Section 6
Physical Habitat Characterization—Non-wadeable Rivers

by
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In the broad sense, physical habitat in rivers includes all those physical attributes that influence or provide sustenance to river organisms. Physical habitat varies naturally, as do biological characteristics; thus expectations differ even in the absence of anthropogenic disturbance. Within a given physiographic-climatic region, river drainage area and channel gradient are likely to be strong natural determinants of many aspects of river habitat, because of their influence on discharge, flood stage, and stream power (the product of discharge times gradient). Summarizing the habitat results of a workshop conducted by EMAP on stream monitoring design, Kaufmann (1993) identified seven general physical habitat attributes important in influencing stream ecology that are likely applicable in rivers as well. They include:

- Channel Dimensions
- Channel Gradient
- Channel Substrate Size and Type
- Habitat Complexity and Cover
- Riparian Vegetation Cover and Structure
- Anthropogenic Alterations
- Channel-Riparian Interaction

All of these attributes may be directly or indirectly altered by anthropogenic activities. Nevertheless, their expected values tend to vary systematically with river size (drainage area) and overall gradient (as measured from

[1]U.S. EPA, National Health and Environmental Effects Research Laboratory, Western Ecology Division, 200 SW 35th St., Corvallis, OR 97333.

topographic maps). The relationships of specific physical habitat measurements described in this EMAP-SW field manual to these seven attributes are discussed by Kaufmann (1993). Aquatic macrophytes, riparian vegetation, and large woody debris are included in this and other physical habitat assessments because of their role in modifying habitat structure and light inputs, even though they are actually biological measures. The field physical habitat measurements from this field habitat characterization are used in the context of water chemistry, temperature, and other data sources (e.g., remote sensing of basin land use and land cover). The combined data analyses will more comprehensively describe additional habitat attributes and larger scales of physical habitat or human disturbance than are evaluated by the field assessment alone.

This protocol is intended for evaluating physical habitat in non-wadeable streams and rivers. Kaufmann and Robison (1998) describe other methods for use in smaller, wadeable streams. Like the methods for wadeable streams, these methods are most efficient during low flow conditions and when leaves are on terrestrial vegetation, but may be applied during other seasons and higher flows except as limited by safety considerations. It is designed for monitoring applications where robust, quantitative descriptions of reach-scale habitat are desired, but time is limited.

Like the wadeable streams protocol (Kaufmann and Robison 1998) this habitat characterization approach employs a randomized, systematic spatial sampling design to minimize bias in the placement and positioning of measurements. Measures are taken over defined channel areas and these sampling areas or points are placed systematically at spacings that are proportional to baseflow channel width. This systematic sampling design scales the sampling reach length and resolution in proportion to stream size. It also allows statistical and series analyses of the data that are not possible under other designs. We strive to make the protocol objective and repeatable by using easily learned, repeatable measures of physical habitat in place of estimation techniques wherever possible. Where estimation is employed, we direct the sampling crew to estimate attributes that are otherwise measurable, rather than estimating the quality or importance of the attribute to biota or its importance as an indicator of disturbance. We have included the more traditional visual classification of channel unit scale habitat types because they have been useful in past studies and enhance comparability with other work.

The time commitment to gain repeatability and precision is greater than that required for more qualitative methods. In our field trials, two people typically complete the specified channel, riparian, and discharge measurements in about three hours of field time. However, the time required can vary considerably with channel characteristics, flow conditions, and the location of boat launching areas.

The protocol defines the length of each sampling reach proportional to river wetted width and then systematically places measurements to statistically represent the entire reach. Stream thalweg depth measurements, habitat classification, and mid-channel substrate observations are made at very tightly spaced intervals; whereas channel "littoral" and riparian stations for measuring or observing substrate, fish cover, large woody debris, bank characteristics and riparian vegetation structure are spaced further apart. The tightly spaced depth measures allow calculation of indices of channel structural complexity, objective classification of channel units such as pools, and quantification of residual pool depth, pool volume, and total stream volume.

6.1 Components of the Field Habitat Assessment

Field data collection for the physical habitat assessment is accomplished in a single float down each river sample reach. Depending on the survey region, river sample reach lengths are defined as either 40 or 100 times the wetted width in the vicinity of the point of entry (Figure 6-1). In addition to physical habitat assessment, the 2-person habitat team of the field crew collects chemical, macroinvertebrate, and periphyton samples (if applicable). They may also recon the channel if they precede the electrofishing boat down the river. To characterize mid-channel habitat (Table 6-1), they measure a longitudinal thalweg (or mid-channel) depth profile, tally snags, classify channel habitat types, characterize mid-channel substrate, and locate the 11 systematic transect locations for littoral/riparian sampling and other habitat observations (Figures 6-1 and 6-2). At each of the 11 marked reach transect locations (A-K), they measure channel wetted width, bankfull channel dimensions, incision, channel constraint, bearing and gradient; then assess near-shore, shoreline, and riparian physical habitat characteristics by measuring or observing littoral depths, riparian canopy cover, substrate, large woody debris, fish cover, bank characteristics, riparian vegetation, and evidence of human activities (Table 6-1). They also collect benthic macroinvertebrates (Section 9), take benthic algal samples (if applicable), and measure conductivity and water temperature using procedures described in section 5.

Mid-channel habitat measurements and observations are recorded on multiple pages of the Thalweg Profile Form (Figure 6-3). Instructions for these mid-channel procedures are given in section 6.5. Measurements made while anchored or tied up to the 11 littoral/riparian plot stations ("transects") are recorded on 11 copies of the two sided Channel/Riparian Transect Form (Figures 6-4 and 6-5). Instructions for these transect or littoral/riparian assessment activities are discussed in subsection 6.6.

6.2 Habitat Sampling Locations On The Study Reach

Measurements are made at two scales of resolution along the mid-channel length of the reach; the results are later aggregated and expressed for the entire reach, a third level of resolution (Figure 6-1). We want to assess habitat and other river indices over river reach lengths that are long enough to incorporate the habitat variability due to river meandering and pool-riffle structure. To accommodate habitat variability in a way that adjusts for varying sizes of rivers, EMAP protocols specify sample reach lengths that are a multiple of their average wetted width (40 or 100 Channel-Widths). Water velocity, habitat complexity, fish abundance, and species richness may also affect capture efficiency and consequently the required sample reach length. In the Oregon river pilot, it was found that 85 channel widths is adequate for Oregon rivers (Hughes et al. In Review). In the Mid-Atlantic region, river reaches of 40 channel widths long were used in order to make this aspect of field methods consistent between wadeable and non-wadeable streams. For this field manual, we discuss the methods used to

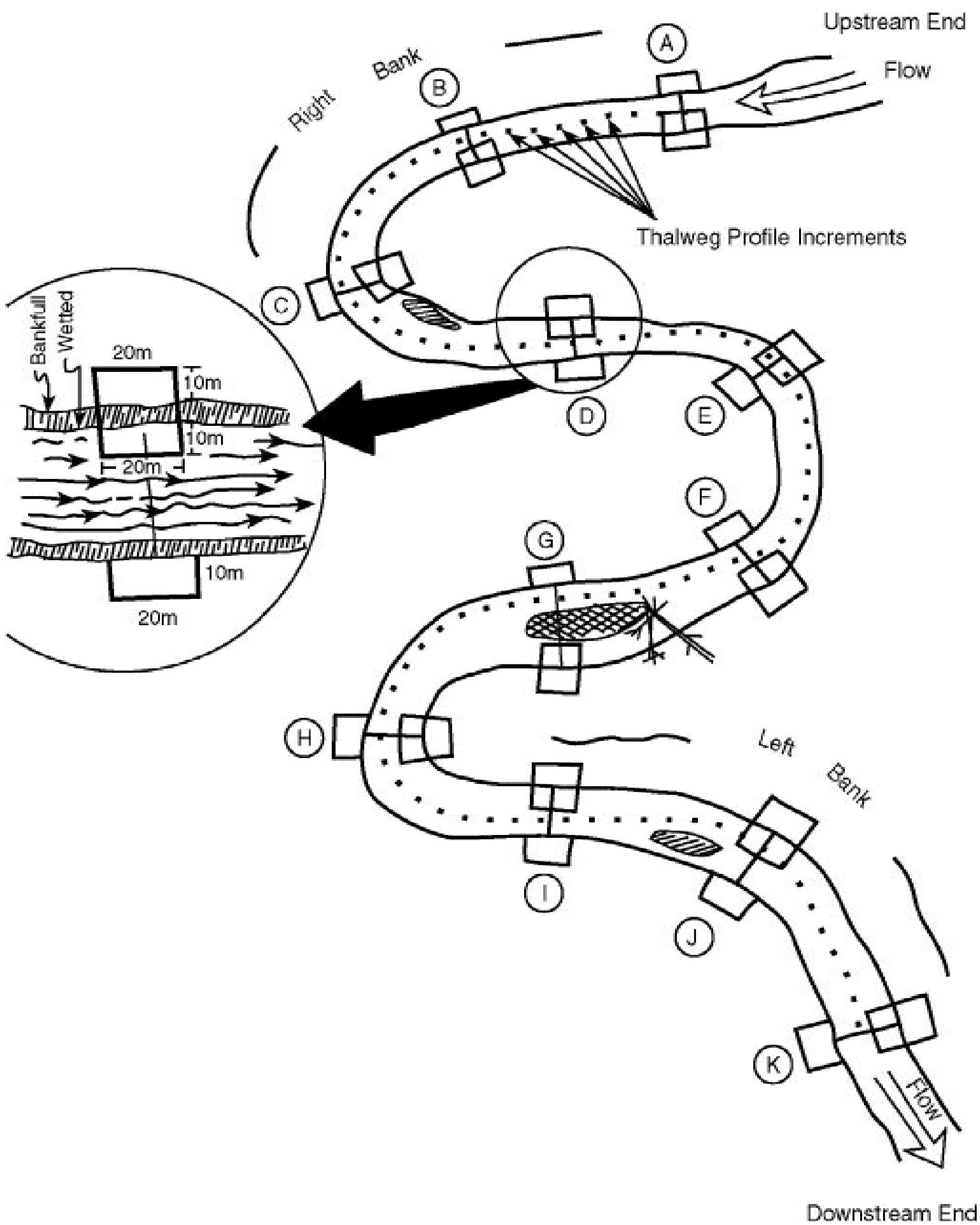

Figure 6-1. River reach sample layout.

Table 6-1. Components of River Physical Habitat Protocol.

1. Thalweg Profile:

   At 10 equally spaced intervals between each of 11 channel cross-sections (100 along entire reach):

   * Classify habitat type, record presence of backwater and off-channel habitats. (10 between cross sections, 100 total)
   * Determine dominant substrate visually or using sounding rod. (10 between cross-sections, 100 total)

   At 20 equally spaced intervals (for 100 ChW reach) or 10 equally spaced intervals (for 40 ChW reach) between each of 11 channel cross-sections:

   * Tally mid-channel snags - 10 (or 20) between cross-sections, 100(or 200) total.
   * Measure thalweg (maximum) depth using Sonar or rod - 10 (or 20) between cross-sections, 100(or 200) total.

2. Littoral/Riparian Cross-Sections: @ 11 stops ("transects") at equal intervals along reach length:

   Measure/estimate from one chosen bank on 11 channel cross-sections:

   * Gradient (clinometer or Abney level) between cross-section and next one downstream.
   * Bearing (compass) between cross-section and next one downstream.
   * Wetted width (laser range finder).
   * Mid-channel bar width (laser range finder).
   * Bankfull width and height (estimate).
   * Incision height (estimate).
   * Bank angle (estimate).
   * Riparian canopy cover (densiometer) in four directions from chosen bank.
   * Shoreline Substrate in the first 1m above waterline (est. dominant and subdominant size class).

In 20m long Littoral Plot extending streamward 10m from chosen bank:

* Littoral depth at 5 locations systematically-spaced within plot (Sonar or sounding rod).
* Dominant and Subdominant substrate size class at 5 systematically-spaced locations (visual or sounding rod).
* Tally large woody debris in littoral plot and in bankfull channel by size and length class.
* Areal cover class of fish concealment and other features, including:

filamentous algae	overhanging vegetation
aquatic macrophytes	undercut banks
large woody debris	boulders and rock ledges
brush and small woody debris	artificial structures

In 20m long Littoral Plot extending 10m landward starting at bankfull margin:[1]

* Estimate areal cover class and type (e.g., woody) of riparian vegetation in Canopy, Mid-Layer, and Ground Cover
* Observe and record human activities and disturbances and their proximity to the channel.

For largest visible Riparian Tree:

* Estimate diameter (Dbh), height, species, and distance from river edge.

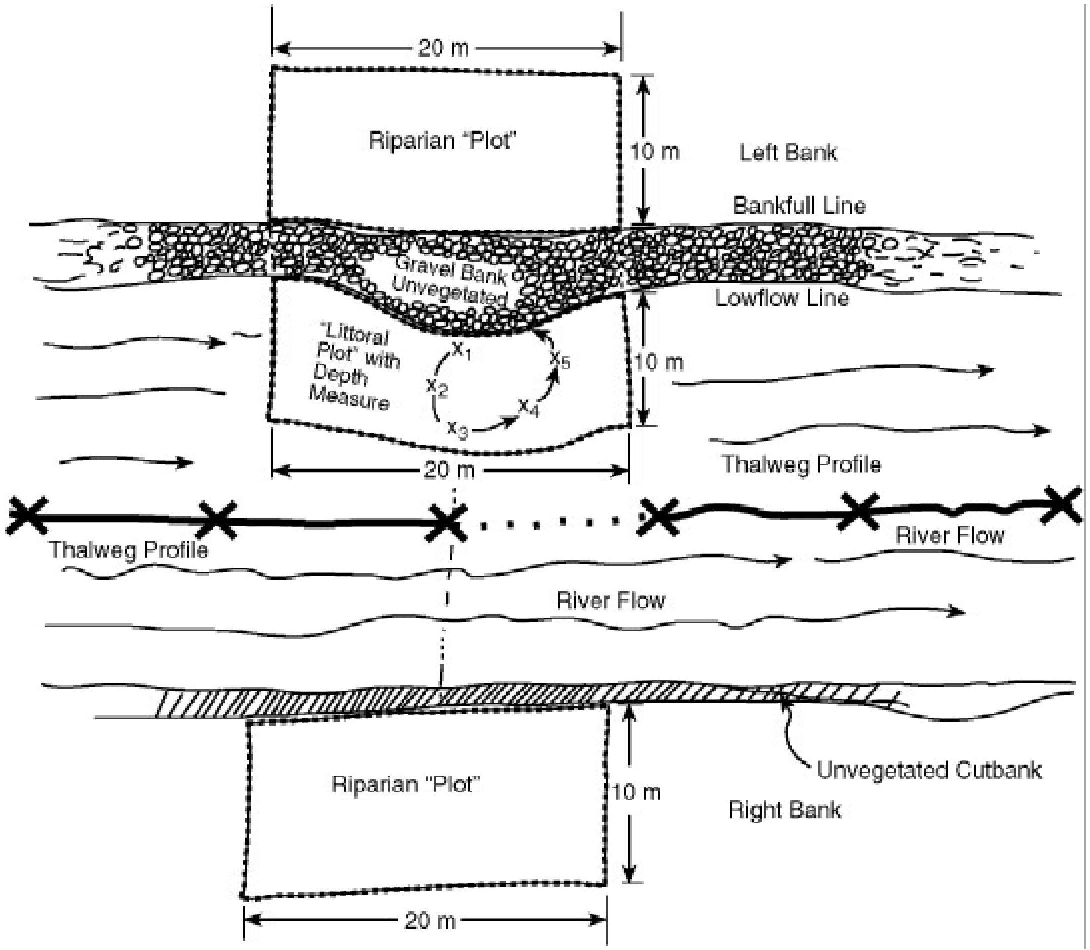

Figure 6-2. Littoral-Riparian Plots for characterizing riparian vegetation, human influences, fish cover, littoral substrate, and littoral depths.

sample reaches 40 times the mean wetted width at the vicinity of the launch point in Mid-Atlantic region streams and 100 times the mean wetted width in Oregon streams.

Section 4 describes the procedure for locating the X-site that defines the midpoint of the sample reach. This sampling location is already marked on a 1:24,000 map prior to going into the field. It has precise coordinates of latitude and longitude, and was selected by the EMAP design group using a randomized systematic sampling design. Subsections 6.3 and 6.4 describe the protocol for delineating a sample reach that is 40 or 100 times its width. Those sections also describe the protocol for measuring out (with a laser range finder) and locating the 11 littoral/riparian stations where many habitat measurements will be made. The distance between each of these stations is 1/10th the total length of the sample reach.

The thalweg profile measurements must be spaced as evenly as practicable over the entire sample reach length. In addition, they must be sufficiently close together that they do not "miss" deep areas and habitat units that are in a size range of about 1/3 to 1/2 of the average channel width distance. To set the

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PHab: THALWEG PROFILE FORM - RIVERS

SITE NAME: BEAVER RIVER DATE: 8 / 5 / 98 VISIT ☐0 ☒1 ☐2 ☐3

SITE ID: ORRV 98-999 TEAM ID (X): ☒1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8

TRANSSECT (X) ☒A-B ☐B-C ☐C-D ☐D-E ☐E-F ☐F-G ☐G-H ☐H-I ☐I-J ☐J-K

SUBSTRATE CODES	CHANNELHABITAT CODES	OTHER
BH = Bedrock/Hardpan (smooth or rough) • (larger than a car) BL = Boulder (250 to 4000 mm) • (basketball to car) CB = Cobble (64 to 250) • (tennis ball to basketball) GR = Coarse to Fine Gravel (2 to 64) • (ladybug to tennis ball) SA = Sand (0.06 to 2 mm) • (gritty - up to ladybug size) FN = Silt/Clay/Muck • (not gritty) OT = Other ☺ (Comment Please)	PO = Pool GL= Glide RI = Riffle RA= Rapid CA= Cascade FA= Falls DR = Dry Channel	Off Ch. = Off Channel or Backwater
Circle One Substrate Code for Each Station	Circle One Channel Habitat Code for Each Station	X if Yes

REMEMBER: A = Upstream End of Reach and K = Downtown End of Reach

STATION	SNAG (X)	DEPTH (ETHER) SONAR (ft) xx	DEPTH (ETHER) POLE (m) x.x	SUBSTRATE (CIRCLE ONE)	CHANNEL HABITAT (CIRCLE ONE)	OFF CH. (X)	FLAG
1		12		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
2		10					
3		9		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
4		9					
5		6		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
6		5					
7		4		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
8		6					
9	X	3		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
10		4					
11		5		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
12		6					
13		8		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
14		8					
15		7		BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		F1
16							
17				BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
18							
19				BH BL CB GR SA FN OT	PO GL RI RA CA FA DR		
20							

Flag Codes: K = no measurement made; U = suspect measurement; F1, F2, etc. = misc. flags assigned by each field crew . Explain all flags on Comment Form.

F1 = STATIONS 1-15 SPREAD THROUGH PROFILE

Rev. 05/29/98 (_rvph_1.98) PHab: THALWEG PROFILE FORM - RIVERS - 1

Figure 6-3. Thalweg Profile Form.

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PHab: CHANNEL/RIPARIAN TRANSECT FORM - RIVERS

SITE NAME: BEAVER RIVER DATE: 8 / 5 / 98 VISIT ☐1 ☒2 ☐3 ☐3

SITE ID: ORRV 98-999 TEAM ID (X): ☒1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8

TRANSSECT (X): ☐A ☐B ☐C ☒D ☐E ☐F ☐G ☐H ☐I ☐J ☐K

"LITTORAL" SUBSTRATE INFORMATION

BOTTOM SUBSTRATE FROM (X ONE): ☐ JUDGEMENT -OR- ☒ OBS. @ 5 LITTORAL DEPTHS

SHORE DOM	SHORE SEC	BOTTOM DOM	BOTTOM SEC	CLASS
RS	RS	RS	RS	RS = BEDROCK (SMOOTH) • (LARGER THAN A CAR)
RR	RR	RR	RR	RR = BEDROCK (ROUGH) • (LARGER THAN A CAR)
BL	BL	BL	BL	BL = BOULDER (250 TO 4000 MM) • (BASKETBALL TO CAR)
CB	CB	CB	CB	CB = COBBLE (64 TO 250 MM) • (TENNIS BALL TO BASKETBALL)
GC	GC	GC	GC	GC = COARSE GRAVEL (16 TO 64 MM) • (MARBLE TO TENNIS BALL)
GF	GF	GF	GF	GF = FINE GRAVEL (2 TO 16 MM) • (LADYBUG TO MARBLE)
SA	SA	SA	SA	SA = SAND (0.06 TO 2MM) • (GRITTY - UP TO LADYBUG SIZE)
FN	FN	FN	FN	FN = SILT/CLAY/MUCK • (NOT GRITTY)
HP	HP	HP	HP	HP = HARDPAN • (FIRM, CONSOLIDATED FINE SUBSTRATE)
WD	WD	WD	WD	WD = WOOD • (ANY SIZE)
OT	OT	OT	OT	OT = OTHER (COMMENT)

SLOPE / BEARING / DISTANCE

INTENDED TRANSECT SPACING xxx (m) → 400

SLOPE xx.x %	BEARING 0 - 360°	DISTANCE xxx (m)	FLAG
0.75	183	450	F1

CANOPY DENSITY @ BANK - DENSIOMETER (0 TO 17 MAX)

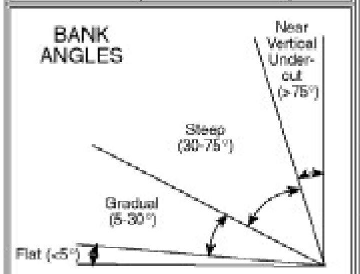
UP	0	DOWN	1
LEFT	8	RIGHT	0
FLAG			

BANK CHARACTERISTICS

CIRCLE ONE	ANGLE
V	Near Vertical/Undercut (>75°)
S	Steep (30 - 75°)
G	Gradual (5 - 30°)
F	Flat (< 5°)

	XXX (m)	FLAG
WETTED WIDTH	47	
BAR WIDTH	0	
BANKFULL WIDTH	75	
BANKFULL HT.	0.9	
INCISED HT.		K

BANK ANGLES



LARGE WOODY DEBRIS in Wet Channel (10 x 20m Plot)

DIAMETER LARGE END	LENGTH 5 - 15 m	15 - 30 m	> 30 m
WOOD ALL/PART IN WETTED CHANNEL			
0.3 - 0.6 m	0	0	0
0.6 - 0.8 m	0	0	0
0.8 - 1.0 m	0	0	0
> 1.0 m	0	0	0
DRY OUT ALL/PART IN BANKFULL CHANNEL			
0.3 - 0.6 m	0	0	0
0.6 - 0.8 m	0	0	0
0.8 - 1.0 m	0	0	0
> 1.0 m	0	0	0

DEPTH

SONAR (ft) xx	POLE (m) x.x
	0.4
	0.6
	0.6
	0.6
	0.6

IN SITU WATER MEASUREMENTS

WATER TEMPERATURE °C (xx.x): 15.9

CONDUCTIVITY µS/CM (xxxx): 105

FLAG	COMMENTS
	No BIG TREES
F1 =	RAPID ∴
	OVERSHOT
K =	NO TERRACE

Flag Codes: K = no measurement made; U = suspect measurement; F1, F2, etc. = misc. flags assigned by each field crew . Explain all flags in comments section on this side or on Side 2 of this form.

Rev. 05/29/98 (_rvphc_.98) PHab: CHANNEL/RIPARIAN TRANSECT FORM - RIVERS - 1

Figure 6-4. Channel/Riparian transect form - page 1 (front side).

interval between thalweg profile measurements, measure the wetted channel width with a laser range finder at several locations near the upstream end of the reach and multiply it by 40 (100) to set the river sample reach length. Then divide that reach length by 100 (or 200) to set the thalweg increment distance. Following these guidelines, you will be making 100 or 200 evenly-spaced thalweg profile measurements, 10 or 20 between each detailed channel cross section where littoral/riparian observations are made. The number and spacing of measurements are as follows for the two different sample reach lengths:

	40 Ch-W		100 Ch-W	
	number	spacing	number	spacing
Transects and Riparian Plots	10	4 Ch-W	10	10 Ch-W
Thalweg Depth measurements	100	0.4 Ch-W	200	0.5 Ch-W
Thalweg Substrate, Habitat Class	100	0.4 Ch-W	100	1.0 Ch-W

6.3 Logistics, Work Flow, and Defining Sample Locations

The two-person habitat assessment team uses the most nimble of the selection of watercraft judged capable of navigating the river reach. In a single midstream float down the 40 or 100 Channel-width reach, the team accomplishes a reconnaissance, a sonar/pole depth profile, and a pole-drag to tally snags and characterize mid-channel substrate. The float is interrupted by stops at 11 transect locations for littoral/riparian observations. They determine (and mark -- optional) the position of each successive downstream transect using a laser range finder to measure out and mentally note each new location 4 (or 10) channel-width's distance from the preceding transect immediately upstream. The crew then floats downstream along the thalweg to the new transect location, making thalweg profile measurements and observations at 10 (or 20) evenly-spaced increments along the way. When they reach the new downstream transect location, they stop to do cross-section, littoral, and riparian measurements. Equipping the boat with a bow or stern anchor to stop at transect locations can greatly ease the shore marking operation and shoreline measurement activities. In addition, while they are stopped at a cross-section station, the crew can fill out the habitat "typing" entries retrospectively and prospectively for the portion of the stream distance that is visible up- and downstream. They can also record reconnaissance and safety notes at this time. While stopped at the transect location, the crew makes the prescribed measurements and observations, collects biological samples, backsites slope and bearing towards the previous upstream transect, and sets or mentally notes eye-level flags or reference points on shore for subsequent backsites. The habitat crew also assists the electrofishing boat crew over jams and helps to conduct shuttles (this can take considerable time where put-ins and take-outs are distant).

6.4 Reconnaissance and Reach Marking

The purpose of the reconnaissance is to locate (and optionally mark) the reach sampling location and to inform the second boat of the route, craft, and safety precautions needed during its subsequent electrofishing activities. After finding adequate put-in and take-out locations, the team may opt to mark the upstream end of the sample reach end with colored flagging. Based on several channel width measurements using a laser range finder, they determine the sample reach length (40 x or 100 x Channel Width), the transect spacing (4 x or 10 x Channel Width) and thalweg sampling interval (0.5 x Channel Width). As the crew floats downstream, they stop (and optionally flag) 11 transect locations along the riverbank in the process of carrying out slope, bearing, and distance backsites. As the team floats downstream, they may choose and communicate to the electrofishing crew the most practical path to be used when fishing with a less maneuverable boat, taking into consideration multiple channels, blind channels, backwaters, alcoves, impassible riffles, rapids, jams, and hazards such as dams, bridges and power lines. They determine if and where tracking or portages are necessary.

6.5 Thalweg Profile

"Thalweg" refers to the flow path of the deepest water in a river channel. The thalweg profile is a longitudinal survey of maximum depth and several other selected characteristics at 100 (or 200) near-equally spaced points along the centerline of the river between the two ends of the river reach (Figure 6-1). For practical reasons, field crews will approximate a thalweg profile by sounding along the river course that they judge is deepest, but also safely navigable. Data from the thalweg profile allows calculation of indices of residual pool volume, river size, channel complexity, and the relative proportions of habitat types such as riffles and pools. The procedure for obtaining thalweg profile measurements is presented in Table 6-2. Record data on the Thalweg Profile Form as shown in Figure 6-3.

6.5.1 Thalweg Depth Profile

A thalweg depth profile of the entire 40 or 100 Channel-width reach shall be approximated by a sonar or sounding rod profile of depth while floating downstream along the deepest part of the channel (or the navigable or mid-channel path). In the absence of a recording fathometer (sonar depth sounder with strip-chart output or electronic data recorder), the crew records depths at frequent, relatively evenly-spaced downstream intervals while observing a sonar display and holding a surveyor's rod off the side of the boat (see subsection 6.5.2, below). The sonar screen is mounted so that the crew member can read depths on the sonar and the rod at the same time. The sonar sensor may need to be mounted at the opposite end of the boat to avoid mistaking the rod's echo for the bottom, though using a narrow beam (16 degree) Sonar transducer minimizes this problem. It is surprisingly easy to hold the sounding rod vertical when you are going at the same speed as the water. In our river trials, one measurement every half-channel-width (10 to 15 m) in current moving at about 0.5 m/s resulted in one measurement every 20 to 30 seconds. To facilitate accomplishing this work fast enough, the field form only requires "checks" for any observations other than depth measurements. To speed operations further, it may also be advantageous to mount a bracket on the boat to hold the clipboard.

6.5.2 Pole Drag for Snags and Substrate Characteristics

The procedure for obtaining pole drags for snags and substrate characteristics is presented in Table 6-2. While floating downstream, one crew member holds a calibrated PVC sounding tube or fiberglass surveying rod down vertically from the gunwale of the boat, dragging it lightly on the bottom to simultaneously "feel" the substrate, detect snags, and measure depth with the aid of sonar. The number of large snags hit by this rod shall be recorded as an index of fish cover complexity (modification of Bain's "snag drag"). While dragging the sounding rod along the bottom, the crew member shall record the dominant substrate type sensed by dragging the rod along the bottom (bedrock/ hardpan, boulder, cobble, gravel, sand, silt & finer) (Figure 6-3). In shallow, "wild," fast-water situations, where pole-dragging might be hazardous, crews will estimate bottom conditions the best they can visually and by using paddles and oars. If unavoidable, suspend measurements until out of whitewater situations, but make notes and appropriately flag observations concerning your best judgements of depth and substrate.

6.5.3 Channel Habitat Classification

The crew will classify and record the channel habitat types shown in Figure 6-3 (fall, cascade, rapid, riffle, glide, pool, dry) and check presence of off-channel and backwater habitat at a spatial resolution of about 0.4 channel-widths on a 40 Channel-width reach. On a 100 Channel-width reach habitat classifications are made every 1.0 channel-widths and off-channel and backwater habitat presence is checked every 0.5 channel-width distance -- the same interval as thalweg depths. The resulting database of traditional visual habitat classifications will provide a bridge of common understanding with other studies. The procedures for classifying channel habitat are presented in Table 6-2. The designation of side channels, backwaters and other off-channel areas is independent of the main-channel habitat type. Main channel habitat units must meet a minimum size criteria in addition to the qualitative criteria listed in Table 6-3. Before being considered large enough to be identified as a channel-unit scale habitat feature, the unit should be at least as long as the channel is wide. For instance, if there is a small, deep (pool-like) area at the thalweg within a large riffle area, don't record it as a pool unless it occupies an area about as wide or long as the channel is wide.

Mid-Channel Bars, Islands, and Side Channels pose some problems for the sampler conducting a thalweg profile and necessitate some guidance. Mid-channel bars are defined here as channel features below the bankfull flow level that are dry during baseflow conditions (see Section 6.6.4 for definition of bankfull channel). Islands are channel features that are dry even when the river is at bankfull flow. If a mid-channel feature is as high as the surrounding flood plain, it is considered an island. Both mid-channel bars and islands cause the river to split into side channels. When a bar or island is encountered along the thalweg profile, choose to navigate and survey the channel that carries the most flow.

When side channels are present, the comments column of the Thalweg Profile form should reflect their presence by checking the "Off-Channel" column. These checkmarks will begin at the point of divergence from the main channel, continuing downstream to the point of where the side channel converges with the main channel. In the case of a slough or alcove, the "off-channel" checkmarks should continue from the point of divergence.

6.6 Channel Margin ("Littoral") And Riparian Measurements

Components of this section include slope and bearing, channel margin depth and sub-

Table 6-2. Thalweg Profile Procedure.

1. Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach.
2. Complete the header information on the Thalweg Profile Form, noting the transect pair (upstream to downstream).
3. Begin at the upstream transect (station "1" of "20" or station "1" of "10").

Thalweg Depth Profile

a) While floating downstream along the thalweg, record depths at frequent, approximately even-spaced downstream intervals while observing a sonar display and holding a surveyor's rod off the side of the boat.

b) A depth recording approximately every 0.4 (or 0.5) channel-width distance is required, yielding 10 (or 20) measurements between channel/riparian cross-section transects.

c) If the depth is less than approximately 0.5 meters, or contains a lot of air bubbles, the sonar fathometer will not give reliable depth estimates. In this case, record depths using a calibrated measuring rod. In shallow, "wild," fast-water situations depths may have to be visually estimated to the nearest 0.5 meter.
d) Measure depths to nearest 0.1 m and record in the "SONAR" or "POLE" column on the Thalweg Profile Form.

Pole Drag for Snags and Substrate Characteristics

a) From the gunwale of the boat, hold a fiberglass surveying rod or calibrated PVC sounding tube down vertically into the water.
b) Lightly drag the rod on the river bottom to "feel" the substrate and detect snags.
c) Observations are taken at half the frequency as depth measurements (i.e., at every other depth measurement point on 100 Channel-Width reaches).
d) Record the number of snags hit by the rod and the dominant substrate type sensed by dragging the rod along the bottom.
e) On the Thalweg Profile Form, circle the appropriate "SUBSTRATE" type and tally the number of "SNAGS".

Channel Habitat Classification

a) Classify and record the channel habitat type at increments of every 1.0 channel width.
b) Check for off-channel and backwater habitat at increments of every 0.4 (or 0.5) channel width.
c) If channel is split by a bar or island, navigate and survey the channel with the most discharge.
d) When a side channel is encountered, check the "OFF-CHANNEL" column beginning with the point of divergence from the main channel, continuing downriver until the side channel converges with the main channel.
e) On the Thalweg Profile Form, circle the appropriate "CHANNEL HABITAT" and check the off-channel column as described in (d) above.

4. Proceed downriver to the next station ("2"), and repeat the above procedures.
5. Repeat the above procedures until you reach the next transect. Prepare a new Thalweg Profile Form, then repeat the above procedures for each of the reach segments, until you reach the downriver end of the sampling reach (Transect "K").

Table 6-3. Channel Unit Categories.

Channel Unit Habitat Classes[a]	
Class (Code)	Description
Pools (PO):	Still water, low velocity, smooth, glassy surface, usually deep compared to other parts of the channel:
Plunge Pool	Pool at base of plunging cascade or falls.
Trench Pool	Pool-like trench in the center of the stream
Lateral Scour Pool	Pool scoured along a bank.
Backwater Pool	Pool separated from main flow off the side of the channel.
Dam Pool	Pool formed by impoundment above dam or constriction.
Glide (GL)	Water moving slowly, with a smooth, unbroken surface. Low turbulence.
Riffle (RI)	Water moving, with small ripples, waves and eddies -- waves not breaking, surface tension not broken. Sound: "babbling", "gurgling".
Rapid (RA)	Water movement rapid and turbulent, surface with intermittent whitewater and breaking waves. Sound: continuous rushing, but not as loud as cascade.
Cascade (CA)	Water movement rapid and very turbulent over steep channel bottom. Most of the water surface is broken in short, irregular plunges, mostly whitewater. Sound: roaring.
Falls (FA)	Free falling water over a vertical or near vertical drop into plunge, water turbulent and white over high falls. Sound: from splash to roar.
Dry Channel (DR)	No water in the channel
Off-Channel Areas	Side-channels, sloughs, backwaters, and alcoves that are separated from the main channel.

[a] Note that in order for a channel habitat unit to be distinguished, it must be at least as wide or long as the channel is wide.

strate, large woody debris, bank angle and channel cross-section morphology, canopy cover, riparian vegetation structure, fish cover, and human influences. All measurements are recorded on the two-sided Channel/Riparian Transect Form (Figures 6-4 and 6-5).

6.6.1 Slope and Bearing

The slope, or gradient, of the stream reach is useful in three different ways. First, the overall stream gradient is one of the ma-

Reviewed by (initial) DKA

PHab: CHANNEL/RIPARIAN TRANSECT FORM - RIVERS (continued)

SITE NAME: BEAVER RIVER DATE: 8 / 5 / 98 VISIT ☐0 ☒1 ☐2 ☐3

SITE ID: ORRV 98 - 999 TEAM ID (X): ☒ 2 3 4 5 6 7 8

TRANSSECT (X): ☐A ☐B ☐C ☒D ☐E ☐F ☐G ☐H ☐I ☐J ☐K

VISUAL RIPARIAN ESTIMATES	LEFT BANK	RIGHT BANK	FLAG
RIPARIAN VEGETATION COVER (10 m x 20 m Plot)	0 = ABSENT (0%) 1 = SPARSE (< 10%) 2 = MODERATE (10 - 40%) 3 = HEAVY (40 - 75%) 4 = VERY HEAVY (> 75%)	D = DECIDUOUS C = CONIFEROUS E = BROADLEAF EVERGREEN M = MIXED N = NONE	
CANOPY (> 5 m HIGH)			
VEGETATION TYPE	D C E M N	D C E M N	
BIG TREES (TRUNK > 0.3 m DBH)	0 1 2 3 4	0 1 2 3 4	
SMALL TREES (TRUNK < 0.3 m DBH)	0 1 2 3 4	0 1 2 3 4	
UNDERSTORY (0.5 to 5 m HIGH)			
VEGETATION TYPE	D C E M N	D C E M N	
WOODY SHRUBS & SAPLINGS	0 1 2 3 4	0 1 2 3 4	
NON-WOODY HERBS, GRASSES & FORBS	0 1 2 3 4	0 1 2 3 4	
GROUND COVER (< 0.5 m HIGH)			
WOODY SHRUBS & SEEDLINGS	0 1 2 3 4	0 1 2 3 4	
NON-WOODY HERBS, GRASSES & FORBS	0 1 2 3 4	0 1 2 3 4	
BARREN, BARE, DRY OR DUFF	0 1 2 3 4	0 1 2 3 4	
HUMAN INFLUENCE (10 m x 20 m Plot)	0 = NOT PRESENT C = WITHIN 10 m	P = > 10 m B = ON BANK	FLAG
WALL/DIKE/REVETMENT/RIPRAP/DAM	0 P C B	0 P C B	
BUILDINGS	0 P C B	0 P C B	
PAVEMENT	0 P C B	0 P C B	
ROAD/RAILROAD	0 P C B	0 P C B	F2
PIPES (INLET/OUTLET)	0 P C B	0 P C B	
LANDFILL/TRASH	0 P C B	0 P C B	
PARK/LAWN	0 P C B	0 P C B	
ROW CROPS	0 P C B	0 P C B	
PASTURE/RANGE/HAY FIELD	0 P C B	0 P C B	
LOGGING OPERATIONS	0 P C B	0 P C B	
MINING ACTIVITY	0 P C B	0 P C B	

FISH COVER/ OTHER (10 m X 20 m Plot)	COVER IN-CHANNEL 0 = ABSENT (0%) 1 = SPARSE (< 10%) 2 = MODERATE (10 - 40%) 3 = HEAVY (40 - 75%) 4 = VERY HEAVY (> 75%) — CIRCLE ONE	FLAG
FILAMENTOUS ALGAE	0 1 2 3 4	
MACROPHYTES	0 1 2 3 4	
WOODY DEBRIS (> 0.3 m - BIG)	0 1 2 3 4	
BRUSH/WOODY DEBRIS (< 0.3 m - SMALL)	0 1 2 3 4	
OVERHANGING VEG. (≤ 1 m OF SURFACE)	0 1 2 3 4	
UNDERCUT BANKS	0 1 2 3 4	
BOULDERS/LEDGES	0 1 2 3 4	
ARTIFICIAL STRUCTURES	0 1 2 3 4	

CHANNEL CONSTRAINT	
DISTANCE FROM SHORE TO RIPARIAN VEGETATION (XX) XXX ►	0
CIRCLE ONE	
C	CHANNEL IS CONSTRAINED.
U	CHANNEL IS UNCONSTRAINED IN BROAD VALLEY.
B	CHANNEL IS IN BROAD VALLEY BUT CONSTRAINED BY INCISION.
N	CHANNEL IS IN NARROW VALLEY BUT NOT VERY CONSTRAINED.
CIRCLE ONE	
YES	I COULD READILY SEE OVER THE BANK.
NO	I COULD NOT READILY SEE OVER THE BANK.

FLAG	COMMENTS (Additional space available on Side 1)
F2	RAILROAD GRADE

Flag Codes: K = no measurement made; U = suspect measurement; F1, F2, etc. = misc. flags assigned by each field crew . Explain all flags in comments section on this side or on Side 1 of this form.

Rev. 05/29/98 (_rvphc_.98) PHab: CHANNEL/RIPARIAN TRANSECT FORM - RIVERS - 2

Figure 6-5. Channel/Riparian transect form - page 2 (back side).

jor stream classification variables, giving an indication of potential water velocities and stream power; both of which are in turn important controls on aquatic habitat and sediment transport within the reach. Second, the spatial variability of stream gradient is a measure of habitat complexity, as reflected in the diversity of water velocities and sediment sizes within the stream reach. Lastly, using methods described by Stack (1989), Robison and Kaufmann (1994), and Kaufmann et al., (1999), the water surface slope will allow us to compute residual pool depths and volumes from the multiple depth and width measurements taken in the thalweg profile (Subsection 6.5). Compass Bearings between cross section stations, along with the distance between stations, will allow us to estimate the sinuosity of the channel (ratio of the length of the reach divided by the straight line distance between the two reach ends).

Measure slope and bearing by "backsiting" upstream from cross-section station B to A, C to B, D to C, etc., down to the 11th cross section (Figure 6-1). To measure the slope and bearing between adjacent stations, use an Abney Level (or clinometer), and a bearing compass following the procedure presented in Table 6-4. Record data for slope and bearing in the Slope/Bearing/Distance section of the Channel/Riparian Transect Form (Figure 6-4).

It may be necessary to set up intermediate slope and bearing stations between the normal 11 stations if you do not have direct line-of-site along (and within) the channel between stations. This can happen if brush is too heavy or if there are tight meander bends or sharp slope breaks. To backsite upstream from supplemental stations, treat them just as you do a normal transect location in steps 1 to 6 of Table 6-4. Record supplemental slope, bearing, and distance backsites sequentially in the spaces provided on the field form.

6.6.2 Channel Margin Depth and Substrate

Substrate size is one of the most important determinants of habitat character for fish and macroinvertebrates in streams. Along with bedform (e.g., riffles and pools), substrate influences the hydraulic roughness and consequently the range of water velocities in the channel. It also influences the size range of interstices that provide living space and cover for macroinvertebrates, salamanders, and sculpins (as well as other benthic fishes). Substrate characteristics are often sensitive indicators of the effects of human activities on streams. Decreases in the mean substrate size and increases in the percentage of fine sediments, for example, may destabilize channels and indicate changes in the rates of upland erosion and sediment supply.

Channel margin depths are measured along the designated shoreline at each transect within the 10m swath of the 20m channel margin length that is centered on the transect location. Dominant and sub-dominant bottom substrates are determined and recorded at 5 systematically-spaced locations that are located by eye within the 10m x 20m plot. These methods are an adaptation of those used by the U.S.EPA for evaluating littoral substrates in lakes (Kaufmann and Whittier 1997), where the substrate size may be visually assessed or estimated by "feel" using the surveyors rod or PVC sounding tube in deep, turbid water. The procedure for obtaining channel margin depth and substrate measurements is described in more detail in Table 6-5. Record these measurements on the Channel/Riparian Transect Form as shown in Figure 6-4.

Table 6-4. Procedure for Obtaining Slope and Bearing Data.

1. Set eye-level flagging at upstream transect: Place flagging or mentally note a landmark at a standardized eye level along the shoreline at Transect A while doing shoreline measurements. To accomplish this, sit in the boat with your clinometer or Abney level held against your measuring rod at a comfortable, standardized height above the water surface (or designated place on bottom of boat). This shall be the same height you plan to use for all slope backsites from downstream. Site towards the nearby bank with the clinometer or Abney level indicating 0% slope. Note the level on the object sited and place flagging on it (optional). Accuracy of the clinometer measurements can be checked occasionally against a surveyors level.
2. Using the laser rangefinder, determine and record the intended location and distance of the next downstream Transect.
3. Float downstream (doing your thalweg profile measurements at 10 or 20 increments) to Transect B, where the next channel/riparian station is located.
4. Measure (w/ laser rangefinder) and record the distance back to the flagged upstream transect. (Note that, because of hazards and maneuvering problems, this distance may unavoidably differ from the "intended transect spacing" that is set at 4 (or 10) times the wetted width in the near vicinity of the furthest upstream transect (A).
5. Backsite the river gradient: While at the bank at Transect B, hold your Abney or clinometer at the same level on your measuring rod that you used at the previous station when you set up the eye-level flagging. Site back upstream at your flagging at Station A; read and record **percent** Slope on the field form. Be careful, the clinometer reads both percent slope and degrees of the slope angle. **Percent slope is the scale on the right hand side as you look through most clinometers. If using an Abney Level, insure that you are reading the scale marked "PERCENT."**
6. Backsite the compass bearing: From the bank at Station B, site back with your compass to the flagging you placed at Station A and record your compass bearing ("Azimuth"). It does not matter for these measurements whether or not you adjust your compass bearings for magnetic declination, but **it is important that you are consistent in the use of magnetic (unadjusted) or true (adjusted) bearings** throughout all the measurements you make on a given reach. Write on the field form which type of bearings you take. Also guard against recording "reciprocal" bearings (erroneous bearings 180 degrees from what they should be). The best way to do this is to know where the primary (cardinal) directions are in the field -- north (0 degrees), east (90 degrees), south (180 degrees), and west (270 degrees) -- and insure that your bearings "make sense."
7. Repeat step 1, setting your eye-level flagging at Transect B before floating down to a new downstream transect. Then repeat steps 2 through 7.

Again adapting methods developed for lake shorelines by Kaufmann and Whittier (1997), identify the dominant and subdominant substrate present along a shoreline swath 20 meters long and 1 meter back from the waterline. The substrate size class choices are as shown in Table 6-5.

6.6.3 Large Woody Debris

Methods for tallying large woody debris (LWD) are adapted from those described by Kaufmann and Robison (1998). This component of the EMAP Physical Habitat protocol allows estimates of the number, size, and total volume of large woody debris within the river reach. LWD is defined here as woody material with small end diameter of at least 30 cm (1ft) and length of at least 5 m (15 ft). These size criteria are larger than those used by Kaufmann and Robison (1998) in wadeable streams because of the lesser role that small wood plays in controlling velocity and morphology of larger rivers.

The procedure for tallying LWD is presented in Table 6-6. The tally includes all pieces of LWD that are at least partially in the baseflow channel (Wetted Channel). Sepa-

Table 6-5. Channel Margin Depth and Substrate Procedure.

1. If not already done, fill in the header information on page 1 of a Channel/Riparian Transect Form. Be sure to indicate the letter designating the transect location.

2. Measure depth and observe bottom substrates within a 10m swath along the 20m of the channel margin that is centered on each transect location.

3. Determine and record the depth and the dominant and subdominant substrate size class at 5 systematically-spaced locations estimated by eye within this 10m x 20m plot and 1m back from the waterline. **If the substrate particle is "artificial" (e.g. concrete or asphalt), choose the appropriate size class, flag the observation and note that it is artificial in the comment space.**

Code	Size Class	Size Range (mm)	Description
RS	Bedrock (Smooth)	>4000	Smooth surface rock bigger than a car
RR	Bedrock (Rough)	>4000	Rough surface rock bigger than a car
HP	Hardpan		Firm, consolidated fine substrate
BL	Boulders	>250 to 4000	Basketball to car size
CB	Cobbles	>64 to 250	Tennis ball to basketball size
GC	Gravel (Coarse)	>16 to 64	Marble to tennis ball size
GF	Gravel (Fine)	> 2 to 16	Ladybug to marble size
SA	Sand	>0.06 to 2	Smaller than ladybug size, but visible as particles - gritty between fingers
FN	Fines	<0.06	Silt Clay Muck (not gritty between fingers)
WD	Wood	Regardless of Size	Wood & other organic particles
OT	Other	Regardless of Size	Concrete, metal, tires, car bodies etc. (describe in comments)

4. On page 1 of the Channel/Riparian Transect Form, circle the appropriate shore and bottom substrate type and record the depth measurements ("SONAR" or "POLE" columns).

5. Repeat Steps 1 through 4 at each new cross section transect.

rately tally wood that is presently dry but contained within the "Bankfull" or active channel (flood channel up to bankfull stage). Include wood that spans above the active channel or spanning above the active channel with the "Dry but within Bankfull" category. For each tally (Wetted Channel and Dry but within Bankfull), the field form (Figure 6-4) provides 12 entry boxes for tallying debris pieces visually estimated within three length and four diameter class combinations. Each LWD piece is tallied in only one box. Woody debris is not tallied in the area between channel cross sections, but the presence of large debris dams and accumulations should be mapped and noted in the comments.

For each LWD piece, first visually estimate its length and its large and small end diameters in order to place it in one of the diameter and length categories. The diameter classes on the field form (Figure 6-4) refer to the large end diameter. The diameter classes are 0.3m to <0.6m, 0.6m to <0.8m, and 0.8m to <1.0m and >1.0m. The length classes are 5m to <15m, 15m to <30m, and >30m. Sometimes LWD is not cylindrical, so it has no clear "diameter". In these cases visually estimate what the diameter would be for a piece of wood with circular cross section that would have the same volume. When evaluating length, include only the part of the LWD piece that has a diameter greater than 0.3m (1 ft).

Table 6-6. Procedure for Tallying Large Woody Debris.

Note: Tally pieces of large woody debris (LWD) within the 11 transects of the river reach at the same time the shoreline measurements are being determined. Include all pieces whose large end is located within the transect plot in the tally.

1. LWD in the active channel is tallied in 11 "plots" systematically spaced over the entire length of the stream reach. These plots are each 20 m long in the upstream-downstream direction. They are positioned along the chosen bank and extend from the shore in 10m towards mid-channel and then all the way to the bankfull margin.
2. Tally all LWD pieces within the plot that are at least partially within the baseflow channel. Also tally LWD that is dry but contained within the active channel. First, determine if a piece is large enough to be classified as LWD (small end diameter 30 cm [1 ft.]; length 5 m [15 ft.])
3. For each piece of LWD, determine its diameter class based on the diameter of the large end (0.3 m to < 0.6 m, 0.6 m to <0.8 m, 0.8 m to <1.0 m, or >1.0 m), and the length class of the LWD pieces based on the part of its length that has diameter 30 cm. Length classes are 5m to <15m, 15m to <30m, or >30m.
   - If the piece is not cylindrical, visually estimate what the diameter would be for a piece of wood with circular cross section that would have the same volume.
   - When estimating length, include only the part of the LWD piece that has a diameter greater than 0.3 m (1 ft.)
4. Place a tally mark in the appropriate diameter × length class tally box in the "WOOD All/Part in WETTED Channel" section of the Channel/Riparian Transect Form.
5. Tally all shoreline LWD pieces along the littoral plot that are at least partially within or above (bridging) the bankfull channel, but not in the wetted channel. For each piece, determine the diameter class based on the diameter of the large end (0.3 m to < 0.6 m, 0.6 m to <0.8 m, 0.8 m to <1.0 m, or >1.0 m), and the length class based on the length of the piece that has diameter 30 cm. Length classes are 5m to <15m, 15m to <30m, or >30m.
6. Place a tally mark for each piece in the appropriate diameter × length class tally box in the "DRY BUT ALL/PART IN Bankfull Channel" section of the Channel/Riparian Transect Form.
7. After all pieces within the segment have been tallied, write the total number of pieces for each diameter × length class in the small box at the lower right-hand corner of each tally box.
8. Repeat Steps 1 through 7 for the next river transect, using a new Channel/Riparian Transect Form.

Count each of the LWD pieces as one tally entry and include the whole piece when assessing dimensions, even if part of it is outside of the bankfull channel. If you encounter massive, complex debris jams, estimate their length, width, and height. Also estimate the diameter and length of large "key" pieces and judge the average diameter and length of the other pieces making up the jam. Record this information in the comments section of the form.

6.6.4 Bank Angle and Channel Cross-Section Morphology

Undercut, vertical, steep, and gradual bank angles are visually estimated as defined on the field form (Figure 6-4). Observations are made from the wetted channel margin up 5 m (a canoe's length) into the bankfull channel margin on the previously chosen side of the stream.

The channel dimensions to be measured or estimated are the wetted width, mid-channel bar width, bankfull height and width, the amount of incision, and the degree of channel constraint. These shall be assessed for the whole channel (left and right banks) at each of the 11 cross section transects. Each are recorded on the Channel/Riparian Transect Form (Figure 6-4). The procedure for obtaining bank angle and channel cross-section morphology measurements is presented in Table 6-7.

Table 6-7. Procedure for Bank Angle and Channel Cross-Section.

1. Visually estimate the bank angle (undercut, vertical, steep, gradual), as defined on the field form. Bank angle observations refer to the area from the wetted channel margin up 5 m (a canoe's length) into the bankfull channel margin on the **previously chosen side of the river**. Circle the range within which the observed band angle falls on the "Bank CHARACTERISTIC" section of the Channel/ Riparian Transect Field Form.
2. With a laser rangefinder at a cross-section transect, measure and record the **wetted width** value in the "Wetted Width" field in the bank characteristics section of the field data form. Also determine the **bankfull channel width** and the **width of exposed mid-channel bars (if present)** with the laser rangefinder and surveyor's rod. Record these values in the "Bank CHARACTERISTIC" section of the field data form.
3. To estimate bankfull height, hold the surveyor's rod vertical, with its base planted at the water's edge. Using the rod as a guide while examining both banks, estimate (by eye) the height of bankfull flow above the present water level. Look for evidence on one or both banks such as:
   - An obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel.
   - A transition from exposed river sediments to terrestrial vegetation.
   - A transition from sorted river sediments to unsorted terrestrial soils.
   - Transition from bare rock to moss growth on rocks along the banks.
   - Presence of drift material caught on overhanging vegetation.
   - Transition from flood- and scour-tolerant vegetation to that which is relatively intolerant of these conditions.
4. Hold the surveyor's rod vertical, with its base planted at the water's edge. Using the surveyor's rod as a guide while examining both banks, estimate (by eye) the channel incision as the **height up from the water surface to the elevation of the first terrace of the valley floodplain** (Note this is at or above the bankfull channel height). Record this value in the "Incised Height" field of the Bank Characteristic section on the field data form.
5. Repeat Steps 1 through 4 at each cross-section transect. Record data for each transect on a separate field data form.

Wetted width refers to the width of the channel as defined by the presence of free-standing water; if greater than 15m, it can be measured with the laser range finder. Mid-channel bar width, the width of exposed mid-channel gravel or sand bars in the channel, is included within the wetted width, but is also recorded separately. In channel cross-section measurements, the wetted and active channel boundaries are considered to include mid-channel bars. Therefore, the wetted width shall be measured as the distance between wetted left and right banks. It is measured across and over mid-channel bars and boulders. If islands are present, treat them like bars, but flag these measurements and indicate in the comments that the "bar" is an island. If you are unable to see across the full width of the river when an island separates a side channel from the main channel, record the width of the main channel, flag the observation, and note in the comments section that the width pertains only to the main channel.

Bankfull height and width shall be estimated with the aid of the surveyor's rod and laser range finder. The "bankfull" or "active" channel is defined as the channel that is filled by moderate sized flood events that fill the channel to its flood banks. Measure bankfull width over and across mid-channel bars. Bankfull flows typically recur every 1 to 2 years and do not generally overtop the channel banks to inundate the valley floodplain. They are believed to be largely responsible for the observed channel dimensions in most rivers and streams. If the channel is not greatly incised, bankfull channel height and the amount of incision will be the same. However, if the channel is incised greatly, the bankfull level will be below the level of the first terrace of the valley floodplain, making "Bankfull Height" smaller than "Incision" (Figure 6-6). You will need to look for evidence of recent flows (within about 1 year) to distinguish bankfull and incision heights, though recent flooding of extraordinary magnitude may be misleading.

Estimating the level of bankfull flow during baseflow conditions requires judgement and practice; even then it remains somewhat subjective. In many cases there is an obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel. Because scouring and inundation from bankfull flows are often frequent enough to inhibit many types of terrestrial vegetation, the bankfull channel may be evident by a transition from exposed river sediments and water-loving plants to upland ter-

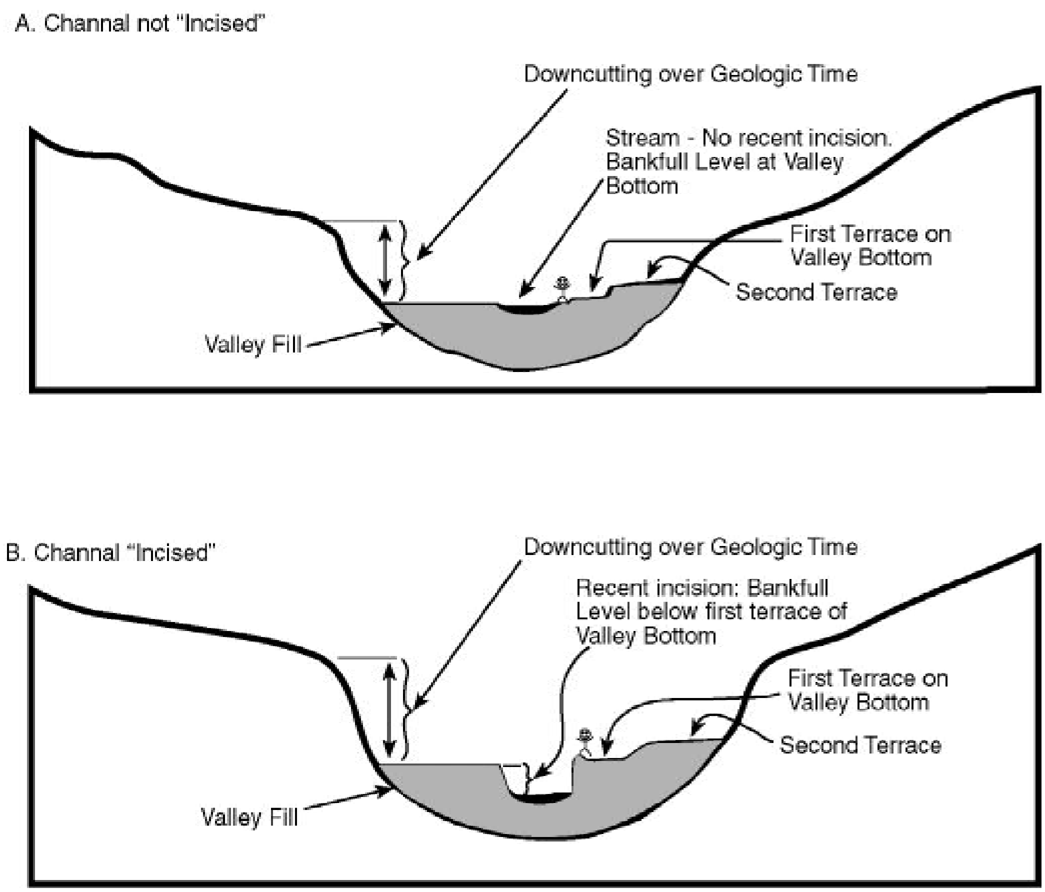


Figure 6-6. Schematic showing bankfull channel and incision for channels. (A) not recently incised, and (B) recently incised into valley bottom. Note level of bankfull stage relative to elevation of first terrace on valley bottom (Stick figure included for scale).

restrial vegetation. Similarly, it may be identified by noting where moss growth on rocks along the banks has been removed by flooding. The bankfull flow level may also be seen by the presence of drift material caught on overhanging vegetation.

As described in Table 6-7 and shown in Figure 6-6, examine both banks and estimate (by eye) the amount of channel incision from the water surface to the elevation of the first terrace of the valley floodplain. In cases where the channel is cutting a valley sideslope and has oversteepened and destabilized that slope, the bare "cutbank" is not necessarily an indication of recent incision. Examine both banks to make a more accurate determination of channel downcutting. Finally, assess the degree of river channel constraint by answering the four questions on the form (Figure 6-5) regarding the relationships among channel incision, valley sideslope, and width of the valley floodplain.

6.6.5 Canopy Cover (Densiometer)

Riparian canopy cover over a river is important not only for its role in moderating water temperatures through shading, but also as riparian wildlife habitat, and as an indicator of conditions that control bank stability and the potential for inputs of coarse and fine particulate organic material. Organic inputs from riparian vegetation become food for river organisms and structure to create and maintain complex channel habitat.

Vegetative cover over the river margin shall be measured at the chosen bank at each of the 11 transect locations (A-K). This measurement employs the Convex Spherical Densiometer, model B (Lemmon, 1957). The densiometer must be taped exactly as shown in Figure 6-7 to limit the number of square grid intersections to 17. Densiometer readings can range from 0 (no canopy cover) to 17 (maximum canopy cover). Four measurements are obtained at each cross-section transect (upriver, downriver, left, and right). Concentrate on the 17 points of grid intersection on the densiometer. If the reflection of a tree or high branch or leaf overlies any of the intersection points, that particular intersection is counted as having cover. The measure to be recorded on the form is the count (from 0 to 17) of all the intersections that have vegetation covering them. Therefore, a higher number indicates greater canopy extent and density. In making this measurement, it is important that the densiometer be leveled using the bubble level (Figure 6-7).

The procedure for obtaining canopy cover data is presented in Table 6-8. These bank densiometer readings complement your visual estimates of vegetation structure and cover within the riparian zone (Section 6.6.6). For each of the four directions, count the number of covered densiometer intersection points. Record these counts in the "Canopy Density @ Bank" section of the Channel/Riparian Transect Form as shown in Figure 6-4.

6.6.6 Riparian Vegetation Structure

The previous section (6.6.5) described methods for quantifying the cover of canopy over the river margin. The following visual estimation procedures, adapted from Kaufmann and Robison (1998), are a semi-quantitative evaluation of riparian vegetation structure, the type and amount of different types of riparian vegetation. These field characterizations shall be used to supplement interpretations of riparian vegetation from aerial photos and satellite imagery. Together, they

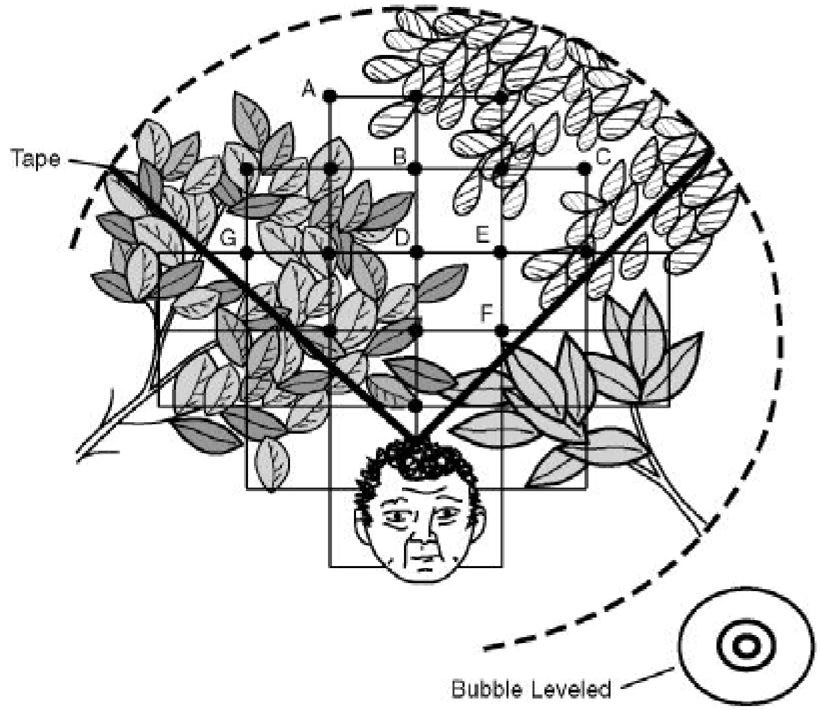


Figure 6-7. Schematic of modified convex spherical canopy densiometer (From Mulvey et al., 1992). In this example, 10 of the 17 intersections show canopy cover, giving a densiometer reading of 10. Note proper positioning with the bubble leveled and face reflected at the apex of the "V".

Table 6-8. Procedure for Canopy Cover Measurements.

1. Take densiometer readings at a cross-section transect while anchored or tied up at the river margin.
2. Hold the densiometer 0.3 m (1 ft) above the surface of the river. Holding the densiometer level using the bubble level, move it in front of you so your face is just below the apex of the taped "V".
3. At the channel margin measurement locations, count the number of grid intersection points within the "V" that are covered by either a tree, a leaf, a high branch, or the bank itself.
4. Take 1 reading each facing upstream (UP), downstream (DOWN), left bank (LEFT), and right bank (RIGHT). Right and left banks are defined with reference to an observer facing downstream.
5. Record the UP, DOWN, LEFT, and RIGHT values (0 to 17) in the "CANOPY COVER @ BANK" section of the Channel/Riparian Transect Form.
6. Repeat Steps 1 through 5 at each cross-section transect. Record data for each transect on a separate field data form.

are used to evaluate the health and level of disturbance of the river/riparian corridor. They also indicate the present and future potential for various types of organic inputs and shading. The cover and structure of riparian vegetation is estimated in three riparian layers within 10m x 20m plots along the river shoreline that are centered on the transect location with boundaries estimated by eye. As employed by Allen-Gill (unpublished manuscript), these plots shall be set back from the channel so that they describe vegetation above bankfull flow. As a result, gravel bars within the bankfull channel are not included in the vegetation plot (Figure 6-2).

Observations to assess riparian vegetation apply to the riparian area upstream 10 meters and downstream 10 meters from each of the 11 cross-section stations (Figure 6-2). They include the visible area from the river bankfull margin back a distance of 10m (30 ft) shoreward from both the left and right banks, creating a 10m X 20m riparian plot on each side of the river (Figure 6-2). The riparian plot dimensions are estimated, not measured. On steeply sloping channel margins, the 10m X 20m plot boundaries are defined as if they were projected down from an aerial view. If the wetted channel is split by a mid-channel bar, the bank and riparian measurements shall be for each side of the channel, not the bar. If an island obscures the far bank of the main channel, assess riparian vegetation on the bank of the island.

Table 6-9 presents the procedure for characterizing riparian vegetation structure and composition. Figure 6-5 illustrates how measurement data are recorded in the "Visual Riparian Estimates" section of the field form. Conceptually divide the riparian vegetation into three layers: a CANOPY LAYER (>5m high), an UNDERSTORY (0.5 to 5m high), and a GROUND COVER layer (<0.5 high). Note that several vegetation types (eg. grasses or woody shrubs) can potentially occur in more than one layer. Similarly note that some things other than vegetation are possible entries for the "Ground Cover" layer (eg. barren ground and duff, which includes fallen leaves, needles and twigs).

Before estimating the areal coverage of the vegetation layers, record the type of vegetation (**D**eciduous, **C**oniferous, Broadleaf **E**vergreen **M**ixed, or **N**one) in each of the two taller layers (Canopy and Understory). Consider the layer "Mixed" if more than 10% of the areal coverage is made up of the alternate vegetation type.

You will estimate the areal cover separately in each of the three vegetation layers. Note that the areal cover can be thought of as the amount of shadow cast by a particular layer alone when the sun is directly overhead. The maximum cover in each layer is 100%, so the sum of the areal covers for the combined three layers could add up to 300%. The four entry choices for areal cover within each of the three vegetation layers are "0" (absent: zero cover), "1" (sparse: <10%), "2" (moderate: 10-40%), "3" (heavy: 40-75%), and "4" (very heavy: >75%). These ranges of percentage areal cover corresponding to each of these codes are also shown on the Field Form. When rating vegetation cover types, mixtures of two or more subdominant classes might all be given sparse ("1") moderate ("2") or heavy ("3") ratings. One very heavy cover class with no clear subdominant class might be rated "4" with all the remaining classes either moderate ("2"), sparse ("1") or absent ("0"). Two heavy classes with 40-75% cover can both be rated "3".

As an additional assessment of the "old growth" character of riparian zones, search for the largest riparian tree visible on either side of the river from the littoral-riparian station. Identify if possible the species or the taxonomic group of this tree and estimate its height, diameter (Dbh), and distance from the wetted river margin.

6.6.7 Fish Cover, Algae, Aquatic Macrophytes

This portion of the EMAP physical habitat protocol is a visual estimation procedure modified from methods developed for lake shorelines (Kaufmann and Whittier 1997) and for wadeable streams (Kaufmann and Robison 1998). The aim is to evaluate, semi-quantitatively, the type and amount of important types of cover for fish and macroinvertebrates. Over

Table 6-9. Procedure For Characterizing Riparian Vegetation Structure.

1. Anchor or tie up at the river margin at a cross-section transect; then make the following observations to characterize riparian vegetation structure.

2. Estimate the distance from the shore to the riparian vegetation plot; record it just below the title "Channel Constraint" on the field form.

3. Facing the left bank (left as you face downstream), estimate a distance of 10 m back into the riparian vegetation, beginning at the bankfull channel margin. Estimate the cover and structure of riparian vegetation in 3 riparian layers along the river shoreline within an estimated 10m x 20m plot centered on the transect, and beginning at the bankfull river margin along the river shoreline.

   - On steeply-sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.

4. Within this 10 m × 20 m area, conceptually divide the riparian vegetation into three layers: a CANOPY LAYER (>5m high), an UNDERSTORY (0.5 to 5 m high), and a GROUND COVER layer (<0.5 m high).

5. Within this 10 m × 20 m area, determine the dominant vegetation type for the CANOPY LAYER (vegetation > 5 m high) as either Deciduous, Coniferous, broadleaf Evergreen, Mixed, or None. Consider the layer "Mixed" if more than 10% of the areal coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the "Visual Riparian Estimates" section of the Channel/Riparian Cross-section and Thalweg Profile Form.

6. Determine separately the areal cover class of large trees (> 0.3 m [1 ft] diameter at breast height [DBH]) and small trees (< 0.3 m DBH) within the canopy layer. Estimate areal cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form ("0"=absent: zero cover, "1"=sparse: <10%, "2"=moderate: 10-40%, "3"=heavy: 40-75%, or "4"=very heavy: >75%).

7. Look at the UNDERSTORY layer (vegetation between 0.5 and 5 m high). Determine the dominant vegetation type for the understory layer as described in Step 5 for the canopy layer.

8. Determine the areal cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described in Step 6 for the canopy layer.

9. Look at the GROUND COVER layer (vegetation < 0.5 m high). Determine the areal cover class for woody shrubs and seedlings, non-woody vegetation, and the amount of bare ground present as described in Step 6 for large canopy trees.

10. Repeat Steps 1 through 9 for the opposite bank.

11. Repeat Steps 1 through 10 for all cross-section transects, using a separate field data form for each transect.

a defined length and distance from shore at 11 systematically spaced plot locations, crews shall estimate by eye and by sounding the proportional cover of fish cover features and trophic level indicators including large woody debris, rootwads and snags, brush, undercut banks, overhanging vegetation, rock ledges, aquatic macrophytes, filamentous algae, and artificial structures. Alone and in combination with other metrics, this information is used to assess habitat complexity, fish cover, and channel disturbance.

The procedure to estimate the types and amounts of fish cover is outlined in Table 6-10. Data are recorded in the "Fish Cover/ Other" section of the Channel/Riparian Transect Form as shown in Figure 6-5. Crews will estimate the areal cover of all of the fish cover and other listed features that are in the water and on the banks within the 10m x 20m plot (refer to Figure 6-2).

Observations to assess fish cover and several other in-channel features apply to a 10 m x 20 m inundated area adjacent to the selected bank extending 10 m out from the channel margin, and then upstream 10 m and downstream 10 m from each of the 11 transect cross-sections (Figure 6-2). These plot dimensions are estimated by eye. The ranges of percentage areal cover corresponding to each of these codes are the same as for riparian vegetation cover (Section 6.6.6) and are also shown on the Field Form.

Table 6-10. Procedure For Estimating Fish Cover.

1. Stop at the designated shoreline at a cross-section transect and estimate a 10m distance upstream and downstream (20m total length), and a 10m distance out from the banks to define a 20m x 10m littoral plot.
2. Examine the water and the banks within the 20m x 10m littoral plot for the following features and types of fish cover: filamentous algae, aquatic macrophytes, large woody debris, brush and small woody debris, overhanging vegetation, undercut banks, boulders, and artificial structures.
3. For each cover type, estimate its areal cover by eye and/or by sounding with a pole. Record the appropriate cover class in the "Fish Cover/Other" section of the Channel/ Riparian Transect Form ("0"=absent: zero cover, "1"=sparse: <10%, "2"=moderate: 10-40%, "3"=heavy: 40-75%, or "4"=very heavy: >75%).
4. Repeat Steps 1 through 3 at each cross-section transect, recording data from each transect on a separate field data form.

Filamentous algae pertains to long streaming algae that often occur in slow moving waters. Aquatic macrophytes are water loving plants in the river, including mosses, that could provide cover for fish or macroinvertebrates. If the river channel contains live wetland grasses, include these as macrophytes. Woody debris includes the larger pieces of wood that can provide cover and influence river morphology (i.e., those pieces that would be included in the large woody debris tally [Section 6.6.3]). Brush/ woody debris pertains to the smaller wood that primarily affects cover but not morphology. The entry for trees or brush within one meter above the water surface is the amount of brush, twigs, small debris etc. that is not in the water but is close to the river and provides cover. Boulders are typically basketball to car sized particles. Many streams contain artificial structures designed for fish habitat enhancement. Streams may also have in-channel structures discarded (e.g. cars or tires) or purposefully placed for diversion, impoundment, channel stabilization, or other purposes. Record the cover of these structures on the form.

6.6.8 Human Influences

Field characterization of the presence and proximity of various important types of human activities, disturbances, and land use in the river riparian area is adapted from methods developed by Kaufmann and Robison (1998) for wadeable streams. This information shall be used in combination with riparian and watershed landuse information from aerial photos and satellite imagery to assess the potential degree of disturbance of the sample river reaches.

For the left and right banks at each of the 11 detailed Channel/Riparian Cross-Sections, evaluate the presence/absence and the proximity of 11 categories of human influences outlined in Table 6-11. Confine your observations to the river and riparian area within 10m upstream and 10m downstream from the cross-section transect (Figure 6-2). Four proximity classes are used: On the riverbank within 10m upriver or downriver of the cross-section transect, present within the 10m x 20m riparian plot, present outside of the riparian plot, and not present. Record human influences on the Channel/Riparian Transect Form (Figure 6-5).

You may mark "P" more than once for the same human influence observed outside of more than one riparian observation plot (e.g. at both Transect D and E). The rule is that you count human disturbance items as often as you see them, BUT NOT IF you have to site through a previously counted transect or its 10x20m riparian plot.

6.7 Summary of Workflow

Table 6-12 lists the activities performed at and between each transect for the physical habitat characterization. The activities are performed along the chosen river bank and mid-channel (thalweg profile).

6.8 Equipment and Supplies

Figure 6-8 lists the equipment and supplies required to conduct all the activities described for characterizing physical habitat. This checklist is similar to the checklist presented in Appendix A, which is used at the base location (Section 3) to ensure that all of the required equipment is brought to the river. Use this checklist to ensure that equipment and supplies are organized and available at

Table 6-11. Procedure for Estimating Human Influence.

1. Stop at the designated shoreline at a cross-section transect, look toward the left bank (left when facing downstream), and estimate a 10m distance upstream and downstream (20m total length). Also, estimate a distance of 10m back into the riparian zone to define a riparian plot area.
2. Examine the channel, bank and riparian plot area adjacent to the defined river segment for the following human influences: (1) walls, dikes, revetments, riprap, and dams; (2) buildings; (3) pavement (e.g., parking lot, foundation); (4) roads or railroads, (5) inlet or outlet pipes; (6) landfills or trash (e.g., cans, bottles, trash heaps); (7) parks or maintained lawns; (8) row crops; (9) pastures, rangeland, or hay fields; (10) logging; and (11) mining (including gravel mining).
3. For each type of influence, determine if it is present and what its proximity is to the river and riparian plot area. Consider human disturbance items as present if you can see them from the cross-section transect. Do not include them if you have to site through another transect or its 10m × 20m riparian plot.
4. For each type of influence, record the appropriate proximity class in the "Human Influence" part of the "Visual Riparian Estimates" section of the Channel/Riparian Transect Form. Proximity classes are:
   - B ("Bank") Present within the defined 20m river segment and located in the stream or on the wetted or bankfull bank.
   - C ("Close") Present within the 10 × 20m riparian plot area, but above the bankfull level.
   - P ("Present") Present, but observed outside the riparian plot area.
   - O ("Absent") Not present within or adjacent to the 20m river segment or the riparian plot area at the transect
5. Repeat Steps 1 through 4 for the opposite bank.
6. Repeat Steps 1 through 5 for each cross-section transect, recording data for each transect on a separate field form.

Table 6-12. Summary of Workflow - River Physical Habitat Characterization.

A. At the chosen bank on first transect (farthest upstream):

1. Move boat in a "loop" within 10 x 20 meter littoral plot, measuring five littoral depths and probing substrate.
2. Estimate dominant and subdominant littoral substrate, based on probing the five locations.
3. Estimate areal cover of fish concealment features in 10 x 20 meter littoral plot.
4. Tally LWD within or partially within the 10 x 20 meter littoral plot.
5. Measure water conductivity and temperature.
6. Do densiometer measurements at bank (facing upstream, downstream, left, right).
7. Choose bank angle class, estimate bankfull height, width and channel incision. (Note that width and incision estimates incorporate both left and right banks.).
8. Tally LWD entirely out of water but at least partially within the bankfull channel.
9. Estimate and record distance to riparian vegetation on the chosen bank.
10. Make visual riparian vegetation cover estimates for the 10 x 20 meter riparian plot on both sides of the channel. (Note that riparian plot starts at bankfull and continues back 10m away from the bankfull line).
11. Identify species, height, Dbh, and distance from riverbank of largest riparian tree within your vision.
12. Make visual human disturbance tally. It has the same plot dimensions as the riparian vegetation -- except if a disturbance item is observed in the river or within the bankfull channel, then the proximity code is "B", the closest rating. Disturbances within the plot get a rating of "C"; those visible beyond the plot are rated "P".
13. Siting clinometer level (0%) towards the near or far bank at the current transect, mark or remember an eye-level point to which you will be siting when backsiting from the next downstream transect.
14. Get out far enough from the bank so you can see downstream. Then use the laser rangefinder to site and record the distance to the intended position of the next downstream transect.

B. Thalweg Profile:

1. As soon as you get out from the bank after doing transect activities, take the first of 20 thalweg depth measurements and substrate/snag probes using sonar and pole -- also classify habitat type.
2. Estimate thalweg measurement distance increments by keeping track of boat lengths or channel-width distances traversed; each increment is 1/10th (or 1/20th) the distance between transects.
3. At the 20th thalweg measurement location, you are one increment upstream of the next transect. Backsite compass bearing mid-channel, then measure the distance and % slope back to your visual "mark" on the bank at the previous transect.

C. Repeat the Whole Process (for the remaining 10 transects and spaces in between).

the river site in order to conduct the activities efficiently.

6.9 Literature Cited

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Equipment and Supplies for Physical Habitat		
Qty.	Item	
1	Surveyor's telescoping leveling rod (round profile, fiberglass, metric scale, 7.5m extended)	
1	Clinometer (or Abney level) with percent and degree scales.	
1	Convex spherical canopy densiometer (Lemmon Model B), modified with taped "V"	
1	Bearing compass (Backpacking type)	
1 roll ea.	Colored surveyor's plastic flagging (2 colors)	
2	Covered clipboards (lightweight, with strap or lanyard to hang around neck)	
	Soft (#2) lead pencils (mechanical are acceptable)	
2 pair	Chest waders with felt-soled boots for safety and speed if waders are the neoprene "stocking" type	
1	Camera - waterproof 35mm with standard and wide angle lens	
	Film - 35mm color slide film, ASA 400 and 100	
1	Fiberglass Tape and reel (50m metric) with good hand crank and handle	
1	SONAR depth sounder - narrow beam (16 degrees)	
1	Laser rangefinder - 400 ft. distance range - and clear waterproof bag	
11 plus extras	Channel/Riparian Transect Forms	
11 plus extras	Thalweg Profile Forms	
1 copy	Field operations and methods manual	
1 set	Laminated sheets of procedure tables and/or quick reference guides for physical habitat characterization	

Figure 6-8. Checklist of equipment and supplies for physical habitat

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