as related to fish management. Transactions of the American Fisheries Society 88:155-163.

Hunt, R. L. 1969. Effects of habitat alteration on production, standing crops, and yield of brook trout in Lawrence Creek, Wisconsin. Pages 281-312 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Hunt, R. L. 1978. Instream enhancement of trout habitat. Pages 19-27 in K. Hashagen, editor. Proceedings of a national symposium on wild trout management. California Trout, Inc. San Francisco, California, USA.

Itzkovitz, M. 1979. Territorial tactics and habitat quality. The American Naturalist 114:585-614.

Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. (Translated from the Russian by Douglas Scott). Yale University Press, New Haven, Connecticut, USA.

Jenkins, T. M., Jr. 1969. Social structure, position choice and micro-distribution of two trout species (Salmo trutta and Salmo gairdneri) resident in mountain streams. Animal Behaviour Monographs 2:55-123.

June, J. A. 1981. Life history and habitat utilization of cutthroat trout (Salmo clarki) in a headwater stream on the Olympic Peninsula, Washington. Master's thesis, University of Washington, Seattle, Washington, USA.

Kalleberg, H. 1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout (Salmo salar L. and S. trutta). Reports of the Institute of Freshwater Research Drottningholm 39:55-98.

Keenleyside, M. H. A., and F. T. Yamamoto. 1962. Territorial behavior of juvenile Atlantic salmon (Salmo salar L.). Behavior 19:138-169.

Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Transactions of the American Fisheries Society 98:14-19.

Lister, D. B., and H. S. Genoe. 1979. Stream habitat utilization by cohabiting underyearlings of chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1215-1224.

Mason, J. C. 1969. Hypoxial stress prior to emergence and competition among coho salmon fry. Journal of the Fisheries Research Board of Canada 26:63-91.

Mason, J. C. 1976. Response of underyearling coho salmon to supplemental feeding in a natural stream. Journal of Wildlife Management 40:775-788.

Moreau, G., and L. Legendre. 1979. Relation entre habitat et peuplements de poissons: essai de definition d'une methode numerique pour des rivieres nordiques. Hydrobiologia 67:81-87.

Mortensen, E. 1977. Density-dependent mortality of trout fry (Salmo trutta L.) and its relationship to the management of small streams. Journal of Fish Biology 11:613-617.

Mundie, J. H. 1969. Ecological implications of the diet of juvenile coho in streams. Pages 135-152 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Nickelson, T. E., and R. E. Hafele. 1978. Streamflow requirements of salmonids. Oregon Depratment of Fish and Wildlife, Progress Report AFS-62, Portland, Oregon, USA.

Northcote, T. G. 1978. Chapter 13: migratory strategies and production in freshwater fishes. Pages 326-359 in S. D. Gerking, editor. Ecology of freshwater fish production. Blackwell Scientific Publications, Oxford, England.

Osborn, J. G. 1981. The effects of logging on cutthroat trout (Salmo clarki) in small headwater streams. Fisheries Research Institute, FRI-UW-8113, University of Washington, Seattle, Washington, USA.

Peterson, N. P. 1980. The role of spring ponds in the winter ecology and natural production of coho salmon (Oncorhynchus kisutch) on the Olympic Peninsula, Washington. Master's thesis. University of Washington, Seattle, Washington, USA.

Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification. United States Forest Service, Surface Environment and Mining Report, Washington, District of Columbia, USA.

Platts, W. S. 1977. Validity of methodologies to document stream environments for evaluating fishery conditions. Pages 267-284 in Proceedings of the symposium and special conference on instream flow needs, volume II. Western Division, American Fisheries Society and American Society of Civil Engineering, Boise, Idaho, USA.

Rosenzweig, M. L. 1981. A theory of habitat selection. Ecology 62:327-335.

Ruggles, C. P. 1966. Depth and velocity as a factor in stream rearing and production of juvenile coho salmon. Canadian Fish Culturist 38:37-53.

Saunders, J. W., and M. W. Smith. 1962. Physical alterations of stream habitat to improve brook trout production. Transactions of the American Fisheries Society 91:185-188.

Sedell, J. R., P. A. Bisson, and J. A. June. 1980. Ecology and habitat requirements of fish populations in South Fork Hoh River, Olympic National Park. Pages 47-63 in Proceedings of the Second Conference on Scientific Research in National Parks, Volume 7. National Park Service, NPS/ST-80/02-7, Washington, District of Columbia, USA.

Slaney, P. A., and T. G. Northcote. 1974. Effects of prey abundance on density and territorial behavior of young rainbow trout (Salmo gairdneri) in laboratory strea channels. Journal of the Fisheries Research Board of Canada 31:1201-1209.

Stewart, P. A. 1970. Physical factors influencing trout density in a small stream. Doctoral dissertation. Colorado State University, Fort Collins, Colorado, USA.

Tramer, E. J. 1977. Catastrophic mortality of stream fishes trapped in shrinking pools. The American Midland Naturalist 97:469-478.

Ward, B. R., and P. A. Slaney. 1979. Evaluation of in-stream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: progress 1977 and 1978. Province of British Columbia, Ministry of Environment, Fish and Wildlife Branch, Fisheries Technical Circular Number 45, Victoria, British Columbia, Canada.

Wesche, T. A. 1980. The WRRI trout cover rating method: development and application. Water Resources Research Institute, Water Resources Series Number 78, University of Wyoming, Laramie, Wyoming, USA.

Williams, D. D., and B. W. Coad. 1979. The ecology of temporary streams III. Temporary stream fishes in southern Ontario, Canada. Internationale Revue der Gesamten Hydrobiologie 64:501-515.

Yang, C. T. 1971. Formation of riffles and pools. Water Resources Research 7:1567-1574.

APPENDIX E.

APPENDIX D

Key to Habitat Unit Types (Sullivan)

Johnson, S. W., and J. Heifetz. 1985. Methods for assessing effects of timber harvest on small streams. NOAA Technical memorandum NMFS F/NWC-73.

Morisawa, M. 1968. Streams their dynamics and morphology. McGraw-Hill, N.Y. 175 pp.

National Handbook of Recommended Methods for Water-Data Acquisition. 1977 with updates. U.S. Geological Survey, U.S. Department of the Interior.

Pfankuch, D. J. 1975. Stream reach inventory and channel stability evaluation. U.S. Forest Service, Missoula, Montana.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. Intermountain Forest and Range Experiment Station. U.S. Forest Service, Ogden, Utah.

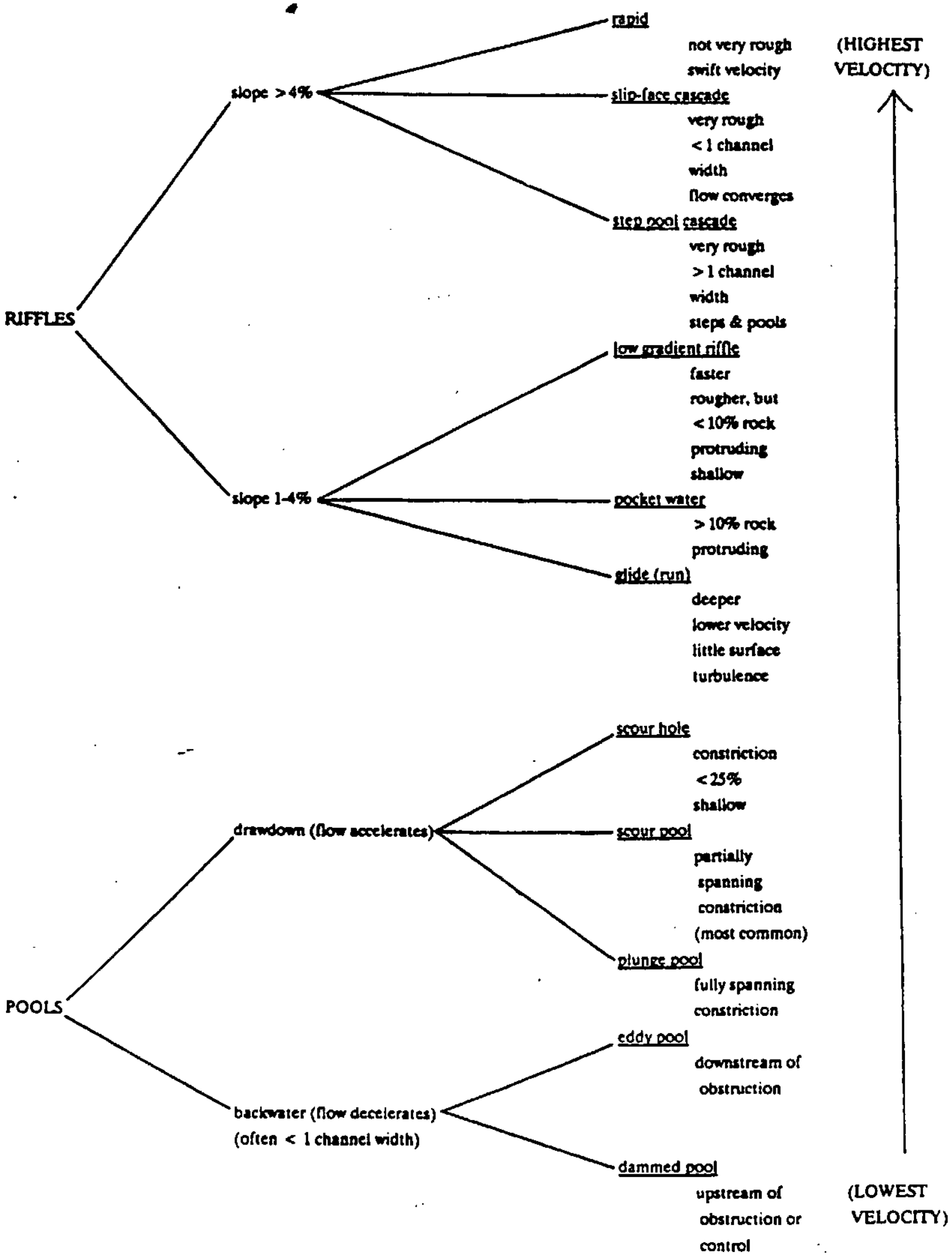
Section V.: Glossary. 1984. From a draft "Coastal Forestry/Fisheries Guidelines of British Columbia."

Stream Enhancement Guide. 1980. Published by British Columbia Ministry of Environment, Vancouver, British Columbia.

White, R. J., and O. M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Technical Bulletin No. 39, Wisconsin Department of Natural Resources, Madison, Wisconsin.

Winget, R. N., and F. A. Mangum. 1979. Biotic condition index: Integrated biological, physical, and chemical stream parameters for management. U.S. Department of Agriculture, Intermountain Region, U.S. Forest Service. 51 pp.

KEY TO CHANNEL UNITS (from Sullivan)



SYNOPTICAL KEY TO CHANNEL UNITS

This key is designed to assist in the identification of channel units in third and fourth order streams as they appear during baseflow conditions. Although most of the units have similar characteristics as those described at the more extreme high or low flows, the depth and water surface characteristics, in particular, may vary. The relationship between units is illustrated in Figure 5.12, pg 97.

1a Water flowing or standing in smaller channels (braids) that are connected to the main channel within the active floodplain. These smaller reaches may have both pools and riffles (described below) although they are usually of smaller proportion than main channel units. The channels that are inundated during higher flows are often disconnected from the flow at lower flows leaving pools of standing water along the channel margins.

SECONDARY CHANNEL

(SIDE CHANNEL)

1b Water flowing in a well-defined permanent channel

2a Water is shallower and faster than the reach average; steep water surface slope

RIFFLE UNITS
(macro-units), lead 3a

2b Water is deeper and slower than the reach average; gentle water surface slope

POOL UNITS
(macro-units), lead 8a

1a

1b

RIFFLE UNITS
(Macro-units)

Riffle units are relatively shallow and fast with steep channel gradients; flow is swift and the water surface is rough or wavy; substrate is generally gravel to cobble in size; water surface may be broken by rocks protruding through the surface

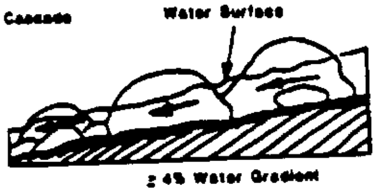
3a Channel and water surface slopes greater than or approximately equal to 0.04; flow uneven or turbulent with whitewater caused by local standing waves

CASCADE UNITS
(meso-units), lead 4a

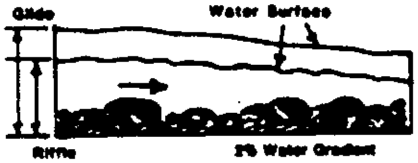
3b Channel gradient less than 4% but greater than 1%; flow is even but turbulent with little white water

RIFFLE UNITS
(meso-units), lead 7a

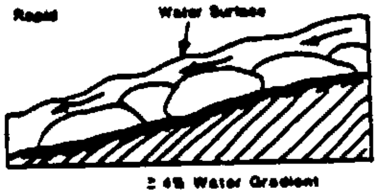
3a



3b



3a

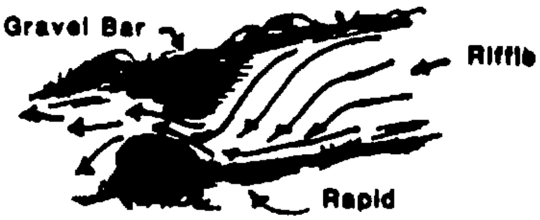


CASCADE UNITS

A meso-unit class of channel units with channel slopes greater than or approximately equal to 4%. Cascade units tend to be associated with obstructions that constrict stream flow, although in smaller, steeper streams they can occur in unconstricted channels.

4a Few rocks protrude through the flow although flow is swift and very turbulent; often found upstream of channel constrictions where gravel bars slope diagonally across the channel funneling streamflow into narrow troughs along one bank; water surface streams and is opaque but whitewater is not common; may have standing waves present at the downstream end of the unit at the junction of the unit and the head of the pool where flow passes channel obstructions.

RAPIDS



4b Rocks protrude through the flow on 10% of more or the surface area of the unit giving these units high relative roughness and causing considerable pooling of water behind the rocks; whitewater scattered throughout the unit at most flows

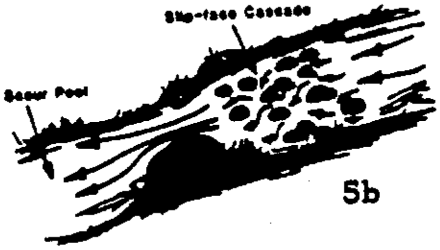
5a Relatively long channel units (length greater than 1 channel width); tend to occur where valley slopes are greater than 3.5% but usually not steeper than 6%; generally in smaller streams (third order or smaller) but are also found in larger streams at valley constrictions (bedrock outcrops, earthflows, debris jams etc.); characterized by a series of boulder bars, composed of strings of boulders wedged together across all or part of the channel, or logs, that form small falls and create a series of steps spaced at 1 channel width or less and separated by short, shallow pools

STEP-POOL CASCADES

5b Shorter units, less than or equal to 1 channel width, that form upstream of local constrictions such as logs, debris jams, bedrock outcrops, etc.; often the downstream end of the unit cuts across the channel at a 45° angle; occur on the steep, downstream face of gravel bars positioned at the channel obstructions; flow converges through the unit and channel width decreases approximately 25% from the upstream to downstream end of the unit

<u>SLIP-FACE CASCADES</u>

5a



5b

6a Small pools on the downstream side of the protruding rocks surrounded by swiftly flowing water

Cascade pools

(also referred to as pocket water)

6b Swiftly flowing water between the protruding rocks

Cascade-mainstream

6b

RIFFLES (MESO-UNITS)

Channel gradient between 1 and 4%; generally composed of gravel to cobble substrate with little of the surface area of the unit made up of large rocks protruding through the flow (although these units often appear rough at very low flows); uniform flow (banks parallel through the length of the unit); standing waves generally absent; moderate to swift velocity; moderate to shallow depth

7a Slower, smoothly flowing water with moderate depth; usually on the lower end of the range of channel gradient (between 1 and 2%); these units can occur anywhere in the stream where riffles may occur, but they most often occur at the transition between particularly elongated pools and the downstream riffle in the zone referred to as the tailout of the pool, but they are usually only identified at particularly elongated pools and therefore these units are not a common feature in small streams.

<u>GLIDE</u>

A unit with similar characteristics is common in larger streams (fourth order or larger).

Run

7b Swiftly flowing with depth shallow enough that submerged particles of the bed disturb the water surface (often producing a diamond-shaped pattern of surface waves) but generally do not protrude through the flow (0 to 10% of the surface area); channel gradient greater than 2% but less than 4%.

<u>LOW-GRADIENT RIFFLES</u>

Low-gradient riffles resemble cascades at the very low flows of the year since many boulders normally submerged become exposed. The 10% surface area cutoff point appears to be a reasonably good separating criteria, even at low flows, but unit slope can always be used to distinguish the two units.

POOL UNITS
(Macro-units)

Flow in pools is relatively deep and slow with gentle energy gradients; water surface is tranquil or slightly disturbed although not to the extent that the surface becomes opaque (some turbulence may occur at the head of the pool as flow passes through the constriction with which the pool is associated); substrate may vary in size from fines to boulders

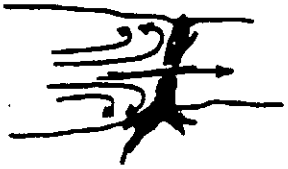
8a Flow decelerates within the unit and the flow path is often lateral or vortical relative to the main stream

BACKWATER POOLS, LEAD 9A

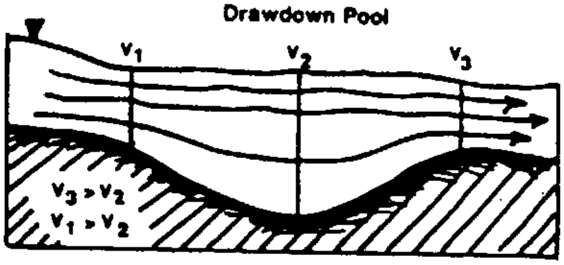
8b Flow accelerates within the pool, speeding up at the downstream end where the depth decreases, and flow path follows the main stream

DRAWDOWN POOLS, LEAD 10A

8a



8b



BACKWATER POOLS (meso-unit)

Backwater pools are always associated with obstructions. Flow lines diverge from the downstream path and flow decelerates within the unit, moving perpendicular or lateral to the main flow; flow is characterized by decreasing velocity and decreasing water surface slope within the unit; units are often without distinct three-dimensional shapes and units are determined relative to the obstructions (not to the streambed); water surface slope less than 0.5%

9a Unit lies upstream of obstruction such as log, debris jam, etc.; unit is often found proximal to slip-face cascades where obstructions partially span the channel (at high flow water often backs up through the unit and drowns out the cascades); can be large (full channel width, several channel widths in length) or small (on the order of one square meter) depending on the degree to which the obstruction blocks the channel

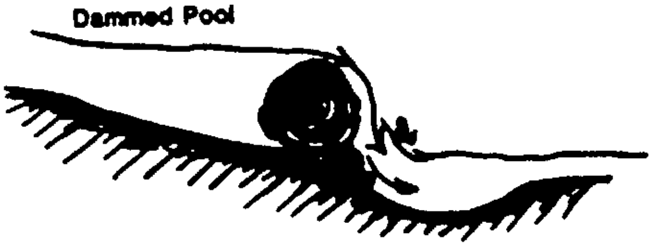
DAMMED POOL

9b Unit lies downstream of an obstruction; eddies formed by the obstruction are relatively large and generally border the thalweg on one side and the downstream edge of the channel on the other

EDDY POOL

This pool type has been described as backwater pools by Bisson et al. (1982), but herein the term backwater pool will be applied only to the general category of pools in which flow decelerates.

9a



9b

DRAWDOWN POOLS

Pools associated with the thalweg of the channel. Flow is usually rapid where flow enters the upstream end of the pool, decelerates where it meets the slower body of water in the pool, but accelerates again at the shallowing downstream end of the pool; submerged jets of flow form at the head of the pool which radiates outward causing diverging flow and channel width from the upstream to downstream end of the pool; water surface slope greater than 0.5 % but less than 1.0%

10a Pool found downstream of an obstruction that spans at least three fourths of entire active channel but which lies within the top one half of the channel depth at bankfull discharge (indicated by the permanent vegetation line) but not above the bank; unit shape is shorter and deeper than other drawdown pools; often found downstream of a free overfall (water fall) where flow leaves the stream bed and plunges into the downstream pool

PLUNGE POOL

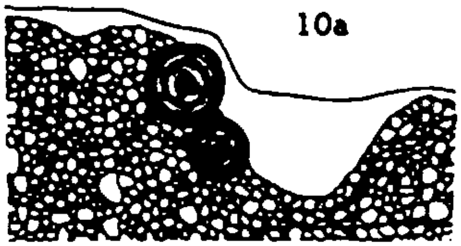
(Smaller plunge pools can occur along the sides of of the channel where obstructions block secondary channels.)

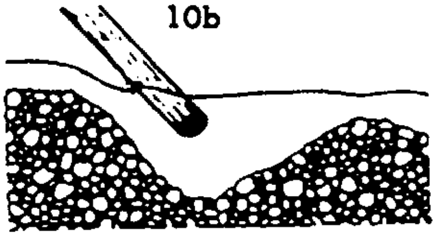
10a

10b

10b Pool found downstream of a partially-spanning channel obstruction that constricts the channel more than 25% but less than 100% of the bankfull width marked by the vegetation line (the maximum constriction that forms these units may be closer to 3/4 bankfull channel width); constrictions cause lateral scour as flow is directed sideways against the banks or vertical scour of the bed

SCOUR POOL





SYNTHESIS OF HANKIN AND REEVES (1988) SAMPLING AND FIELD PROCEDURES FOR VISUAL ESTIMATION OF HABITAT AREAS

The utility of Hankin and Reeves (1988) technique for visual estimation of channel unit (habitat) area derives from 1) its practical nature - relief from slow, costly measurements of every unit within a survey reach, and 2) a sound rooting in sampling theory and statistical inference - relief from the many problems of using a "representative reach". The following narrative and examples are provided as a supplement to Hankin and Reeves (1988) paper to provide a practical overview of this technique and to draw attention to certain important details. The reader is strongly encouraged to read both papers to develop a complete understanding before applying this technique in the field.

With this visual estimation technique, only a fraction of all the habitat units within a valley segment require critical measurement with some device such as a tape, hip chain, or survey rod. The dimensions of all other channel units encountered are estimated by eye. These visual estimates are then corrected for observer bias by using the relationship between actual (true) and estimated dimensions (a paired measurement).

Transforming raw survey data into a usable format involves many computational steps and attention to the assumptions and requirements of stratified sampling, double sampling, and ratio estimation. A database program now being developed by the Northwest Indian Fisheries Commission (NWIFC) eliminates the need for a rigorous treatment of the theory and computational details. This program will provide a screen form for data entry that mirrors the data sheet and will compute certain descriptive statistics. However, some basics must be understood so that important assumptions are not violated, thereby rendering spurious results.

The first and foremost consideration in our Ambient Monitoring effort, or any other sampling effort, is to accurately estimate some parameter (e.g. area of low gradient riffles). The way we have chosen to do this is to stratify a stream into roughly homogeneous segments based on Cupp's (1989) valley segment classification. The stream within each valley segment is then further stratified into habitat (channel) units by the method of Sullivan (1989). Figure 1 diagrams these strata and the overall sampling procedure to estimate total habitat area.

Timber Fish and Wildlife
1989 Ambient Monitoring Program

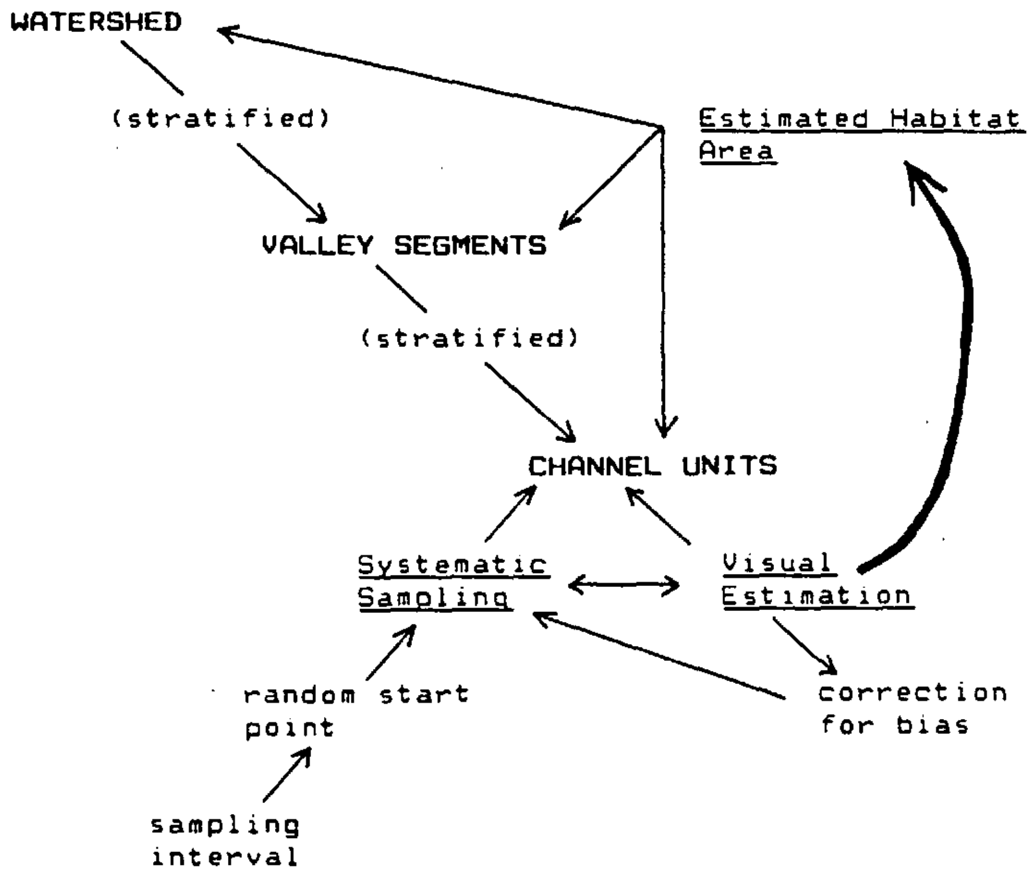


Figure 1. Diagram of procedure using the visual estimation technique of Hankin and Reeves (1988) to estimate habitat area across channel unit strata (classified as per Sullivan (1989)) and valley segment strata (as per Cupp 1989)).

Stratified sampling improves the accuracy of our estimates by sampling within like, or homogeneous, areas based on before-the-fact knowledge of the forces and processes causing variability in the parameters we wish to estimate. For example, the form, sequence, and hydraulic characteristics of pools in a high gradient, mountain slope/headwall segment (a G2 classification) will be somewhat similar to each other but differ significantly from pools in an alluvial fan segment (B3). This is analogous to the upper, middle, and lower zonation (based on gradient) that Hankin and Reeves (1988) provide in their example. It follows that within each valley segment, different channel unit types (the second-stage strata) will differ from each other in terms of form, function, and hydraulic characteristics but will be similar within the same type of unit, when correctly classified.

Thus, we have a rather refined and elegant method of improving our estimates of channel unit area (or volume) by accounting for variability from the following sources: 1) variability <u>between</u> valley segments caused by watershed influences, 2) variability <u>within</u> valley segments caused by the occurrence of different types of channel units, and 3) variability between channel units of the same type caused by local, site-specific features.

SYSTEMATIC SAMPLING

So far we have stratified watersheds into valley segments and assumed that we will be able to correctly classify individual channel units into second stage strata. The next step in the process is to apply a systematic sampling procedure to <u>each type of channel unit</u>, and pay homage to the concept of randomness, which makes the whole estimation procedure statistically valid. This systematic sample is fundamental to developing the relationship between visual estimates of channel unit dimensions and actual (true) measurements, which allows us to account for observer bias.

A systematic sample is obtained by randomly selecting the first channel unit to estimate/measure (a paired measurement) from within the first k units and then sampling every kth unit after that. The term "k" is called the sampling interval. (The number of channel units in sequence between measured units, those that are only visually estimated, is k-1.) This is called a 1-in-k systematic sample where k is appropriately chosen to balance the frequency of occurrence and variability of each type of channel unit, as well as other factors (more on this later). **Each channel unit type may have a different sampling frequency (1-in-k).**

For illustration, let us say that we have decided to sample every 15th scour pool (k=15), every eighth low gradient riffle (k=8), and every third glide within a valley segment. To determine the first scour pool for paired measurement, a random number between one and 15 is needed. If the number five were obtained, the fifth pool encountered from the survey boundary would be measured, and every 15th thereafter. Thus, scour pools five, 20, 35, 50, 65... would be measured. Fourteen (k-1) visually-estimated units separate measured units. Similarly, if the random starts for low gradient riffles and glides were four and one, respectively, the fourth, 12th, 20th, 28th... low gradient riffles would be measured, as would the first, fourth, seventh, 10th... glides. Sampling (paired measurements) would continue in this fashion through the end of the valley segment.

Selecting the Sampling Interval

The sample interval (k) must be chosen before actually beginning sampling and cannot be changed once sampling has begun. There is often a strong temptation to include a more typical, or "representative", or "better", unit than that selected by the sampling interval. Don't give in. If an appropriate sampling interval was chosen, enough varied units will be sampled to obtain reasonable estimates and confidence intervals.

Selection of an appropriate sampling interval (k) can be aided by some advance knowledge of the types and relative composition of channel units within the valley segment. This information may be available from observations during the horizontal control survey or from other sources. Selection of the sampling interval must strike a balance between the following considerations:

1. <u>At least 10 paired measurements need to be obtained for each channel unit type</u>, otherwise the relationship between visual estimates and actual measurements becomes questionable (more on this later). The total number of rare (infrequent) types of units may be so few that all should be measured. (When all units of a particular type are measured, correction of visual estimates is not needed.)

2. Those channel unit types that occur frequently and are relatively similar in area can be sampled less often (k is larger). In low to moderate gradient streams these are typically scour pools, low gradient riffles, slip-face cascades, glides, and scour holes, often linked with smaller eddy and dammed pools. (However, the complexity and unique features of each stream and valley segment will often confound this generalization.)

3. Those channel unit types that are highly variable in area or occur infrequently should be sampled more often (k is small).

4. Relatively long valley segments will allow a proportional increase in the sampling interval for all channel unit types, thereby decreasing the actual time spent doing paired measurements.

Selecting a sampling interval should not be a complicated, time-consuming task. In practice it will likely be an informed, professional judgment that considers those channel unit types that are, or expected to be, most frequently encountered (greatest in area), relatively rare, and those that are intermediately so.

VISUAL ESTIMATES

To be able to utilize the area and depth estimates obtained by eye, these estimates must be corrected to something close to the "true" dimensions. By obtaining both visual estimates and actual measurements (double sampling), a simple, intuitive ratio can be developed. Corrected visual estimates are obtained by multiplying the raw estimates by the ratio of visual estimates/actual > i.e. meas.: measurements. Graphically, the correction factor is nothing more than the slope of a line that best fits an X-Y plot of estimated vs. measured dimensions. This correction factor can be **greater than one** if the observer **consistently underestimates** the actual dimensions, and **less than one** if **overestimation** is the case.

It is very important that the estimator be consistent, not necessarily accurate. This technique accounts for over- or underestimation very handily. But, it can be scuttled by someone who both over- and underestimates dimensions (is inconsistent) and/or is very inaccurate. Fortunately, there are techniques for maintaining consistency in visual estimation.

In practice, one person is designated the "caller", the other is the "recorder". These roles do not change during the survey day.

The caller does all the estimation; the recorder, besides the obvious, does the actual measuring. Visual estimates are not committee decisions. The recorder should not influence the caller in any way. Above all, the caller should not know the relationship between estimated and measured dimensions. Attempts at compensation by the caller will do nothing but decrease confidence and generate inconsistency. Both the caller and recorder should be aware of fatigue, discomfort, mental state, and other factors that can influence the consistency of visual estimates. It is probably better to take a few breaks or call it a short day than to collect poor data.

Accuracy can be improved by estimating known distances before entering the field. Calibrating the eye to accurately estimate some known distance and working in multiples or fractions thereof is highly advisable. Most every one has some distance that they can accurately estimate based on previous experience (i.e. a car length, a sheet of plywood, a football field). Practice and frequent calibration to some known distance will do much to improve and maintain consistent visual estimates.

AN EXAMPLE

Figure 2 provides a diagrammatic example of selecting sample intervals for a portion of a long valley segment consisting of only scour pools (coded SCP), low gradient riffles (LGR), and glides (GLD). Those units to be measured are indicated by an arrow.

I strongly urge that the notes seen on this example be included with each data set as a comment or an attachment. Also, be aware that no data sheet can account for the number of different channel unit types encountered or the variable sample interval for each. This means that each recorder will have to keep track of the next paired measurement to be obtained as the survey proceeds. To aid this accounting, the sample interval for each type of channel unit should be written on each page.

Finally, a table of random numbers is included for use in selecting first-measured units. Many electronic calculators with basic statistical functions also have the capability to generate random numbers, usually between 0 and 1.0. Disregard the decimal point and simply choose the first digit greater than zero if the sampling interval is between 1 and 10. Choose the first two digits if the sampling interval is greater than 9. If the number is greater than the sampling interval, continue generating numbers until you obtain a usable number.

APPENDIX G.

United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

P.O. Box 245
Berkeley
California 94701

Research Note
PSW-394

December 1987

Using "Residual Depths" to Monitor Pool Depths Independently of Discharge

Thomas E. Lisle

Lisle, Thomas E. 1987. *Using "residual depths" to monitor pool depths independently of discharge.* Res. Note PSW-394. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 4 p.

As vital components of habitat for stream fishes, pools are often monitored to follow the effects of enhancement projects and natural stream processes. Variations of water depth with discharge, however, can complicate monitoring changes in the depth and volume of pools. To subtract the effect of discharge on depth in pools, residual depths can be measured. Residual depth is the difference in depth or bed elevation between a pool and the downstream riffle crest. Residual pool depth or volume can be measured at wadable flows by using only a tape and graduated sounding rod. Residual dimensions represent extreme low-flow conditions, which often determine the capacity of streams to produce fish. The measurement of residual depth is an unbiased way to easily distinguish pools from other reaches. Its application is illustrated by a case study on a stream in northern California.

Retrieval Terms: fish habitat monitoring, pools, stream channel surveys, stream enhancement evaluation

Fishery managers are focusing more and more attention on pools to protect and enhance fish habitat in streams. Pools are vital components of fish habitat in streams, especially for larger fish,[1] because their great depth offers protection from predators. Pools can be highly sensitive to disturbance of watersheds and riparian areas [2,3] and can be enhanced by introducing woody debris, boulders, or artificial structures in streams.[4] Improving strategies to protect pool habitat ultimately depends on unbiased, quantitative methods for monitoring changes in pool dimensions. Comparisons of pool dimensions either between streams or in one stream over time can be confounded, however, by differences in stream discharge, which strongly affect water depth.

To surmount this problem, a method for measuring pool depth independently of variations caused by discharge has been developed by using the concept of "residual depth."[5] Residual depth is the difference in depth or bed elevation between a pool and the downstream riffle crest (*fig. 1*). Residual depth is measured by sounding or surveying a pool with tape, rod, and (optionally) an engineer's level and subtracting the depth or elevation of the riffle crest from those in the pool. Data can be plotted as profiles or used to draw residual-depth contours on a map. The method is simple and unbiased, and can be adapted to measure pool length, area, and volume. Residual pool dimensions can represent low flow conditions that are important for summer rearing habitats of fish.

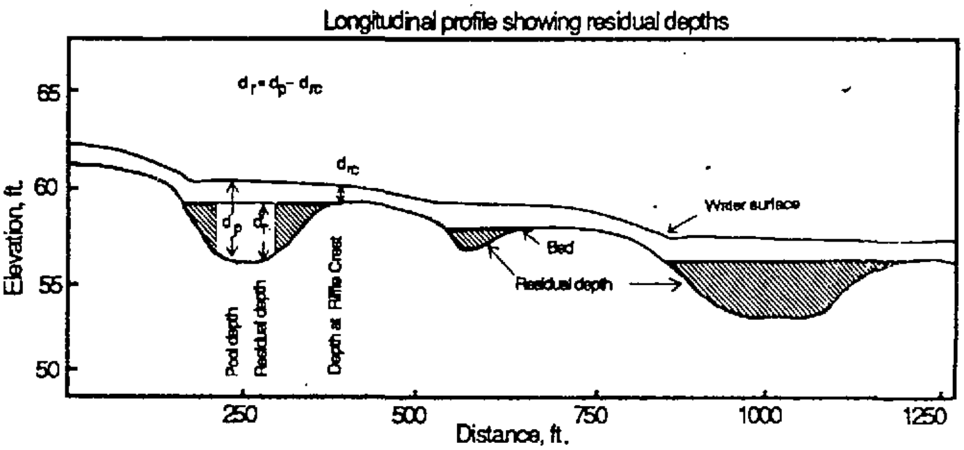


Figure 1—A longitudinal profile of a reach of stream, showing the method for measuring residual depths.

RESIDUAL DEPTH

Water depths in pools depend on both the depth of the depression in the stream bed and the discharge at the time of measurement. How can comparable measurements of pool depth be made without having to measure at equal discharges?

Say, for example, mean depth in a pool was measured as 1.1 ft one summer before placing a rock deflector to increase scour. During the following summer, pool depth is remeasured. Did depth increase or decrease? If depth were measured the second time at Q_a *(fig. 2)*, an observer that was unaware of differences in discharge would conclude that the deflector had increased depth to 2.5 ft; if instead depth were measured at Q_b, the observer would conclude that depth had decreased to 0.8 ft. Repeated measurements of pool depth and discharge before and after treatment would show the true change in pool depth at a given discharge, but this method would be time-consuming and demand a certain schedule of measurement.

"Residual depth" is independent of discharge and need only be measured once before and once after treatment in order to detect changes. Residual depth is the depth that, if flow were reduced to zero, water would fill pools just up to their lips that are located at riffle crests downstream. Depths in pools would then correspond to residual values. Thus residual depths represent extreme low flow conditions, which can limit a stream's capacity to support fish populations. The method also provides an unbiased way to easily distinguish pools from other reach types: pools are simply reaches having residual depths greater than zero.

METHODS

Pool frequency and the residual depth and length of pools in a vertical plane running down the channel can be measured quickly by using the following procedure. It should be done during low flow when the water surface over pools is nearly horizontal. Materials needed include a tape, rod, and notebook.

1. To measure distances between residual depth measurements, stretch a tape along the thalweg (zone of greatest depth) or the centerline of the channel. Thalweg distances give the real distance between depth measurements, but such distances from point to point along the stream channel can vary from year to year because of their wandering. Centerline distances give distances along the channel as a whole and vary little from year to year. Particularly in channels with bends, however, centerline distances do not necessarily equal the distances between depth measurements in the thalweg and thus can introduce error in measurement of residual depths averaged over the reach. In any case, use consistent measures of distance.
2. At distances measured along the tape, note reach type (pool, riffle, run, etc.) and measure depths in the thalweg (deepest thread of the channel). Be certain to measure the distance and depth at riffle crests.
3. To compute residual depths, subtract depth at riffle crests from depths in upstream pools. Mean or maximum residual depths or the entire frequency distribution of residual depth can then be easily determined.

Assuming that the rod is held reasonably vertical the primary sources of error in measuring depth are due to failure to locate the thalweg and the roughness of the bed. I estimate probable error in depth measurement to be approximately twice the median diameter of bed particles. The percent error decreases with increasing ratio of depth to bed particle size. I estimate error in measurement of thalweg distance to be approximately 2 percent. These values for error are estimated from experience and not experimentation. Error probably varies with operator, and stream conditions.

If the water surface over a pool slopes downstream appreciably, residual depths will be over-measured by the method outlined above, which is based on the assumption that the water surface over pools is horizontal. The error created by this assumption would nearly always be negligible during low flows. For instance, if the water surface over a 100-ft-long pool slopes 0.5 percent (a steep slope for low flow), the average error in measuring residual pool depths will equal 0.25 ft. If the error in using this assumption is unacceptable, however, a longitudinal profile of the stream bed can be surveyed by using an engineer's level. After plotting the longitudinal profile, residual depths are measured from horizontal lines extending upstream from riffle crests *(fig. 1)*.

Given that the elevation of the downstream riffle crest sets the size of the residual pool, any dimension—depth, length, area, or volume—can be measured from a planimetric map having depth contours. Residual pool volume, for example, is the difference between total pool volume and the portion of pool volume higher in elevation than the downstream riffle crest.

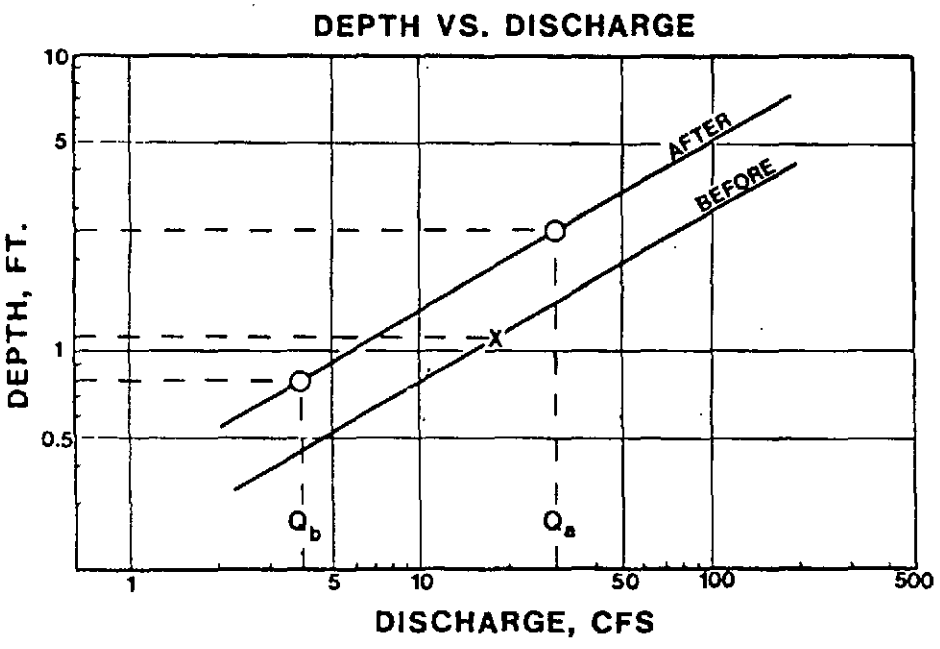


Figure 2—Variation of depth in a pool with discharge before and after a structure was added to increase scour. Depth was measured once before treatment ("X"). An increase or decrease in depth after treatment ("o") would be indicated, depending on whether depth were measured at Q_a or Q_b.

APPLICATION

To illustrate how this method can be used, I describe below its application in evaluating a stream enhancement project by Six Rivers National Forest. The Forest placed three boulder clusters, five gabion weirs, and six bankside deflectors in Red Cap Creek, near Orleans, California, during the summer of 1982 to scour pools and provide cover for juvenile steelhead trout and chinook salmon *(fig. 3)*. We surveyed a longitudinal profile of the streambed and water surface down the thalweg of the channel before the structures were placed *(fig. 4)*. We repeated the survey the next summer after a flood in December caused noticeable channel changes in reaches both with and without structures. Residual depths of all pools, including seven which were not influenced by the structures, were measured from the profiles.

We compared maximum residual pool depths measured before and after the structures were placed *(fig. 5)*, as well as inspected the stream, to judge the effectiveness of the structures to scour pools. Residual depth in pools without structures decreased. Some boulders in riffles and fast runs at locations 7 and 9 *(fig. 3)*, were either buried, moved out of the reach, or left too high on the channel bed to be effective. Others in fast reaches, such as at locations 7 and 8, caused little scour. However, most deflectors and boulder clusters survived the winter and scoured pools. Deflectors such as 2 and 11, that were built along pre-existing pools, scoured the deepest pools, although the pool along structure 9, which was partially destroyed and buried, decreased in depth. Deflector 5 produced little scour, probably because it lay behind a bedrock projection, and deflector 13 became isolated from the thalweg.

Considered as a whole, the project seems to have preserved pool depth during an interval of decreasing pool depth, despite some failures of individual structures. With error estimated at ± 0.6 ft (twice median bed particle size), eight structures increased residual depth significantly, five caused no change, and one resulted in a decrease in depth *(fig. 5)*. Of the pools without structures, two showed no significant change and five showed a decrease in residual depth. Total pool depth cumulated longitudinally remained essentially unchanged. Although only structure 11 created a pool as deep as the major natural pools, the structures increased pool numbers from 11 to 20.

This method allowed us to quickly and conveniently monitor the effects of structures on pools. The entire project took a total of 3 days to survey the profiles and 2 days to analyze the data. This method was also used to detect changes in pools associated with removing woody debris from small streams in Alaska.[6]

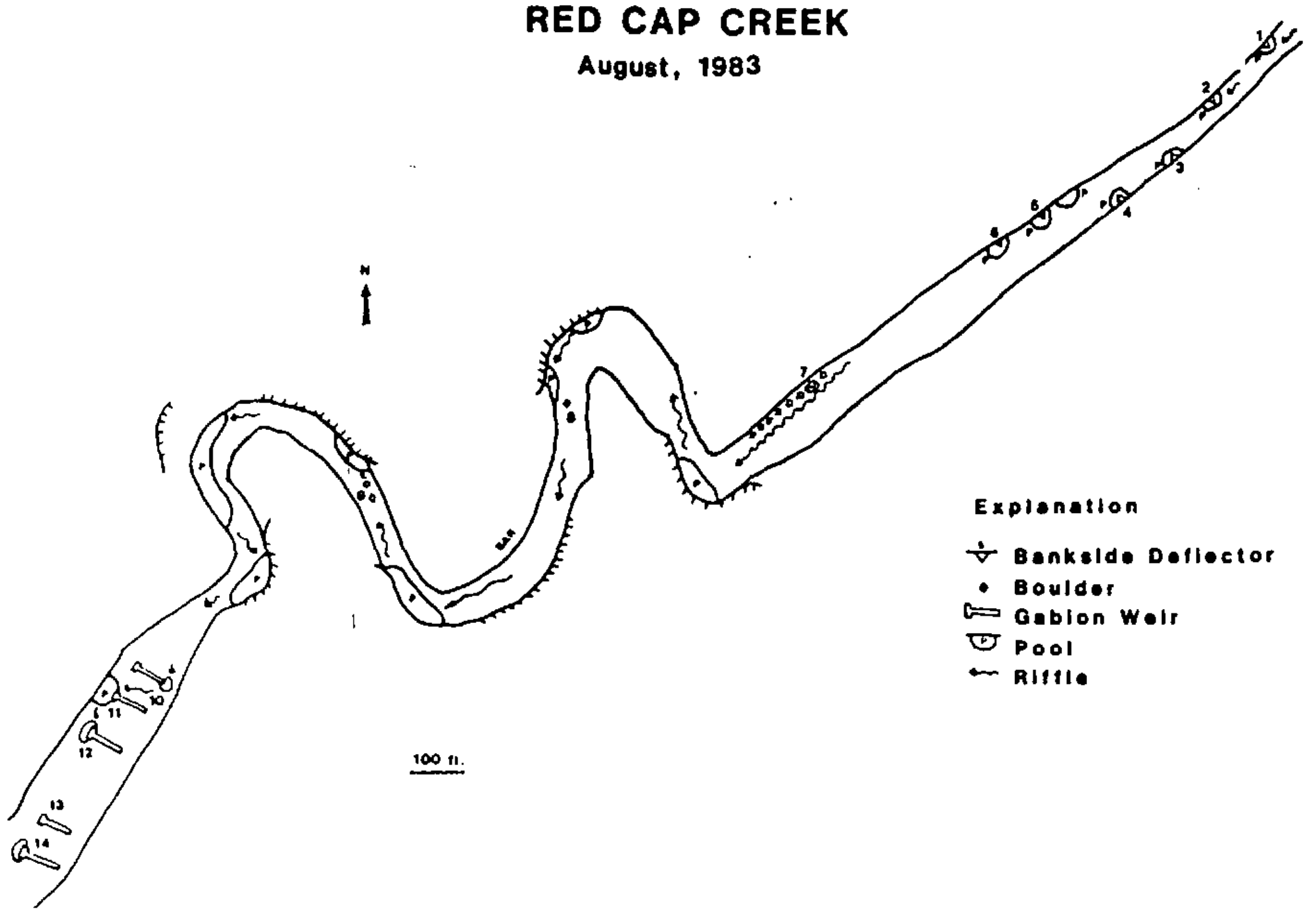


Figure 3—A reach of Red Cap Creek near Orleans, California, was used to apply measurements of residual depth to monitor pools. Artificial structures are identified by number (1-14).

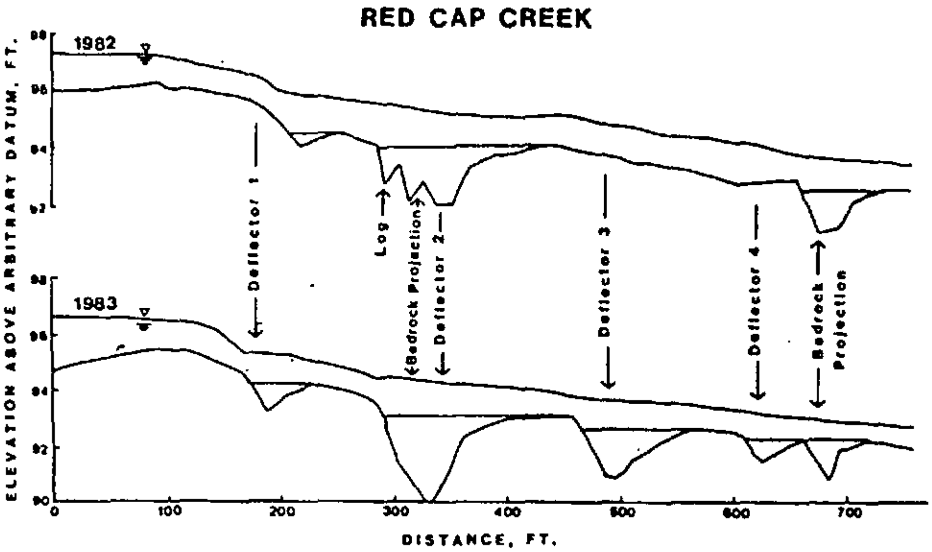


Figure 4—Longitudinal thalweg profiles of a portion of the Red Cap Creek study reach, showing the water surface, stream bed, the location of deflectors placed in the channel to cause scour, and horizontal lines drawn upstream from riffle crests to measure residual depths of pools.

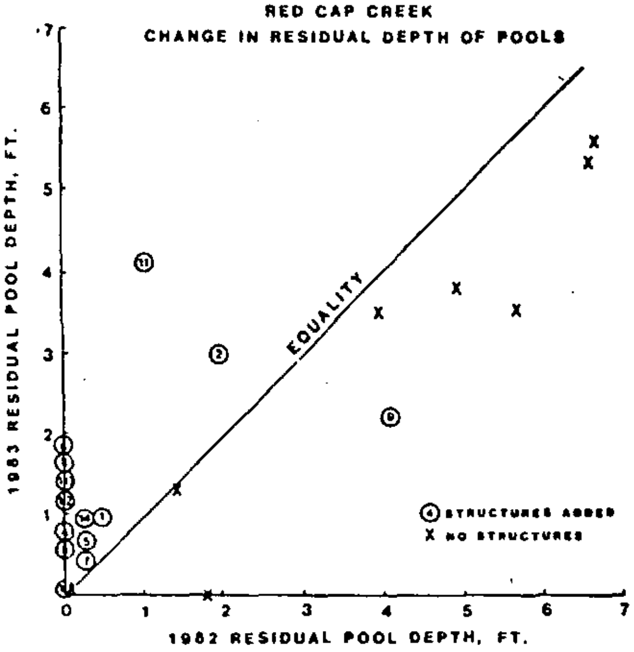


Figure 5—Changes in residual depths of pools in the Red Cap Creek study reach after structures were added in summer 1982, to increase scour. Numbers identify structures shown in *figure 3.* Points falling below the line of equality show a decrease in residual depth; those falling above show an increase. New pools formed around structures plot along the ordinate.

ACKNOWLEDGMENTS

Dean Smith and Alan Clingenpeel, Six Rivers National Forest, Orleans, supervised the Red Cap Creek Enhancement Project and prepared maps of the channel. Linda Folger, Stuart Etherton, and Chester Ogarr, Pacific Southwest Research Station, Arcata, surveyed the longitudinal profiles.

END NOTES AND REFERENCES

[1] Lewis, S.L. 1969. *Physical factors influencing fish populations in pools of a trout stream.* Transactions of the American Fisheries Society 98:14-19.

[2] Bjornn, T.C.; Brusven, M.A.; Molnau, M.P.; Milligan, J.H.; Klamt, R.A.; Chacho, E.; Schaye, C.; 1977. *Transport of granitic sediment in streams and its effects on insects and fish.* Bulletin 17. Moscow, ID: Forest,Wildlife and Range Experiment Station, University of Idaho; 43 p.

[3] Lisle, Thomas E. 1982. *Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California.* Water Resources Research 18(6):1643-1651.

[4] Reeves, Gordon H.; Roelofs, Terry D. 1982. *Rehabilitating and enhancing stream habitat: 2. Field applications.* In: Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America, Gen. Tech. Rep. PNW-140. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 38 p.

[5] Bathurst, James C. 1981. *Discussion of "Bar resistance of gravel-bed streams."* Journal of the Hydraulics Division, American Society of Civil Engineers 104:1587-1603.

[6] Lisle, Thomas E. 1986. *Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska.* North American Journal of Fisheries Management 6(4): 538-550.

The Author ____________________

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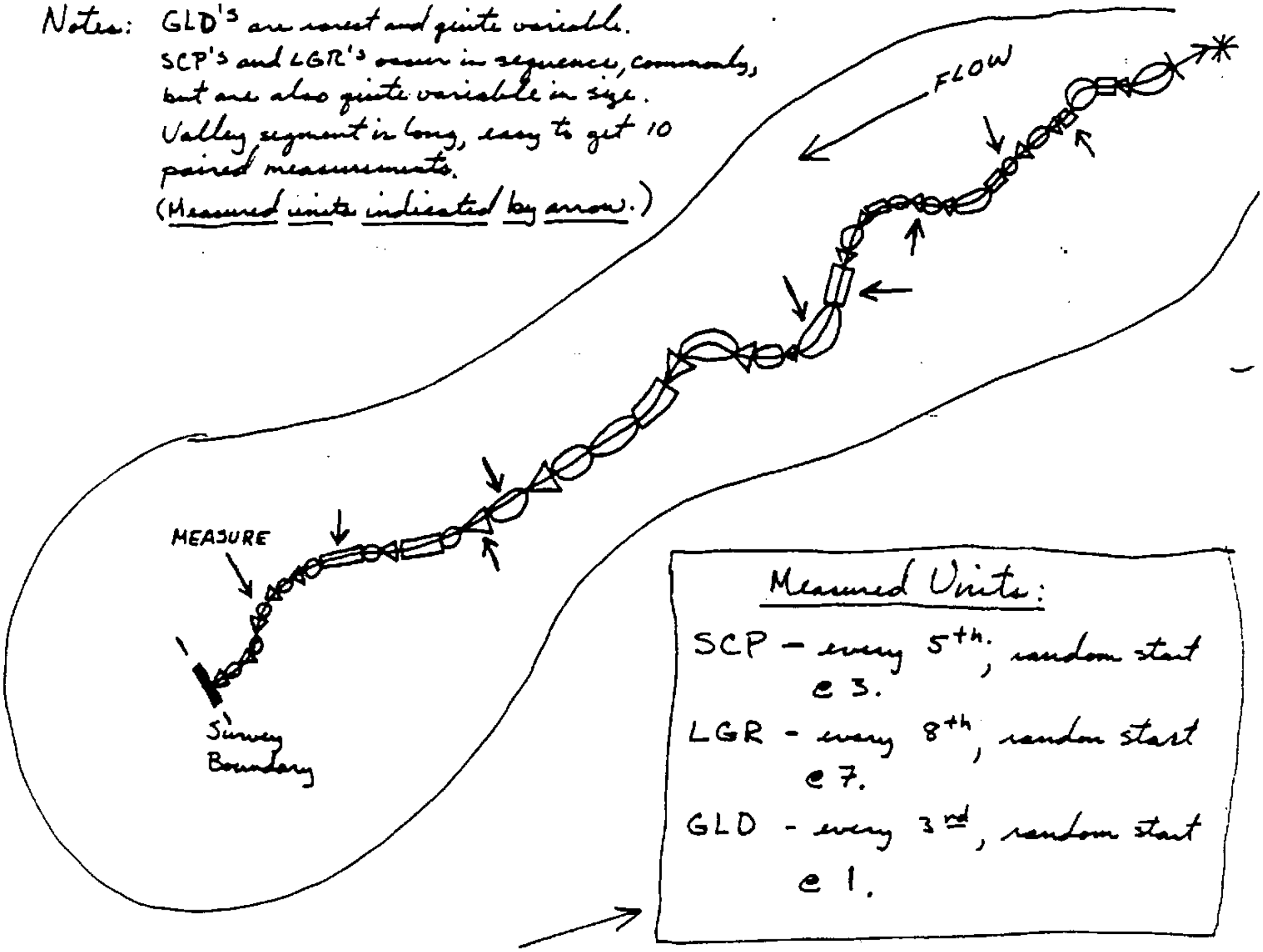
Figure 2. Example of selecting appropriate sampling intervals. The following symbols indicate channel unit types:

○ Scour Pool (SCP)

▽ Low Gradient Riffle (LGR)

□ Glide (GLD).



Notes: GLD's are rarest and quite variable.
SCP's and LGR's occur in sequence, commonly, but are also quite variable in size.
Valley segment is long, easy to get 10 paired measurements.
(Measured units indicated by arrow.)

Measured Units:

SCP – every 5th, random start @ 3.

LGR – every 8th, random start @ 7.

GLD – every 3rd, random start @ 1.

This information should be on data sheets as a reminder to the recorder.

* continues in similar sequence and form to end of valley segment.

APPENDIX H.

SUMMARY OF T/F/W STREAM MONITORING PARAMETERS
1990 FIELD SEASON

PARAMETER	METHOD	FREQUENCY	FORM
1. Segment Summary - Form 1			
Watershed	WRIA #	One # for segment	1
Stream size	Order (map)	One # for segment	1
Discharge	flow meter	Once within a segment at beginning of Habitat Survey	2, 4A, 4B
Location	T, R, Sec	Beg. & end of segment	1
	Turning Points		1,2,3,4A,4B
	WRIA		1,2,3,4A,4B
Elevation	Map	Beg. & end of segment	1
Reference Points	Survey to fixed point	Beg. & end of segment	1
2. Horizontal Control Survey - Forms 2 and 3			
Turning Points	Azimuth distance between points	as needed	2
Photo Points	Horizontal control survey	facing upstream at turning points	
Substrate	particle size distribution	at selected riffles	3
Embeddedness	% covered by fines (code)	at selected riffles	3
Gradient	clinometer	upstream & downstream of bankfull measurements	3
Bankfull Width & Depth	measure	at selected locations	3
Mass Slope Failures Bank Cutting	estimate bracket w/turning points	as encountered	3

APPENDIX H. cont'd

PARAMETER	METHOD	FREQUENCY	FORM
3. Habitat Unit Survey - Forms 3, 4A, and 4B			
Unit Type	identify with code	every unit	4
Length & Width	visually estimate measure	each unit and a fraction of the units for calibration	4A, 4B
Depth	measure max and crest outlet average depth	at pools at other units	4A, 4B
Obstructions	code	pool units only	4A, 4B
Woody Debris	# of logs/root wads/jams	each piece once, as encountered	4A, 4B
Riparian Vegetation			
Seral Stage	Code	Each unit	4A, 4B
Vegetation Type	Code	Each unit	4A, 4B
Land use	Code	Each unit	4A, 4B
Canopy Clos	Densiometer	Measured Units	4A, 4B