TFW AMBIENT MONITORING PROGRAM MANUAL

Modules

Stream Segmemt Identification
Reference Point Survey
Habitat Unit Survey
Large Woody Debris Survey
Salmonid Spawning Gravel Composition
Stream Temperature

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TIMBER FISH & WILDLIFE

July 1993

TIMBER-FISH-WILDLIFE

1993 AMBIENT MONITORING MANUAL

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THE TFW AMBIENT MONITORING PROGRAM

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Acknowledgements

The continued development of the TFW Ambient Monitoring project represents several years of on-going effort by many individuals too numerous to mention. We would like to begin by acknowledging the contributions of people involved in past program development and implementation activities, including present and former members of the Ambient Monitoring Steering Committee and the staff from the past Ambient Monitoring Program at the University of Washington Center for Streamside Studies and the Northwest Indian Fisheries Commission. We would also like to acknowledge past monitoring participants that have contributed data to the statewide data base including: the Colville, Hoh, Lower Elwha, Lummi, Muckleshoot, Nisqually, Nooksack, Quileute, Quinault, Squaxin Island, and Yakima tribes, the Point-No-Point Treaty Council, the Upper Columbia United Tribes, and ITT Rainier.

Manual cover design by Allen Pleus

THE TFW AMBIENT MONITORING PROGRAM

Introduction

The TFW Agreement was initiated in 1988 as a result of negotiations between representatives of the timber industry, state resource agencies, Indian Tribes and environmental groups. These negotiations resulted in agreement on a new forest practices management system which promotes management decisions and actions that result in mutual benefits to the timber, fish and wildlife resources.

A cornerstone of the TFW Agreement is the emphasis on use of scientific information to improve management decisions. However, in many cases inadequate scientific information is available to provide certainty in decision-making. Consequently, TFW utilizes the concept of adaptive management, a process which combines scientific research with on-going evaluation of forest practices and allows adjustment of the management system as new information becomes available.

To develop the scientific information necessary to implement adaptive management, the TFW participants established the cooperative monitoring, evaluation and research (CMER) program. The Ambient Monitoring project, charged with monitoring changes in the condition of stream channels and instream habitat, has been part of the CMER program since its inception.

Goals of the Ambient Monitoring Stream Survey Project

The goals of the Ambient Monitoring stream survey project are:

1. to collect information on the current condition of stream channels in forested areas;

2. to monitor changes in stream channels over time, and identify trends occurring as a result of natural and management-induced disturbance and recovery; and

3. to generate information which assists in identifying the cumulative effects of forest practices over time on a watershed scale.

The Ambient Monitoring methodology is designed as an iterative monitoring tool. Monitoring parameters and methodologies have been evaluated and refined to improve accuracy and repeatability and minimize observer bias, enhancing the capability of the methodology to detect and document changes in stream channel conditions over time.

Ambient Monitoring Supports TFW and Watershed Analysis

The TFW Ambient Monitoring survey methodologies and products have been designed to dovetail with the information needs of "Watershed Analysis", the cumulative effects assessment procedure developed by CMER and approved by the Forest Practices Board. The Stream Segment Identification Module, the Reference Point Survey, the Habitat Unit Survey, the Large Woody Debris Survey, and the Spawning Gravel Fine Sediment Module all provide information that is compatible with the fish habitat and channel assessment modules of Watershed Analysis.

Organization of the TFW Ambient Monitoring Program

The TFW Ambient Monitoring program is designed to be a cooperative endeavor between CMER, TFW cooperators, and other interested parties. All TFW participants, as well as other interested parties, are encouraged to participate.

CMER encourages monitoring by providing funding for development and administration of the program, and by providing support services for monitoring cooperators.

Actual CMER oversight of the TFW Ambient Monitoring Program is the responsibility of the Ambient Monitoring Steering Committee (AMSC), which prepares the workplan and oversees implementation of the program. Most implementation activities are accomplished by the Northwest Indian Fisheries Commission (NWIFC), under contract with CMER through the Washington Department of Natural Resources.

Products and Services Provided by the Ambient Monitoring Program

Some of the services provided by AMSC and the NWIFC to participants in the cooperative monitoring program include:

a. development and evaluation of monitoring methodologies,
b. training sessions in field methods,
c. follow-up field assistance and quality control,
d. development of data forms,
e. scanning of data forms,
f. data processing,
g. preparation of data summaries and reports.

In addition, monitoring information is provided to CMER and TFW participants.

The Modular Structure of the Ambient Monitoring Program

The Ambient Monitoring Program consists of a modular system of standard methodologies organized around specific parameters or concerns, such as large woody debris. The modular system was developed in recognition that stream channel conditions and relevant concerns vary throughout the state. This system allows cooperators to identify watershed-specific concerns and information needs, and choose appropriate standard methodologies to develop a custom monitoring program for their watershed. The 1993 version of the TFW Ambient Monitoring Manual presents the following modules:

1. **Stream Segment Identification Module**. This module provides methods for identifying and labeling discrete stream segments for Ambient Monitoring and Watershed Analysis purposes;

2. **Reference Point Survey Module**. This module provides methods for establishing permanent reference locations along stream channels, and for taking photographs, bankfull width and depth measurements, and canopy closure readings at these locations;

3. **Habitat Unit Survey Module**. This module provides methods for identifying and measuring channel habitat units and determining the percent pools for Watershed Analysis;

4. **Large Woody Debris Survey Module**. This module provides methods of documenting information on the amount and characteristics of large woody debris and computing large woody debris loading rates for Watershed Analysis;

5. **Spawning Gravel Fine Sediment Module**. This module provides methods for sampling and characterizing the quality of spawning gravel and for determining the percentage of fine sediments less than 0.85mm for use in Watershed Analysis, and;

6. **Stream Temperature Module.** This module provides methods for characterizing the maximum temperature of a stream reach and for collecting interpretive information on reach characteristics.

Training, Field Assistance and Quality Control

This manual is intended as a reference for those collecting information using TFW Ambient Monitoring methods. In addition to the manual, the monitoring program offers (and encourages the use of) formal training sessions and informal field assistance visits to help cooperators learn and implement the methodologies.

The Ambient Monitoring Program also provides a quality control service that involves having an experienced crew perform replicate surveys for cooperators. The purpose of quality control surveys is to identify and correct inconsistencies in application of the methods and to provide documentation that data being collected is replicable and consistent throughout the state. The quality control surveys also help to identify problems with the methodologies that need to be addressed.

Data Processing and Outputs

The TFW Ambient Monitoring Program provides field forms for recording monitoring data. Cooperators that use these forms can have their data scanned into a database and will receive both a hard copy data summary sheet for each segment surveyed and a copy of their database on floppy disk.

Data from all cooperators is stored in a statewide database for use in Watershed Analysis and other TFW-related applications.

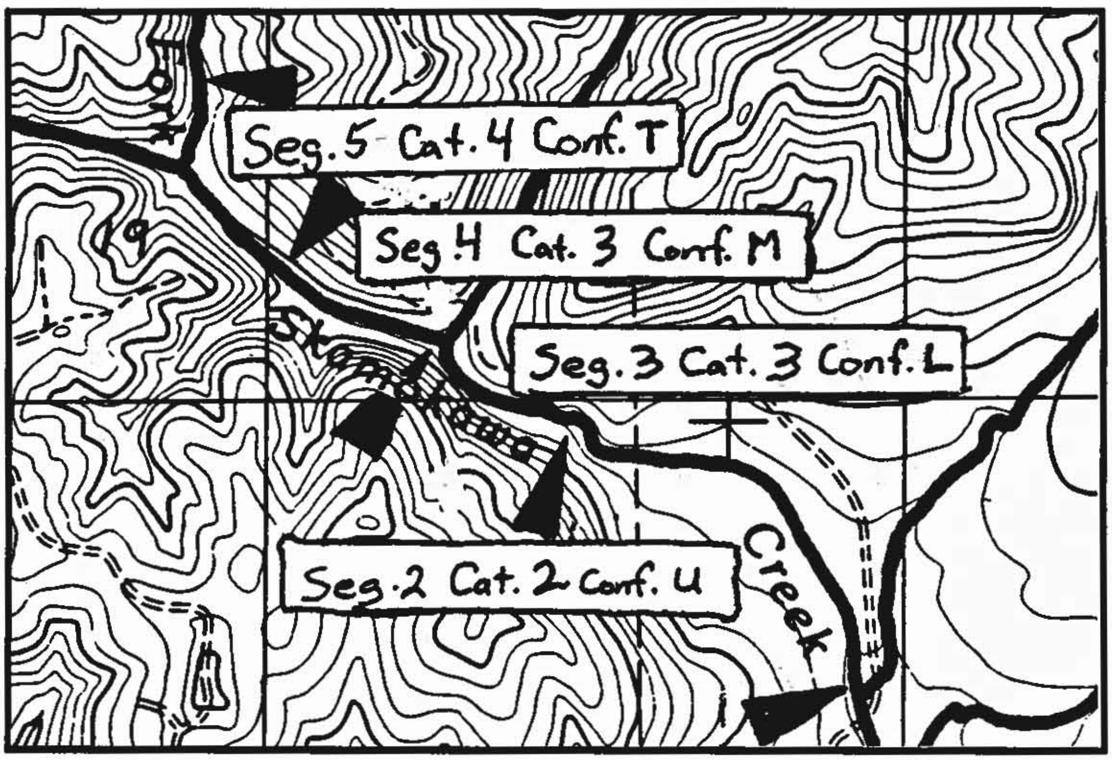
For More Information About Participating in the Program

We encourage organizations interested in conducting stream monitoring to participate in the TFW Ambient Monitoring Program and to utilize the services provided. Please contact the Northwest Indian Fisheries Commission (1-206-438-1180) for more information concerning the TFW Ambient Monitoring Program.

Timber-Fish-Wildlife
Ambient Monitoring Program

STREAM SEGMENT IDENTIFICATION MODULE

July 1993



Dave Schuett-Hames
Allen Pleus

Northwest Indian Fisheries Commission

STREAM SEGMENT IDENTIFICATION MODULE

Contents

Acknowledgements

Thanks to Tim Beechie for contributing to the development of this module.

Manual cover design by Allen Pleus

STREAM SEGMENT IDENTIFICATION MODULE

Introduction

In the TFW Ambient Monitoring system, survey reaches are stratified within a hierarchical framework (Frissell et al., 1986). The highest level of stratification occurs at the eco-region level, addressing factors that affect river systems on a watershed scale, such as precipitation, relief, and lithology. Typically, eco-regions are large areas, often incorporating several watersheds (or portions of watersheds) that share similar climatic, hydrologic, geologic, topographic and vegetational conditions.

The next level of stratification within the classification system occurs at the stream segment scale. Stratification at this level is based on the rationale that given similar watershed conditions and inputs to stream channels within an eco-region, the characteristics of the channels will vary in response to differences in physical factors such as gradient, channel confinement and stream size (Beechie and Sibley, 1990).

Purpose of the Stream Segment Identification Module

The purpose of the stream identification module is to:

1. Identify discrete stream segments for conducting monitoring surveys using a system of channel and floodplain characteristics compatible with Watershed Analysis.

2. Identify characteristics of stream segments for use in analysis of monitoring information.

Stream Segment Identification Methodology

This section describes procedures for identifying and delineating stream segments for TFW Ambient Monitoring purposes and describes documentation of additional information on segment characteristics.

The stream segment classification procedure divides river systems into discrete survey segments based on stream gradient, channel confinement (ratio of valley floodplain width:bankfull channel width), and the location of tributary junctions.

The procedure for delineating stream segments involves two steps:

1. an initial step using information from topographic maps and aerial photographs to identify major tributary junctions, determine stream gradient and estimate channel confinement, and;

2. field verification of mapping information, particularly the initial channel confinement estimate.

Equipment Needed

Segment summary forms (Form 1)
USGS topographic maps (7.5 minute maps work best, if available)
Aerial photos (helpful but not necessary)
Map wheel or gradient template
Architect scale
Colored pens or pencils
Fiberglass tape or rangefinder (metric)

Determining Tributary Junctions

First, identify all significant tributary junctions in the river system. Tributaries supply additional water and sediment loads which result in changes in channel morphology. Consequently, channel characteristics often change below the confluence of significant tributaries (Richards, 1980).

Begin by making photocopies of the USGS 7.5 minute topographic maps for the watershed. Determine the stream order of the channels using the Strahler method described in Dunne and Leopold (1978; pages 498-499). In this system, small headwater streams that have no tributaries (depicted as blue lines on the map) are designated as first-order streams. When two first-order streams meet they form a second-order stream. Where two second-order stream join they form a third-order stream, and so forth. The stream order changes only when two streams of equal order meet, so the confluence of a lower order tributary does not alter the order of a larger stream (Figure 1).

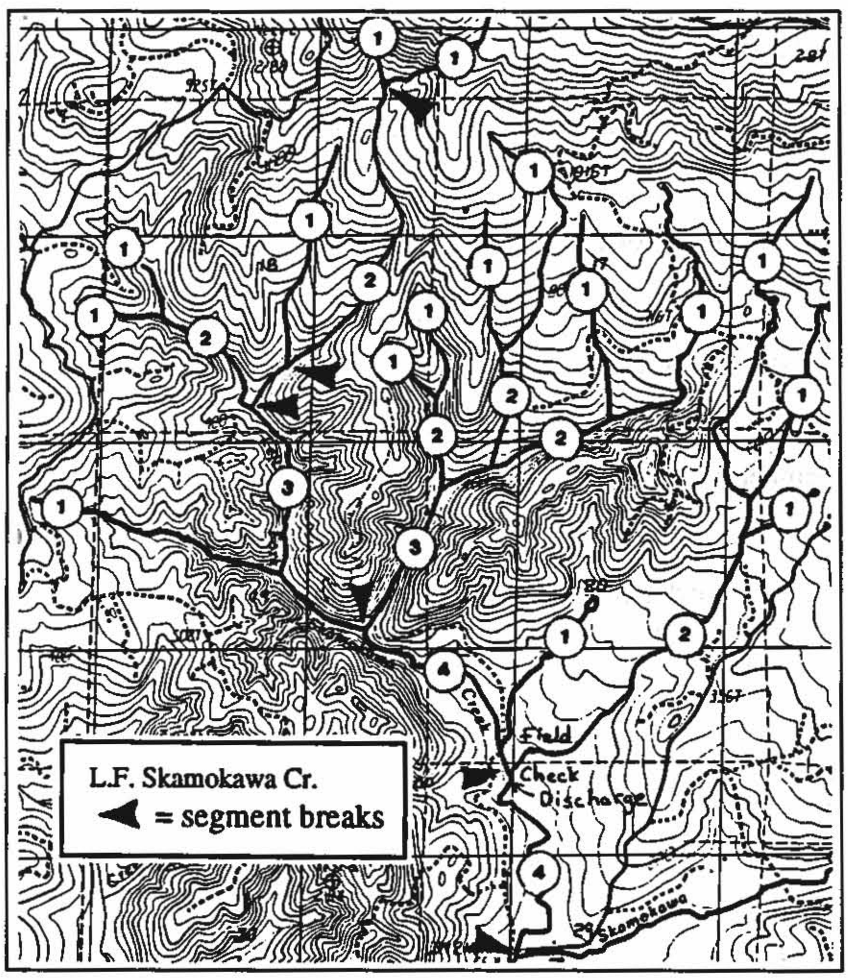


Fig. 1. Example of a stream system broken into segments based on stream order criteria.

Note all tributary junctions where the stream order of the tributary is the same, or the next smaller order, as the main channel. In addition, note any smaller tributary junctions where you are aware of changes in factors such as sediment load, channel width, or channel morphology. Mark all the appropriate tributary junctions on the working copy of your map.

Determining Stream Gradient

Next, determine stream gradients and break the stream system into smaller segments based on the following six gradient categories:

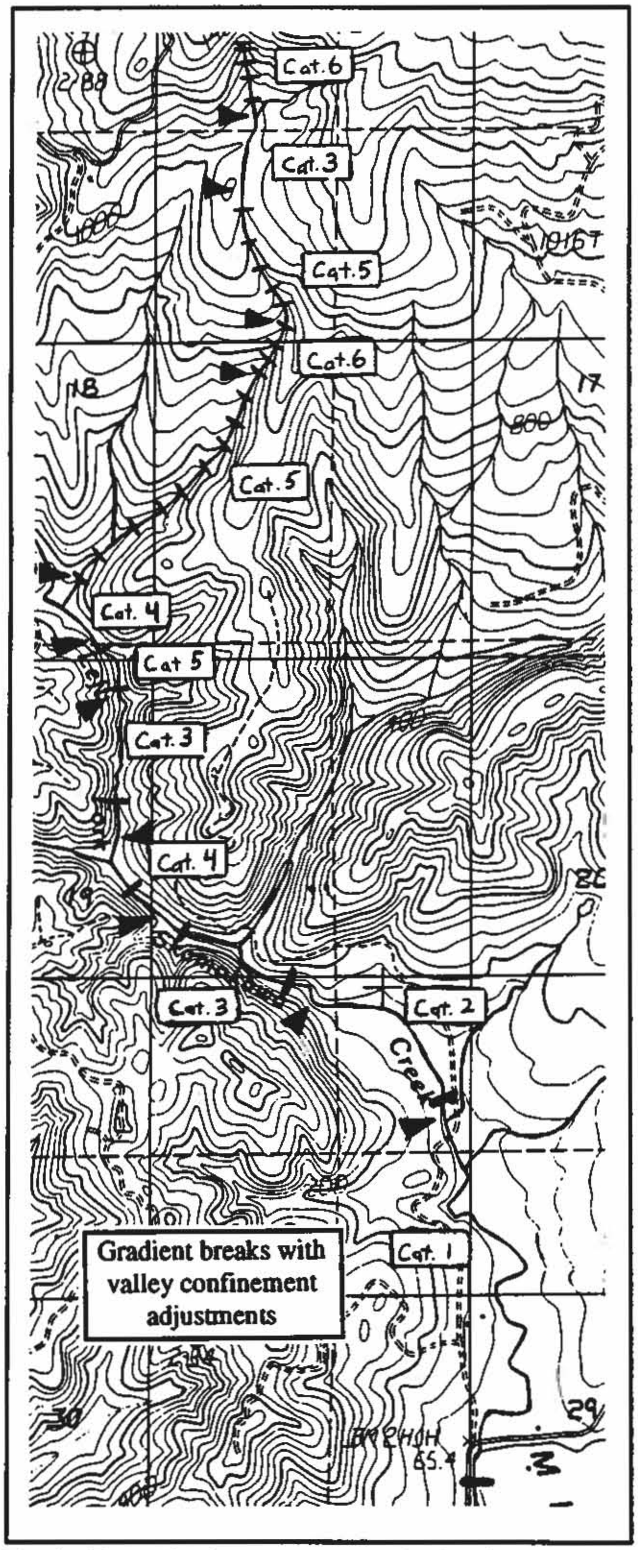


Fig. 2. Example of a stream system broken into segments based on gradient criteria.

Category 1 $\leq$ 1%
1% $>$ Category 2 $\leq$ 2%
2% $>$ Category 3 $\leq$ 4%
4% $>$ Category 4 $\leq$ 6%
6% $>$ Category 5 $\leq$ 17%
17% $>$ Category 6

Highlight the stream channels and mark where each contour line crosses the stream channel with a colored pencil or pen (Figure 2).

Gradient is determined by dividing the difference in elevation (rise) over the horizonal distance (run). There are several ways to determine stream gradient from a topographic map.
In situations where the stream channel is relatively straight, the gradient category can be determined by using a clear plastic sheet marked at intervals corresponding with the breaks between the seven gradient categories. Overlay this template on the stream channel and compare the distance between the marks with the distance between the points where the contour lines cross the stream channel. The distance between the marks will depend upon the scale of the map and the elevation difference between contour lines (which often varies between adjacent USGS topographic maps). To calculate the distance between marks for each gradient break, divide the contour interval used on the map by the desired gradient (expressed as a decimal). For example, on a USGS 7.5 minute topographic map with 40 foot contour intervals, the distance between contour lines at 1% gradient would be 40 feet / .01 = 4,000 feet. Then, from the map legend, determine the actual distance in inches corresponding to 4,000 feet and mark the template at that distance. A copy of the gradient template is provided in Appendix A.

A map wheel can be used to determine gradient in situations where the channel is sinuous. First, identify two places where elevation contour lines cross the stream channel. Then measure the distance between these two points by following the stream channel with the map wheel. Read the distance from the map wheel using the scale corresponding to the scale of the map. Finally, use a calculator to divide the rise (the elevation difference between the two chosen contour lines) by the run (the distance between them along the stream channel) to calculate stream gradient.

When the contour lines cross the stream at regularly spaced intervals, it is not necessary to do a calculation between each individual contour line. Separate calculations are required when the spacing of the contour lines crossing the stream changes, or where spacing is highly variable.

Mark and label the boundaries between the seven gradient categories on the working copy of your map.

Determining Channel Confinement

Channel confinement is the ratio between the width of the valley floodplain and the bankfull channel width. Stream channels are placed in one of four channel confinement categories:

Tightly Confined (T) - valley width less than 2 channel widths
Mod. Confined (M) - valley width 2-4 channel widths
Loosely Confined (L) - valley width 4-10 channel widths
Unconfined (U) - valley width greater than 10 channel widths

Channel confinement is difficult to determine from maps or aerial photographs. Often the channel is obscured by vegetation, making it difficult to ascertain channel width. It is also difficult to differentiate valley floor floodplains from raised terraces that are not flooded (and are not included in the valley width measurement).

Make an initial estimation of channel confinement based on your personal knowledge of the river system and the surrounding landscape, and information from maps and photos. Mark and label the estimated break-points between the channel confinement categories on the working copy of your map.

Then, spend some time in the field examining the stream channels and their floodplains. Take several measurements of channel width and valley floodplain width in representative locations. For this purpose, the valley width is the width of the "active" floodplain that receives waters during large flood events and is susceptible to channel-forming processes such as widening, meandering, braiding, and avulsion. It does not include elevated terraces that do not flood and act to confine an incised channel. Divide the total valley width (including the channel) by the bankfull channel width to compute channel confinement. Compare with your estimated values and mark and label any adjustments or corrections on the working copy of your map.

Finalizing Stream Segment Delineation

Your working map should now be marked with break-points based on tributary junctions, the

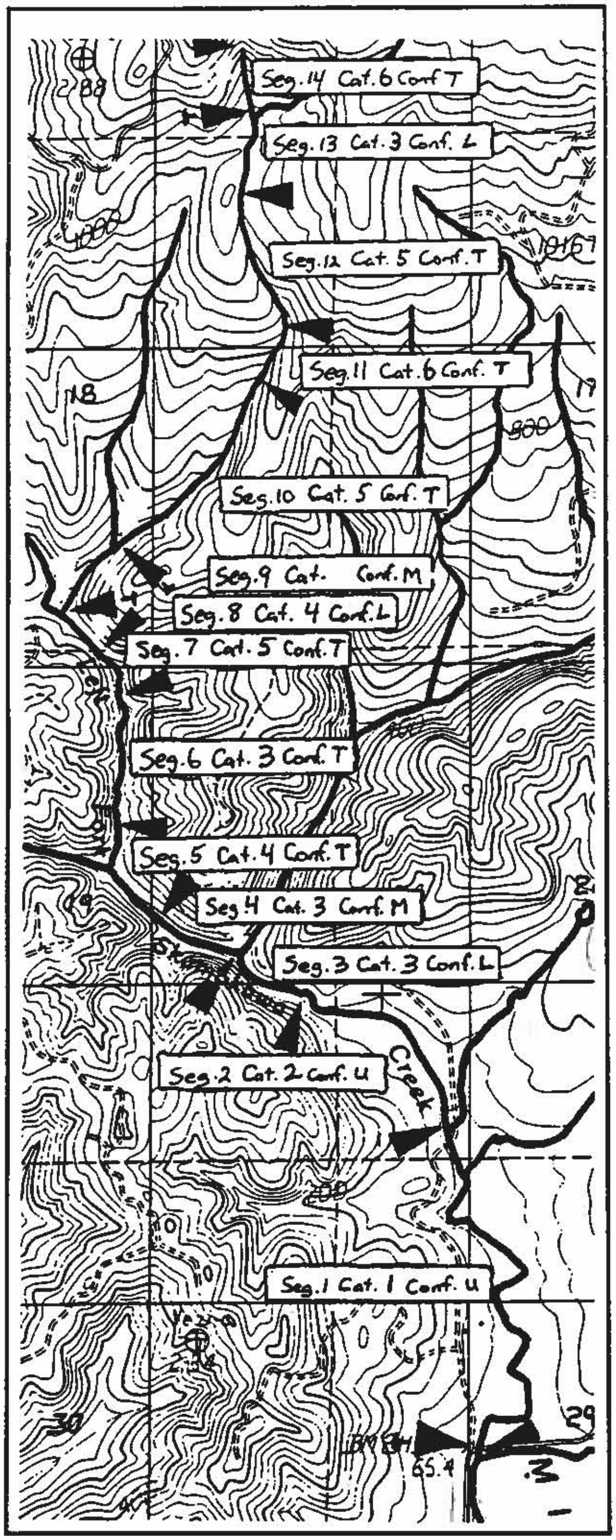


Fig. 3. Finalized segmenting according to tributary junctions, gradient and confinement.

boundaries between stream gradient categories, and the boundaries between channel confinement categories (Figure 3). Each discrete segment on the map represents a reach with a unique combination of stream gradient, channel confinement and watershed area. These segments are the basic units for Ambient Monitoring stream surveys and the habitat module in Watershed Analysis.

In many cases, a stream segment that appears to be uniform according to information from the map may not actually prove to be of uniform gradient or channel confinement in the field. Often, there are short sections of greater or lesser gradient (or confinement) interspersed within a segment that appears homogenous on the map. This poses the question of whether to break out short, anomalous reaches identified in the field (or on the map) as separate segments, or to include them in a larger segment. Combining them with a larger segment has the advantage of reducing the number of segments and simplifying record-keeping, but results in loss of resolution as data from small, unique areas is blended in with that from larger areas. Splitting out smaller segments increases complexity, but documents the unique characteristics of each distinct area.

As a general guideline, anomalous stream reaches longer than 300 meters should be treated as separate segments. The choice of whether to split or lump anomalous reaches shorter than 300 meters is left with the surveyor, and will depend on factors such as the degree of difference and the intended use of the information. For each segment that is surveyed, please describe the extent of variation in gradient and confinement within the section in the field notes section of the segment summary form.

Labeling Stream Segments with Unique Identification Numbers

Each segment should be assigned a unique identification number. Begin by determining the WRIA stream number from the WDF stream catalog (Williams et al., 1975).

The first two digits of the number represent the basin's Water Resource Inventory Area (WRIA) number. The next five spaces are provided for the four digit WRIA stream number. Use the fifth space to record a WRIA code letter if applicable.

The next four spaces are provided for un-numbered tributaries. In these cases, use the spaces provided for the WRIA number to record the WRIA number of the larger stream the un-numbered tributary flows into. Then use the first two spaces in the un-numbered tributary section to record RT for right bank tributaries or LT for left bank tributaries. Use the next two spaces to assign a tributary number beginning with 01, 02, etc. Leave the four un-numbered tributary spaces blank if the stream has a WRIA number.

Finally, use the three segment identification spaces to assign each gradient/confinement segment a unique identification number, beginning with the number 001 at the downstream end of the basin.

WRIA basin number	WRIA stream number	Un-numbered tributary code	Segment identification number
9 9	0 0 3 8 A	R T 0 1	0 0 2

Whenever the WRIA stream number changes, begin with segment number 001 at the downstream end of the next stream. Mark the segment identification numbers on your map.

Filling Out the Segment Summary Form

Segment Summary Form 1 (Appendix B) is used to record information used to identify and characterize each segment surveyed. One form should be filled out for each segment. Begin by filling out the header section of form 1 (Figure 4.)

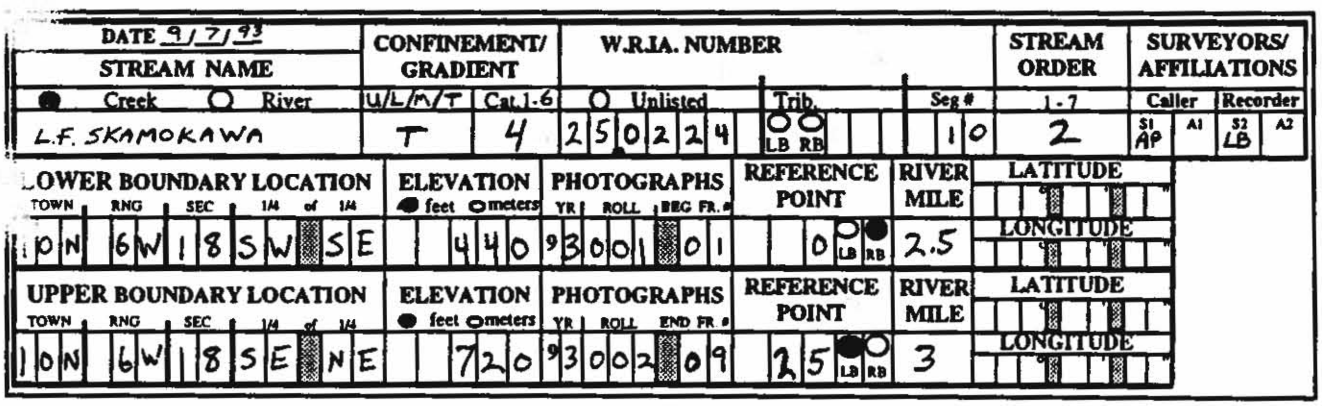


Figure 4. Form 1 information example.

Date - Fill in the date that you began the survey.

Stream name- Fill in the name of the stream you are surveying.

WRIA and segment identification number- Fill in the WRIA and segment identification number you have assigned to the segment being surveyed (see labeling stream segments with unique identification numbers, above).

Confinement- Record the confinement category using **(T)** for Tightly Confined, **(M)** for Moderately Confined, **(L)** for Loosely Confined and **(U)** for Unconfined.

Gradient- Record the appropriate code for the stream gradient category of the segment where:

		Cat. **1**	$\leq$	1%
1%	>	Cat. **2**	$\leq$	2%
2%	>	Cat. **3**	$\leq$	4%
4%	>	Cat. **4**	$\leq$	6%
6%	>	Cat. **5**	$\leq$	17%
17%	>	Cat. **6**		

Stream order- Record the stream order of the segment being surveyed from the working copy of the map.

Surveyors and affiliation- Record the initials and affiliations of the surveyors who completed the survey.

Upper and lower boundary locations- To complete this section of form 1, refer to the examples in Figure 4 (lower half of Form 1) and Figure 5 (topographic elevation and township, range, and section identification). First, locate the upstream boundary of the segment. Record the township, range and section number in the appropriate spaces. In the example in Figure 4, the upper boundary location of Segment 10 is Township 10N, Range 6W, Section 18. Next, divide the section into quarter-sections and decide if the boundary is in the NW, NE, SW or SE quarter-section. Finally, divide the quarter-section into quarters and decide if the boundary is in the NW, NE, SW or SE quarter of the quarter-section. For Segment 10 (Figure 5) the upper boundary location falls into the SE 1/4 of the NE 1/4 of Section 18. Record this information on Form 1, using the first two spaces for the quarter of the quarter-section, and the second two spaces for the quarter-section. For example, the information should read like '*the SE quarter of the NE quarter-section*'. Follow the same procedure for the downstream boundary location.

Elevation of the upper and lower boundaries- From the USGS topographic map, determine the elevation of the upper and lower boundaries of the segment being surveyed. Record the elevation of the contour line that crosses the stream closest to each respective boundary of the segment. For Segment 10 (Figure 5) each contour line represents a 40ft elevation interval (be sure to check each topographic map to find out the elevation scale). Count down the elevation contours from the 1000ft line to find the lower boundary at 720ft. For the lower boundary, count up the contour lines to locate the segment break at 440ft.

River mile of the upper and lower boundaries- From the WDF stream catalog for your area, determine and record the river mile (to the nearest tenth of a mile) of the upstream and downstream segment boundary.

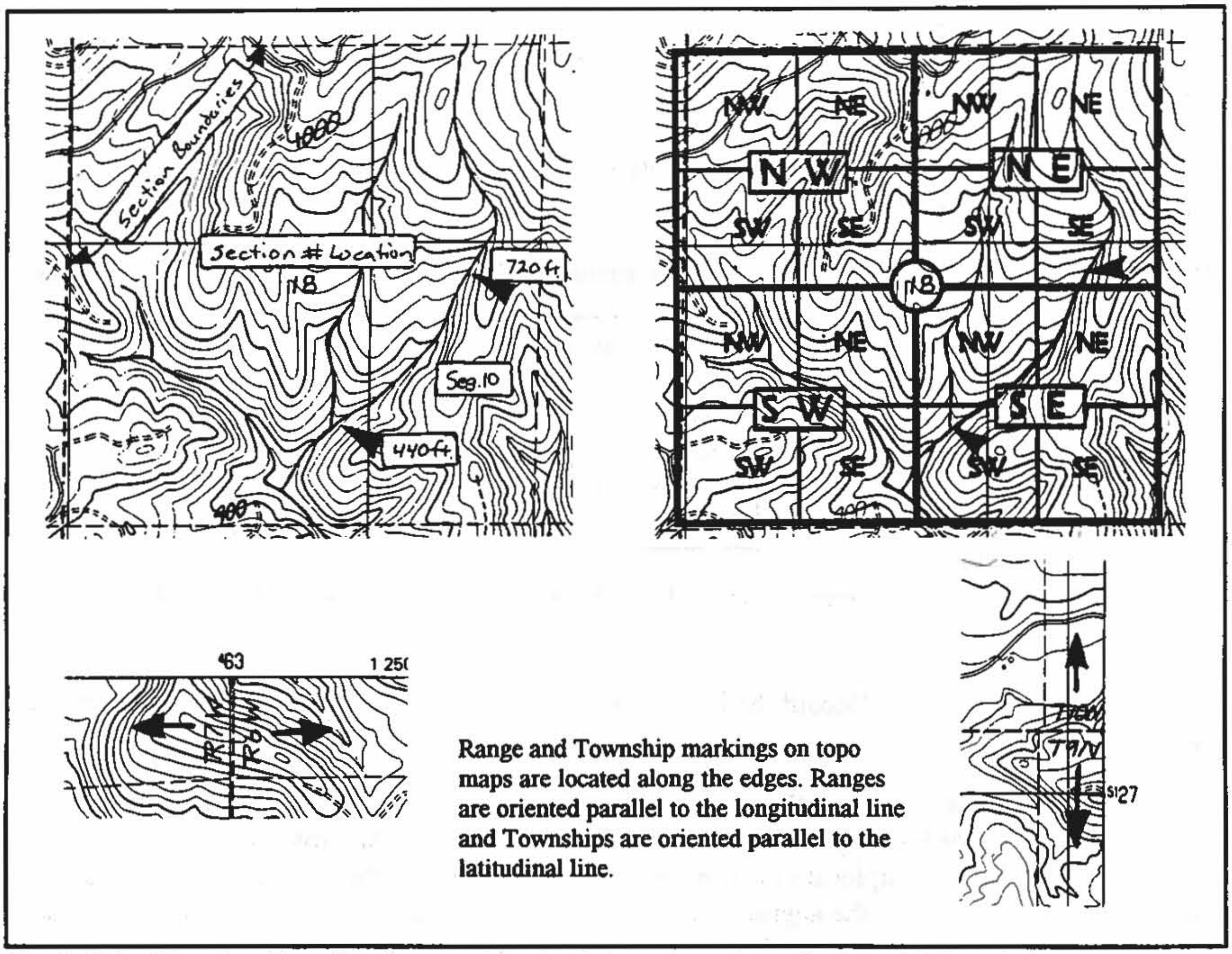


Fig. 5. Using Elevation, Township, Range and Section information to locate Segment 10's boundaries.

Latitude and longitude of the upper and lower boundaries - This field is provided to record location data from global positioning systems as it becomes available. If this information is not available, leave the spaces blank.

Photographs- Record the roll and frame number of the first and last photographs taken in the segment.

Segment Location Maps and Access Information

Please provide the Ambient Monitoring Program with a copy of the USGS map showing the boundaries of each segment surveyed. Also describe access to the segment for future reference.

Using Stream Segments to Develop a Monitoring Strategy

The map should now display all the potential monitoring survey segments in the watershed. The choice of segments to monitor is up to the cooperator. Segments may be selected for a variety of reasons, depending on the needs and goals of the organization undertaking the survey.

Many surveys will be conducted in areas undergoing Watershed Analysis. See the Watershed Analysis manual for suggestion on selecting "response reaches" where the effects of processes such as sedimentation are best monitored (Appendix C).

To obtain a watershed-scale perspective on the current condition of your river system, select segments representing a variety of stream gradient/channel confinement categories. Include a variety of land-use categories, if present, such as areas where forest activities are planned, areas where forest practices have been completed and natural "reference" segments, if available.

You may also want to base your sampling strategy on instream resources of special interest (for example, habitat utilized by a specific salmonid stock). The Ambient Monitoring Program staff are available to assist you in developing a monitoring strategy to meet your needs. See MacDonald et al. (1991) for additional information on designing a monitoring plan.

Training and Field Assistance

This manual is intended as a reference for using the TFW Ambient Monitoring Stream Segment Identification Module. The TFW Ambient Monitoring Program offers formal training sessions and informal field assistance visits to help cooperators learn and implement the stream segment identification methodology.

We encourage cooperators to utilize these services. Please contact the Northwest Indian Fisheries Commission (1-206-438-1180) for more information concerning the TFW Ambient Monitoring Program.

References

Beechie, T.J. and T.H. Sibley. 1990. Evaluation of the TFW stream classification system: stratification of physical habitat area and distribution. Final Report; 1988-1990. Wash. Dept. of Natural Resources. Forest Regulation and Assistance Division. Olympia.

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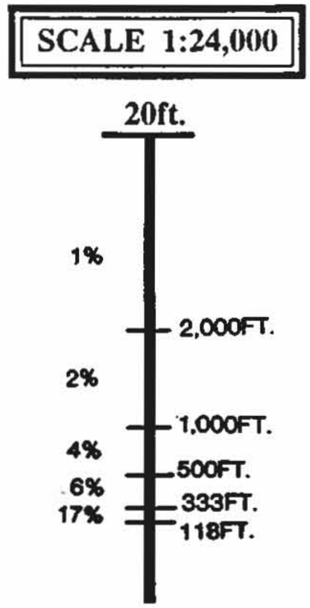
APPENDIXES

Appendix A.
Stream segmenting templates

Appendix B.
Form 1 example

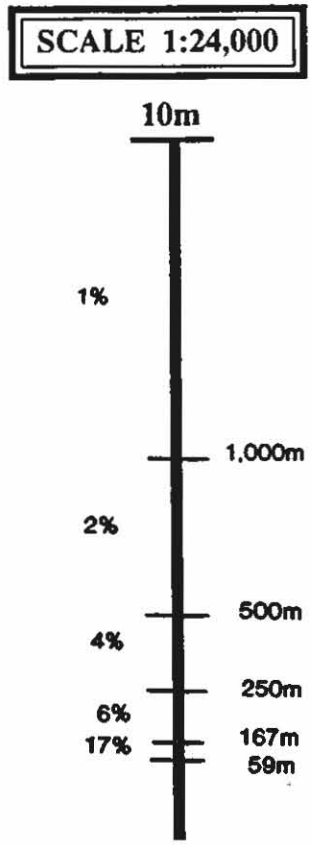
Appendix C.
Watershed Analysis "response reaches" table

APPENDIX A.



Segment Class

Cat. 1 ≤ 1%
1% < Cat. 2 ≤ 2%
2% < Cat. 3 ≤ 4%
4% < Cat. 4 ≤ 6%
6% < Cat. 5 ≤ 17%
17% < Cat. 6



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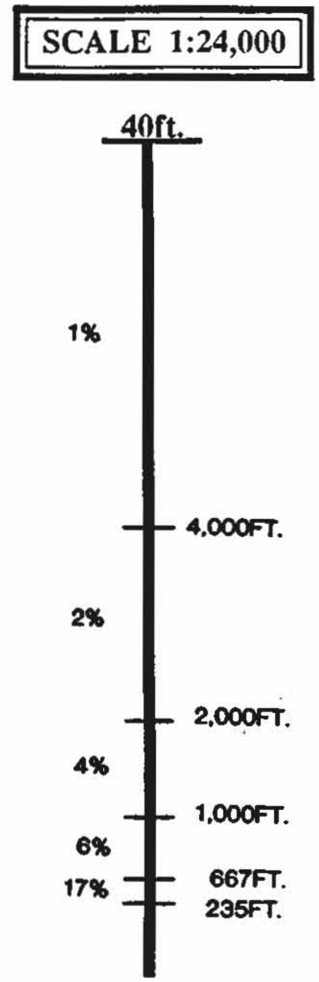

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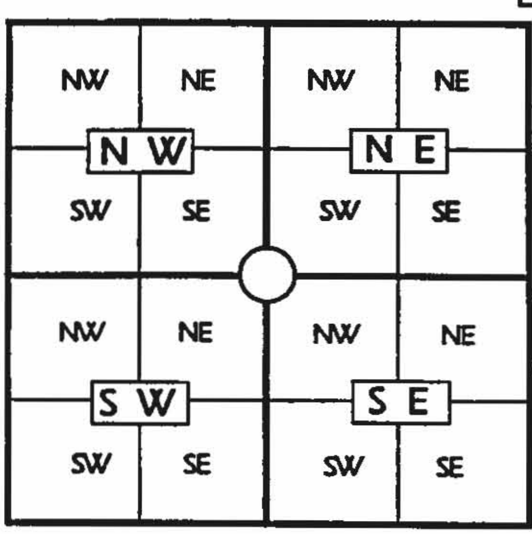
17% < Cat. 6



Template for topographical gradient categories on 7.5 minute USGS maps: 20ft., 40ft., & 10m contour intervals

Template for section of section and segment boundary location

Version 7/10 AP

SEGMENT SUMMARY

FORM 1

TFW - N.W.I.F.C.
Ambient Stream Monitoring 1993

Page ____of____

DATE __/__/__ STREAM NAME	CONFINEMENT/ GRADIENT		W.R.I.A. NUMBER			STREAM ORDER	SURVEYORS/ AFFILIATIONS				IMPORTANT ! Fill out FORM 1- 1ea. per segment. If additional FORM 2's (REF. PT. SURVEY) are necessary - use same temp. form and fill in Form 1 categories: Page; Date; Stream Name; Conf/Grad; &W.R.I.A. #
O Creek O River	T/M/L/U	Cat.1-6	O Unlisted	Trib. O O LB RB	Seg #	1 - 7	Caller S1	A1	Recorder S2	A2	

LOWER BOUNDARY LOCATION	ELEVATION	PHOTOGRAPHS	REFERENCE POINT	RIVER MILE	LATITUDE / LONGITUDE	FIELD NOTES:
TOWN RNG SEC 1/4 of 1/4	O feet O meters	YR ROLL BEG FR. # 9	O O LB RB			

UPPER BOUNDARY LOCATION	ELEVATION	PHOTOGRAPHS	REFERENCE POINT	RIVER MILE	LATITUDE / LONGITUDE	
TOWN RNG SEC 1/4 of 1/4	O feet O meters	YR ROLL END FR. # 9	O O LB RB			

REFERENCE POINT SURVEY

FORM 2

TEMPORARY FORM

	REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
			upstrm frame	dwnstrm frame	WIDTH	DEPTH		
	O O LB RB						%	

	REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
			upstrm frame	dwnstrm frame	WIDTH	DEPTH		
	O O LB RB						%	

	REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
			upstrm frame	dwnstrm frame	WIDTH	DEPTH		
	O O LB RB						%	

	REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
			upstrm frame	dwnstrm frame	WIDTH	DEPTH		
	O O LB RB						%	

	REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
			upstrm frame	dwnstrm frame	WIDTH	DEPTH		
	O O LB RB						%	

APPENDIX B

TABLE E-2: CHANNEL RESPONSE BY GRADIENT/CONFINEMENT CLASS

SEDIMENT	PEAK FLOWS	WOOD	CATASTROPHIC EVENTS
FS - Fine Sediment Deposition MS - Mixed Sediment Deposition CS - Coarse Sediment Deposition	SD - Scour Depth SF - Scour Frequency BE - Bank Erosion	WL - Wood Loss WA - Wood Accumulation	DT - Debris Torrent

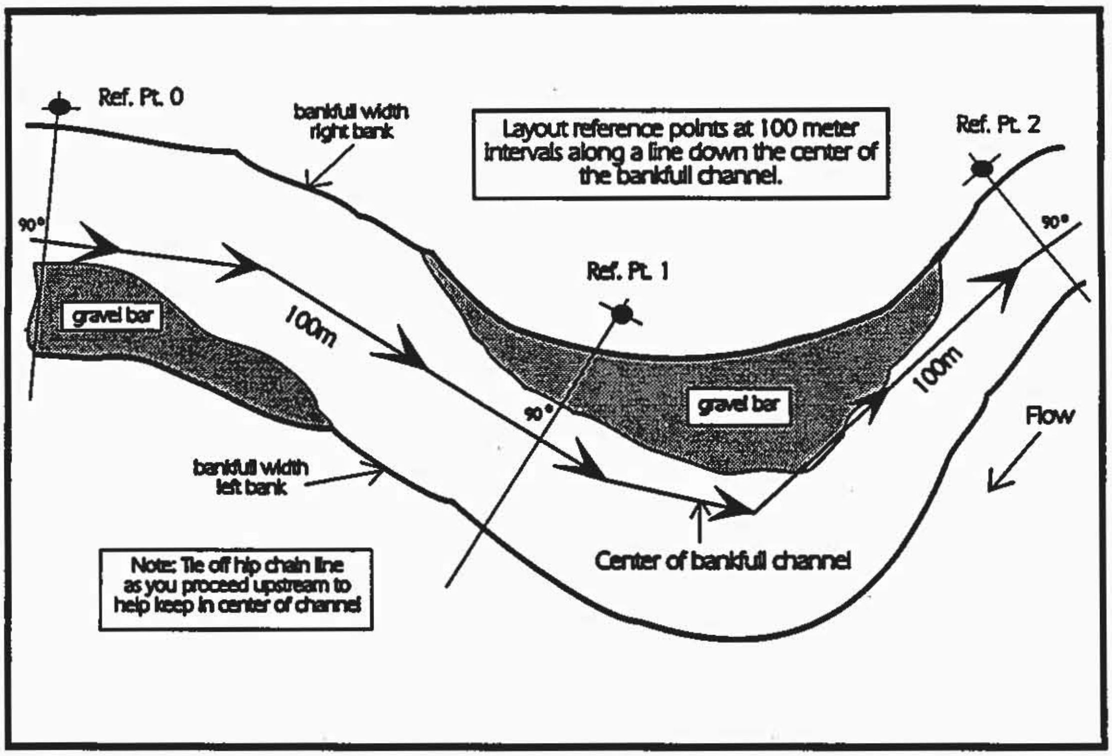
VALLEY CONFINEMENT OF CHANNEL						
VW > 10 CW UC = UNCONFINED	FS WA	MS WL FS	CS WL MS			
4 CW < VW < 10 CW LC = LOOSELY CONFINED	FS WA	MS WL SF FS	DT CS SF WL MS	DT CS WL	DT WL	
2 CW < VW < 4 CW MC = MODERATELY CONFINED	FS WA	MS SD WL FS	CS BE SD DT SF MS WL	DT CS SF WL	DT WL	DT WL
1 CW < VS < 2 CW TC = TIGHTLY CONFINED		WL	CS SD WL BE DT	CS SF WL DT	DT WL	DT WL
	< 1.0 Dune/Ripple	1.0 - 2.0 Riffle/Pool (Meandering)	2 - 4 Riffle/Pool (Obstruction)	4 - 6 Cascade	6 - 17 Step/Pool	>17

VALLEY GRADIENT (PERCENT) AND CHANNEL BED MORPHOLOGY

Timber-Fish-Wildlife
Ambient Monitoring Program

REFERENCE POINT SURVEY MODULE

July 1993



Dave Schuett-Hames
Allen Pleus
Lyman Bullchild

Northwest Indian Fisheries Commission

REFERENCE POINT SURVEY MODULE

Contents

Acknowledgements

Thanks to Jim Hatten and Jeff Light for helpful discussions concerning the methods in this module.

Manual cover design by Allen Pleus

REFERENCE POINT SURVEY MODULE

Introduction

Reference points refer to a series of permanently marked points established along the edge of the stream channel. Channel and habitat features observed during stream surveys are located and described relative to these points. Reference points are also used as systematic sampling sites for data collected at specific points along the stream channel, such as canopy closure and bankfull channel width and depth. In addition, reference points provide permanent locations from which to photograph the stream channel over time.

Purpose of the Reference Point Survey Module

The purpose of the reference point survey module is to:

1. Establish permanent, marked locations along the channel to reference channel features and information from other modules.

2. Establish discrete 100 meter reaches used to characterize segment variation and allow future sub-sampling of stream reaches.

3. Establish permanent photo-points where photographs can be taken and compared over time.

4. Collect information on bankfull width and depth.

5. Collect canopy closure information.

Reference Point Survey Methodology

The following section describes how to establish reference points, take reference photographs, determine bankfull width and depth, and take optional canopy closure measurements.

<u>Information and Equipment Needed</u>

To undertake this module you must first identify a survey segment (see the TFW Ambient Monitoring Stream Segment Identification Module). We also suggest that you secure permission from landowners adjacent to the stream and come to an agreement with them concerning appropriate techniques for marking reference points.

You will need the following equipment:

Reference point survey forms (Form 2)
Number 2 pencils
Hip chain (metric)
Steel (rebar) rods- 24" or longer
Nails- 16d (use aluminum, if available)
Masonry or rock nails
Flagging
Felt tip marker, permanent ink
Hammer
Tags, aluminum or durable plastic
Camera (suitable for use under field conditions)
Film
Fiberglass tape measures (metric, 50 or 100 meter length, depending on channel width)
Stadia rod or measuring stick (metric)
Densiometer (for canopy closure measurement)
Calculator
Field notebook
Hip boots or waders
Rain gear
First aid supplies

FIELD NOTE: Make a copy of this list and use it each time before heading off to the stream. It can ruin your day if one piece of equipment is forgotten.

Establishing Permanent Reference Points

Laying Out Reference Points

To begin establishing reference points, first locate the boundary of the stream segment, using information from the map produced during stream segment identification (see the Stream Segment Identification Module). In some cases, the map boundary may not correspond with actual field conditions. Adjust the boundary as necessary and mark the changes on the stream segment identification map.

Whenever possible, lay out and number the reference points beginning at the downstream boundary and working upstream. The first reference point, at the lower boundary of the segment, is assigned the reference point number 0. Attach one end of the tape measure, or hip chain line, in the center of the channel (midway between the banks). Proceed up the center of the channel, staying midway between the banks and following the curvature of the channel. You will not necessary be at the thalweg or even in the wetted portion of the channel at all times. The idea is to measure the length along the middle of the bankfull channel (Figure 1) because this distance should remain most constant over time.

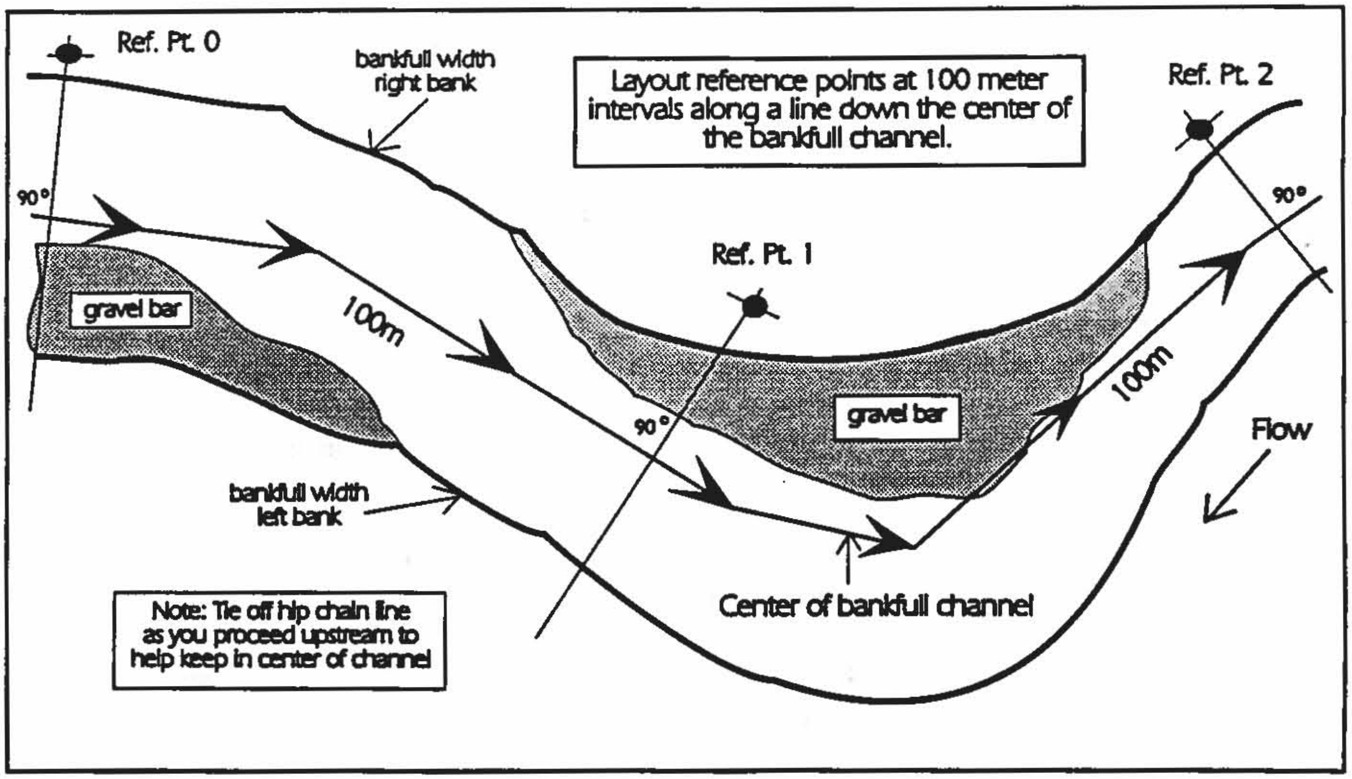


Figure 1. Measuring 100m intervals in the bankfull channel for reference point layout.

As you proceed up the channel, establish another reference point every 100 meters. The reference points should be numbered consecutively (0,1,2,3...) as you move upstream. The distance between reference points should be 100 meters, however the last one, which ends at the segment boundary, will vary in length.

Begin the numbering sequence over again at the boundary of each successive segment. Consequently, the reference point at the end of one segment and the beginning of another will have two numbers. One will correspond to the end of the sequence for the first segment, the other will be number 0 for the next segment.

Tagging and Marking Reference Points

The reference point markers should be placed far enough back from the edge of the channel so they will not be washed out by floods or bank erosion. Place them at least three meters from the bank. More distance may be necessary in locations where extensive bank erosion, braiding or channel migration is occurring.

Three methods are commonly used to permanently mark reference points; nailing a tag into a tree, pounding a steel 'rebar' rod into the ground and attaching a tag, or affixing a tag to a bedrock canyon wall with masonry nails. If there is a large, sturdy tree at the proper location, attaching the tag with a nail is the easiest option. You should have landowner permission to nail tags to trees. Use aluminum nails if possible to minimize potential hazards for loggers and sawyers in the future. The tags should be placed and flagged so they are readily visible from the stream. Trees should be stable and firmly rooted. Those leaning over, or being undercut by the stream are not good prospects for reference points.

Steel "rebar" rods make good reference points when there are no trees in the proper location, or where there are concerns about nailing tags in trees. Locate rebar rods at least three meters back from the bank; further back if the channel appears unstable. Rods should be at least 24 inches long and driven deep enough into the ground so they are difficult to pull out. They should protrude at least six inches (or more) from the ground to be visible and avoid burial, particularly in low-lying floodplain areas where active deposition occurs during floods. Rebar rods should have the tag attached with wire, and be marked with flagging. A plastic locking band would also work to attach a tag. Place flagging on nearby branches to make it easier to find the rods in the future. Finally, masonry or rock nails can be used to attach tags to the walls in bedrock canyons, or bridge abutments, where the other techniques are not possible.

Tags can be of either aluminum or durable plastic. Tags should identify the program (TFW Ambient Monitoring), the segment, and the reference point number.

To aid in locating reference points in the future, keep detailed notes on the type of marker and the distance from the edge of the bank and nearby trees.

Taking Photographs

Photographs should be taken from the center of the channel at each reference point. The first photograph should be taken looking downstream, the second looking upstream. Note the roll and frame number for each shot. Use the first frame of each roll to photograph a sheet of paper with the roll number, segment and date (Figure 2). Streams with dense canopy cover have low light conditions so we recommend using a film with an ASA of 200 or 400.

Figure 2. Allen Pleus with example of information sheet for film identification purposes. Photo by Greg Poels.

Bankfull Width and Depth

The width and depth of a stream channel reflect the discharge and sediment load the channel receives, and must convey, from its drainage area. Channels are formed during peak flow events, and channel dimensions typically reflect hydraulic conditions during bankfull (channel-forming) flows.

Bankfull width and bankfull depth refer to the width and average depth of the channel at bankfull flow. These dimensions are related to discharge at the channel-forming flow, and can be used to characterize the relative size of the stream channel. In addition, the ratio of bankfull width to bankfull depth (the width:depth ratio) of a stream channel provides information on channel morphology. Width:depth ratio is related to bankfull discharge, sediment load, and the resistance of the banks to erosion (Richards, 1982). For example, channels with large amounts of bedload and sandy, cohesionless banks are typically wide and shallow, while channels with suspended sediment loads and silty erosion-resistant banks are usually deep and narrow. Changes in width:depth ratio indicate morphologic adjustment in response to alteration of one of the controlling factors (Schumm, 1977).

Identifying the Boundaries of the Bankfull Channel

To measure bankfull width and depth, you must first determine the edge of the bankfull channel. Unfortunately, the boundaries of the bankfull channel are not always easy to identify. Geomorphologists have used many methods to delineate the bankfull channel. None are without shortcomings, and the most accurate methods are not feasible for stream surveys on remote and ungaged stream reaches because they require long-term discharge records or the use of surveying techniques (Williams, 1978).

The TFW Ambient Monitoring Program uses a combination of indicators developed by Dunne and Leopold (1978) to delineate the bankfull channels. The indicators include floodplain level, the shape of the bank, and changes in vegetation.

Floodplain indicators- In channels with natural (un-diked) riparian areas and a low, flat floodplain, the boundary of the bankfull channel corresponds with the top of the low bank between the active channel and the floodplain (Figure 3). The floodplain must be frequently flooded, i.e., during floods with a recurrence interval of approximately 1.5 - 2 years.

In many streams in forested parts of the state, frequently inundated floodplains are often absent, particularly when the channel is confined between steep hillslopes or is incised into an elevated terrace deposit that is not frequently flooded. This indicator is also not appropriate for streams that have been artificially diked or channelized.

Vegetative indicators- The bankfull channel boundary is often marked by a distinct demarcation line in the vegetation between lower areas that are either bare or have aquatic vegetation, and higher areas vegetated with perennial vegetation such as shrubs, grasses or trees. In boulder or bedrock confined channels, it may be marked by the line between bare rock and moss. Unfortunately, the vegetation line changes over time, retreating due to disturbance during large peak flow events, and advancing durng periods between floods.

Identifying the bankfull channel boundary using vegetative indicators requires caution. The vegetation line can be deceptively low when moisture-tolerant species are present. Reed canary-grass, willow and sedges are examples of plants that may actively invade and colonize areas within the bankfull channel. When using vegetative indicators, use only perennial vegetation greater than 1 meter in height of species that do not invade the active channel.

Other situations- Sometimes it may be possible to identify the height of the bankfull channel on one side of the channel but not the other. For example, this occurs when there is a low floodplain with vegetative indicators on one side of the stream and a steep, eroding bank on the other. In these cases, extend a level line horizonally across the channel from the side with good indicators to determine bankfull height on the side lacking indicators.

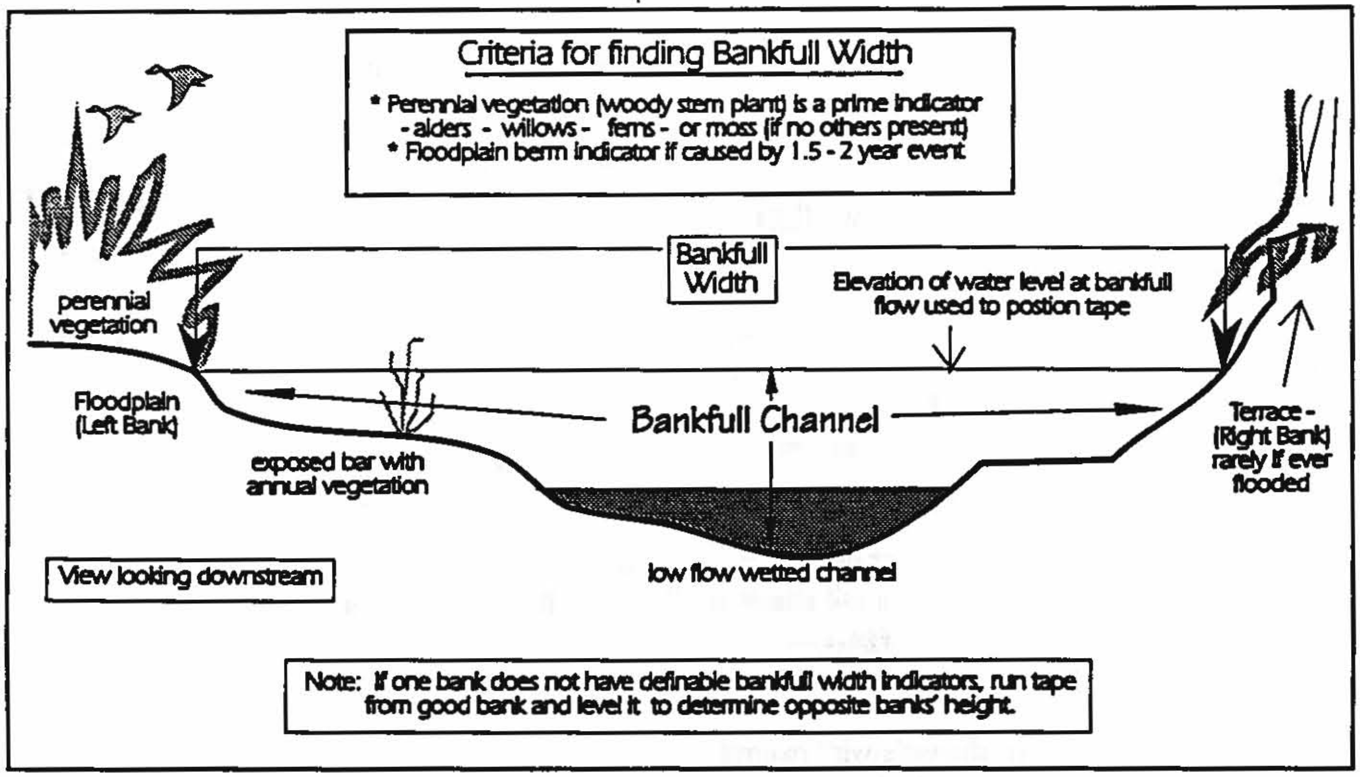


Figure 3. Determining the bankfull width of channels.

One of the most difficult situations is encountered in stream reaches where large gravel bars have been deposited by floods. It can be very difficult to determine if the tops of newly deposited bars protrude above the level of the bankfull channel. Vegetative indicators are unreliable because riparian vegetation is often disturbed during large storm events and revegetation of bars with perennial vegetation may take many years. In these cases, examine the margins of the channel for perennial riparian vegetation and extend a horizonal line across the channel to determine if the bar tops are above or below the bankfull level. If you are still in doubt after doing this, include the area within the bankfull channel.

In other cases, physical obstructions such as debris jams, undercut banks, or complete lack of indicators may make determination or measurement of bankfull dimensions impossible at the reference point. In these cases, take the measurement at the nearest place where it is feasible.

Taking Bankfull Width and Depth Measurements

To measure bankfull width, securely attach the end of the fiberglass tape measure at one boundary of the bankfull channel. Extend the tape across the channel to the other boundary of the bankfull channel. This distance is the bankfull width. If a side-channel is present. add the bankfull width of the side-channel to that of the main channel.

While the tape is stretched between these two points, determine the average bankfull depth. Bankfull depth measurements are taken at regular intervals across the stream channel. The number of measurements, and distance between them, depends on the width of the channel (Figure 4). Take

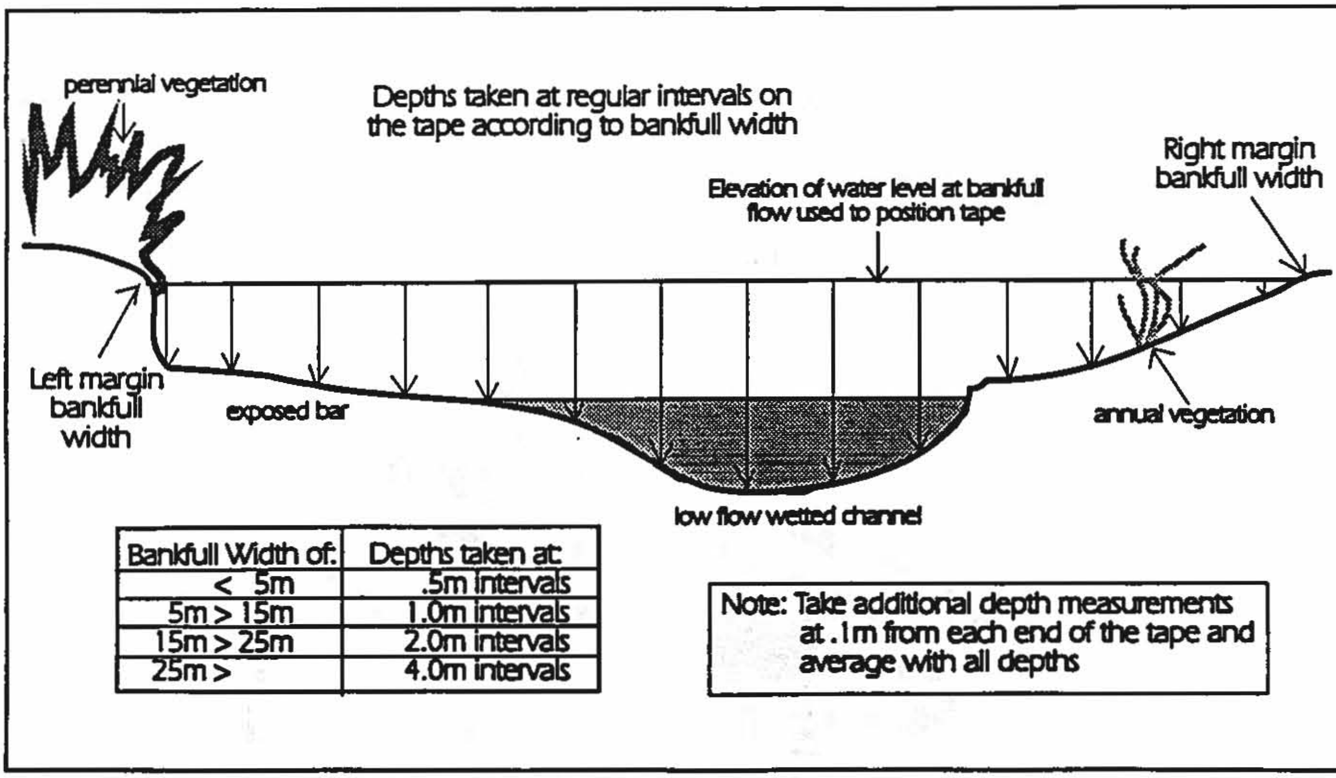


Figure 4. Measuring bankfull depth.

measurements at 0.5 meter intervals in channels less than 5 meters in width, at 1 meter intervals in channels between 5 and 15 meters in width, at 2 meter intervals for channels between 15 and 25 meters, and every 4 meters in channels greater than 25 meters in width. In addition, take an initial measurement 0.1 meter out from the starting point, and 0.1 meter before the endpoint.

Bankfull depth is the distance from the **channel bed** to the estimated water surface elevation at bankfull flow, represented by a tape stretched horizontally between the bankfull boundaries. The depth of water at the time of the survey, or its absence, does not affect this measurement. The sum of all depth measurements are then divided by the number of measurements taken to compute average bankfull depth.

Canopy Closure Measurement

Canopy closure measurement are taken at every reference point. To measure canopy closure, stand in the middle of the wetted portion of the channel and take four readings with the densiometer. Begin with a reading facing directly downstream. Turn clockwise 90 degrees and take a reading facing the right bank. Turn another 90 degrees clockwise and take a reading facing upstream, and finally turn clockwise another 90 degrees and take a reading facing the left bank.

To take a densiometer reading, hold the densiometer 12-18" in front of you at elbow height. Use the circular bubble-level to ensure that it is level. Look down on the surface of the densiometer, which has 24 squares etched into its reflective face. The reflection of your head should be just outside the grid. Imagine that each square is sub-divided into four additional squares, so that there are 96 smaller quarter-squares. Envision a dot in the center of each quarter-square. Count the total number of quarter-square dots covered by the reflection of vegetation (Figure 5). You may want to read the numbers to your partner who can record them in a notebook or a calculator. Multiply the number of quarter-square dots obscured with vegetation by 1.04 to determine percentage of canopy closure. Record this figure in your field notebook and proceed with readings in the other three directions.

When readings have been taken in all four directions. compute the average percentage of canopy closure at the reference point. Sum the percent canopy closure readings for each of the four directions and divide by four.

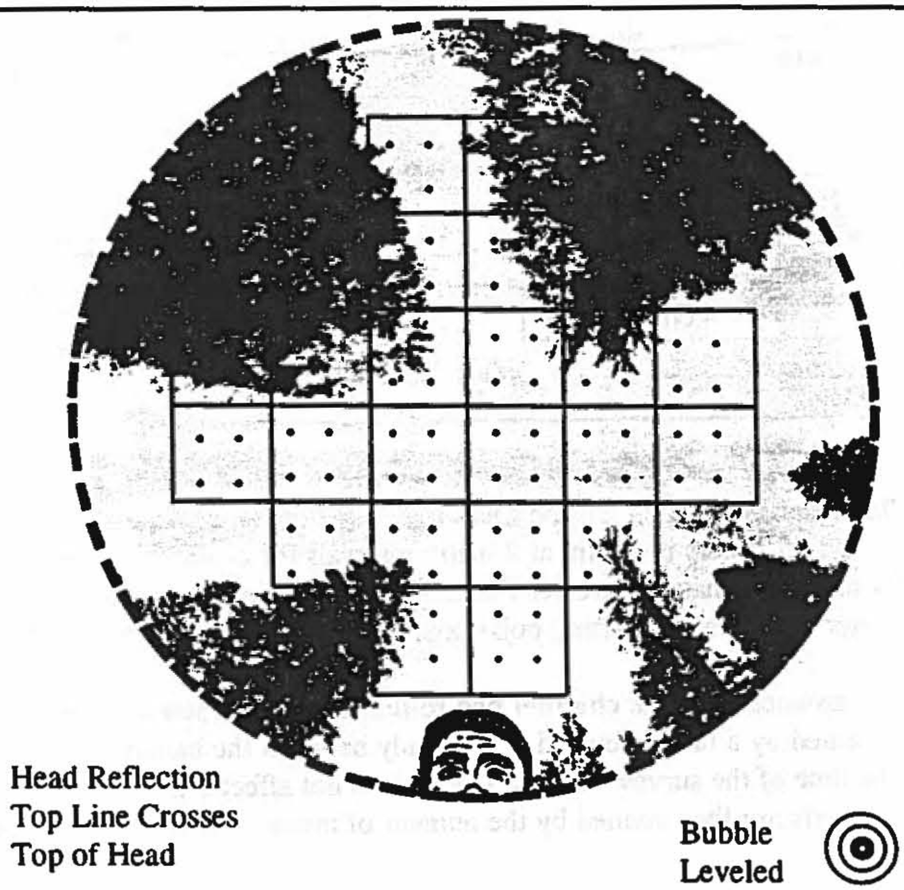


Figure 5. View into a convex spherical densiometer showing placement of head reflection and bubble level. Visualize four equi-spaced dots in each square and count the number covered by vegetation. Note: Concave densiometers are also available.

If more than one channel is present at the site, take a canopy closure measurement in the main channel and each side channel (e.g., main channel = 75%, side channel A = 85%, side channel B = 95%.) Next, measure the wetted width of each channel and then divide the wetted width of each channel by the sum of the wetted width of all the channels to determine the percentage of the total width provided by each channel (main channel = 85%, side channel A = 10%, and side channel B = 5% of the wetted width.) Multiply the canopy closure measurement for each channel by its respective percentage of the total channel width (main channel: 75 X .85 = 63.8 , side channel A: 85 X .10 = 8.5 , and side channel B: 95 X .05 = 4.8.) Finally, sum these measurements to determine the average canopy closure at the refererence point (63.8 + 8.5 + 4.8 = $\boxed{77\%}$ adjusted canopy closure.) Record this number on Form 2.

Filling Out the Reference Point Survey Form

Two options are available for recording information collected in the Reference Point Survey. Use the regular Reference Point Survey Form 2 (Appendix A) to record your data if you want to enter it by hand into the database. Use the scannable version Form 2 (Appendix B) to record your data if you want to scan the data directly into the database. The following section describes how to record data on this form.

Background information - Record the stream name, WRIA and segment number, gradient/ confinement category and beginning and ending rivermiles. Note the date of the survey on each form. Begin a new form at the start of each day. Number the sheets sequentially for the entire segment, e.g., 1 of 10, 2 of 10 and so forth.

Reference point number - Record the number of each reference point in this column, beginning with reference point #0 at the lower boundary of the segment. Note if the tag was placed on the left bank, right bank, or both (right and left bank are always determined looking downstream.)

Cumulative distance - Record the cumulative distance (in meters) from the lower boundary to each successive reference point. For instance, when the reference points are laid out at 100 meter intervals, the cumulative distance to reference point #0 would be 0 meters, to reference point #1 would be 100 meters, to reference point #2 would be 200 meters, and so forth. If one or more of the reference points are not laid out at 100 meter intervals, record the actual cumulative distance.

Photographs - Record the roll and frame number for both the upstream and downstream photographs.

Bankfull width - Record the bankfull width measurement at each reference point to the nearest tenth of a meter.

Bankfull depth - Record the average bankfull depth, computed by adding together the individual bankfull depth measurements and dividing by the number of measurements taken (see measuring bankfull width and depth, above).

Canopy closure - Record the average percentage of canopy closure (sky obscured by vegetation). This the average of the readings taken in each of four directions (see canopy closure measurement, above).

Data Processing and Analysis

After data has been hand entered (by the cooperator) or scanned into the database, it is error checked. Then, reference point survey information is summarized in the Stream Segment Summary Report (Appendix C). This report provides information including: average bankfull width, average bankfull depth, width/depth ratio and average percent canopy closure. In addition, cooperators receive a copy of the database on floppy disk for their use. Data is also stored in a statewide database at NWIFC for future TFW-related use.

Training, Field Assistance and Quality Control

This manual is intended as a reference for those collecting monitoring information using the TFW Ambient Monitoring Program Reference Point Survey Module. Because of the difficulty in relying solely on a manual to learn and implement monitoring methodologies, the TFW Ambient Monitoring Program offers formal training sessions and informal field assistance visits to help cooperators learn and implement the methodologies.

In addition, the Ambient Monitoring Program also provides a quality control service that involves having an experienced crew perform replicate surveys for cooperators. The purpose of these surveys is to identify and correct inconsistencies in application of the methods and to provide documentation that data is being collected in a replicable and consistent manner throughout the state.

We encourage cooperators to utilize these services. Please contact the Northwest Indian Fisheries Commission (1-206-438-1180) for more information concerning the TFW Ambient Monitoring Program.

References

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Co. New York.

Richards, K. 1982. Rivers: form and process in alluvial channels. Methuen. New York.

Schumm, S.A. 1977. The fluvial system. Wiley-Interscience. New York.

APPENDIXES

Appendix A
Reference Point Survey Form 2 - hand entry

Appendix B
Reference Point Survey Form 2 - scan entry

Appendix C
Stream Segment Summary Report sample

SEGMENT SUMMARY

FORM 1

TFW - N.W.I.F.C.
Ambient Stream Monitoring 1993

Version 7/10 AP

Page ____ of ____

DATE __/__/__ STREAM NAME	CONFINEMENT/ GRADIENT		W.R.I.A. NUMBER			STREAM ORDER	SURVEYORS/ AFFILIATIONS				IMPORTANT ! Fill out FORM 1: 1ea. per segment. If additional FORM 2's (REP. PT. SURVEY) are necessary - use same temp. form and fill in Form 1 categories: Page; Date; Stream Name; Conf/Grad; &W.R.I.A. #
O Creek O River	T/M/L/U	Cat.1-6	O Unlisted	Trib.	Seg #	1 - 7	Caller		Recorder		
				O O LB RB			S1	A1	S2	A2	

LOWER BOUNDARY LOCATION	ELEVATION	PHOTOGRAPHS	REFERENCE POINT	RIVER MILE	LATITUDE / LONGITUDE	FIELD NOTES:
TOWN, RNG, SEC, 1/4, of 1/4	O feet O meters	YR, ROLL, BEG FR. #	O O LB RB			
		9				

UPPER BOUNDARY LOCATION	ELEVATION	PHOTOGRAPHS	REFERENCE POINT	RIVER MILE	LATITUDE / LONGITUDE
TOWN, RNG, SEC, 1/4, of 1/4	O feet O meters	YR, ROLL, END FR. #	O O LB RB		
		9			

REFERENCE POINT SURVEY

FORM 2

TEMPORARY FORM

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
		upstrm frame	dwnstrm frame	WIDTH	DEPTH		
O O LB RB						%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
		upstrm frame	dwnstrm frame	WIDTH	DEPTH		
O O LB RB						%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
		upstrm frame	dwnstrm frame	WIDTH	DEPTH		
O O LB RB						%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
		upstrm frame	dwnstrm frame	WIDTH	DEPTH		
O O LB RB						%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL		BANKFULL (meters)		CANOPY CLOSURE	FIELD NOTES:
		upstrm frame	dwnstrm frame	WIDTH	DEPTH		
O O LB RB						%	

APPENDIX A

REFERENCE POINT SURVEY

FORM 2 (cont.)

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

REFERENCE POINT	CUMULATIVE DISTANCE (meters)	PHOTOGRAPHS ROLL (upstrm frame / dwnstrm frame)	BANKFULL (meters) WIDTH / DEPTH	CANOPY CLOSURE	FIELD NOTES:
LB RB				%	

N.W.I.F.C.
6730 Martin Way E, Olympia, WA 98506
Contact:: Scott Hall (206)438-1180

TFW Ambient Monitoring

REFERENCE POINT SURVEY

FORM 2

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.	CONF./ GRAD.	W.R.I.A. NUMBER	UNLISTED TRIB	SEGMENT NUMBER	BEGINNING RIVER MILE	ENDING RIVER MILE
			○ UNLISTED				

REFERENCE POINTS "n"	REFERENCE POINTS "n + 1"	CUMULATIVE DISTANCE (m)	PHOTOGRAPHS ROLL	PHOTOGRAPHS U FRAME	PHOTOGRAPHS D FRAME	CANOPY CLOSURE	BANKFULL WIDTH	BANKFULL DEPTH
○ LEFT BANK ○ RIGHT BANK	○ LEFT BANK ○ RIGHT BANK							

REFERENCE POINTS "n + 2"	REFERENCE POINTS "n + 3"	CUMULATIVE DISTANCE (m)	PHOTOGRAPHS ROLL	PHOTOGRAPHS U FRAME	PHOTOGRAPHS D FRAME	CANOPY CLOSURE	BANKFULL WIDTH	BANKFULL DEPTH
○ LEFT BANK ○ RIGHT BANK	○ LEFT BANK ○ RIGHT BANK							

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APPENDIX B

rev. 8/92

Continue on back of form.

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

REFERENCE POINTS "n + 4"	REFERENCE POINTS "n + 5"	CUMULATIVE DISTANCE (m)	PHOTOGRAPHS ROLL	PHOTOGRAPHS U FRAME	PHOTOGRAPHS D FRAME	CANOPY CLOSURE	BANKFULL WIDTH	BANKFULL DEPTH
○ LEFT BANK ○ RIGHT BANK	○ LEFT BANK ○ RIGHT BANK							

REFERENCE POINTS "n + 6"	REFERENCE POINTS "n + 7"	CUMULATIVE DISTANCE (m)	PHOTOGRAPHS ROLL	PHOTOGRAPHS U FRAME	PHOTOGRAPHS D FRAME	CANOPY CLOSURE	BANKFULL WIDTH	BANKFULL DEPTH
○ LEFT BANK ○ RIGHT BANK	○ LEFT BANK ○ RIGHT BANK							

REFERENCE POINTS "n + 8"	REFERENCE POINTS "n + 9"	CUMULATIVE DISTANCE (m)	PHOTOGRAPHS ROLL	PHOTOGRAPHS U FRAME	PHOTOGRAPHS D FRAME	CANOPY CLOSURE	BANKFULL WIDTH	BANKFULL DEPTH
○ LEFT BANK ○ RIGHT BANK	○ LEFT BANK ○ RIGHT BANK							

APPENDIX C

TFW Ambient Monitoring Stream Segment Summary 1992

Stream Segment Identification

(FileID: CC)

Stream name: DESCHUTES R. WAU name: WAU #:
WRIA number: 13.0028 Segment number: 18
River mile: 35.3 to 36.6

Stream Segment Characteristics

Gradient category: 2	Confinement: U	Stream order: 4
Avg bankfull width: 20.2 M	Avg bankfull depth: 0.4 M	Width / depth: 46.66
Segment length: 2615.0 M	Upper elevation: 550 F	Lower elevation: 510 F

Timber-Fish-Wildlife
Ambient Monitoring Program

HABITAT UNIT SURVEY MODULE

July 1993

Dave Schuett-Hames
Allen Pleus
Lyman Bullchild

Northwest Indian Fisheries Commission

HABITAT UNIT SURVEY MODULE

Contents

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Cover, illustrations, photographs, hand entry field forms by Allen Pleus unless noted.

HABITAT UNIT SURVEY MODULE

Introduction

Hydraulic conditions such as water depth and velocity vary within stream channels. This variation often occurs in somewhat orderly patterns with distinct, alternating areas of deep water (pools) and shallow water (riffles) (Figure 1). These distinct areas are referred to as "habitat units".

Various species and life history stages of aquatic organisms have adapted to the rigors and opportunities presented by particular hydraulic conditions. Consequently, they are more likely to be found in particular habitat units (Bisson et al., 1982). The type and amount of habitat units present in a stream reach can be used as an indicator of its suitability for a particular species or life history stage.

Figure 1. Lyman Bullchild (foreground) and Joe Apfel measuring the length of a riffle unit. West Fork Teanaway Creek. 1991.

Intrinsic factors such as stream size, gradient and confinement influence the type and relative abundance of habitat units found in a particular reach (Beechie and Sibley, 1990). In addition, the relative abundance and characteristics of various habitat units responds to changes in local- and watershed-scale processes that determine sediment supply, runoff during storm events and recruitment of large woody debris. These processes and their inputs may be altered by human activities such as forest practices and by changing natural conditions.

Because the utilization of instream habitat varies by species, life history stage and physiographic region, no single habitat survey methodology can accurately characterize habitat conditions for all salmonids throughout the State of Washington. Instead, the habitat unit survey focuses on partitioning streams into basic morphologic features. The intent of the survey is to characterize current morphologic conditions, and to monitoring changes in the size and frequency of these units in response to changing inputs of sediment, discharge and large woody debris associated with natural or management-induced disturbance and recovery.

Purpose of the Habitat Unit Survey Module

The purpose of the habitat unit module is to:

1. Provide a means of accurately characterizing the current status of basic channel morphology at a level of precision and detail suitable for use as a foundation for monitoring.

2. Provide a replicable methodology that can be repeated over time to document changes and trends in habitat unit distribution and abundance.

3. Provide information on the percentage of pools that is suitable for use as a resource condition index in the Watershed Analysis cumulative effects assessment procedure.

The Habitat Unit Methodology

This section describes procedures for identifying and measuring the characteristics of habitat units. The habitat unit survey uses a classification system consisting of four "macro" habitat units (pools, tailouts, riffles, and cascades). The change to the four unit system from the more complex micro-habitat unit system used prior to 1992 was made to improve observer recognition of units and to improve our ability to replicate surveys. See Ralph et al. (1991) for a discussion of replication problems with the micro-habitat system.

Please record all measurements in metric units to reduce confusion and streamline data processing. The decision to use metric units was made because most scientific studies used for comparison and interpretation of monitoring data are reported in metric units.

Information and Equipment Needed

In order to complete the habitat unit survey, it is necessary to have previously identified a stream segment to survey (see the Stream Segment Identification Module). It is also necessary to have established reference points (see the Reference Point Survey Module) so the habitat units can be associated with a permanent reference location. In addition, you will need to know the average bankfull width for the survey segment. To determine the average bankfull width of the segment, examine the completed reference point survey forms for the segment, sum the bankfull width measurements and divide by the number of measurements.

You will need the following equipment to conduct the survey:

Habitat unit survey forms (Form 3)
Number 2 pencils
Clip board or form holder
Fiberglass tape and/or rangefinder (metric)
Abney level or clinometer
Stadia rod (metric)
Flow meter
Wading rod for flow meter
Field notebook
Map
First aid supplies
Hip boots or waders

Discharge

The surface area of the wetted channel and individual habitat units changes with discharge, so measurements are affected by the amount of water flowing in the channel at the time of the survey. The Habitat Unit Survey methodology is designed to be applied during relatively stable flow conditions characteristic of the summer low flow period. Surveys should not be conducted during periods of high water associated with summer storms, during extreme low base-flow conditions when sections of typically perennial streams are dry, or during periods of rapidly fluctuating discharge.

Discharge should be measured at the time you begin to survey each segment and recorded on the habitat unit survey form. If discharge changes significantly during the time the segment is being surveyed, additional discharge measurements should be taken and recorded on subsequent survey forms.

In order to obtain comparable data, future surveys of the same segment should be conducted at a discharge similar to the discharge at the time of the original survey. At this time, the sensitivity of the methodology to changes in discharge has not been determined. Pending further analysis, we recommend that discharge at the time of repeat surveys be within 10% of the discharge during the original survey.

Discharge should be determined using standard streamflow measurement methods. First, select a suitable location (within the segment being surveyed) with adequate depth and smooth, laminar flow. A suitable site should not have flow diversions, side-channels, or undercut banks. Select sites relatively free of turbulence and flow obstructions such as large rocks, logs, and aquatic vegetation.

Stretch a fiberglass tape across the wetted portion of the stream channel perpendicular to the direction of flow. Attach each side of the tape securely. Note the distance on the tape corresponding to the water's edge on each side of the stream. Assemble your flow meter, attach it to the wading rod, and test it to ensure that it is working properly. A variety of flow meter designs are available that are suitable for this purpose. Operate your meter according to instructions provided by the manufacturer.

The next step is to divide the stream cross-section into cells and to measure water depth and velocity at the center of each cell (Figure 2). Cells can vary in width. The number and size of cells needed will vary depending upon the size and characteristics of the stream channel. Typically, 15-20 cells are necessary. Cells should be chosen so that the depth and velocity measurement taken at the center of the cell represents conditions throughout the cell. Cell boundaries should be placed wherever noticeable breaks or discontinuities in velocity and depth occur. No cell should have more than 10% of the total discharge. If this appears to be the case, the cell should be divided into two or more smaller cells.

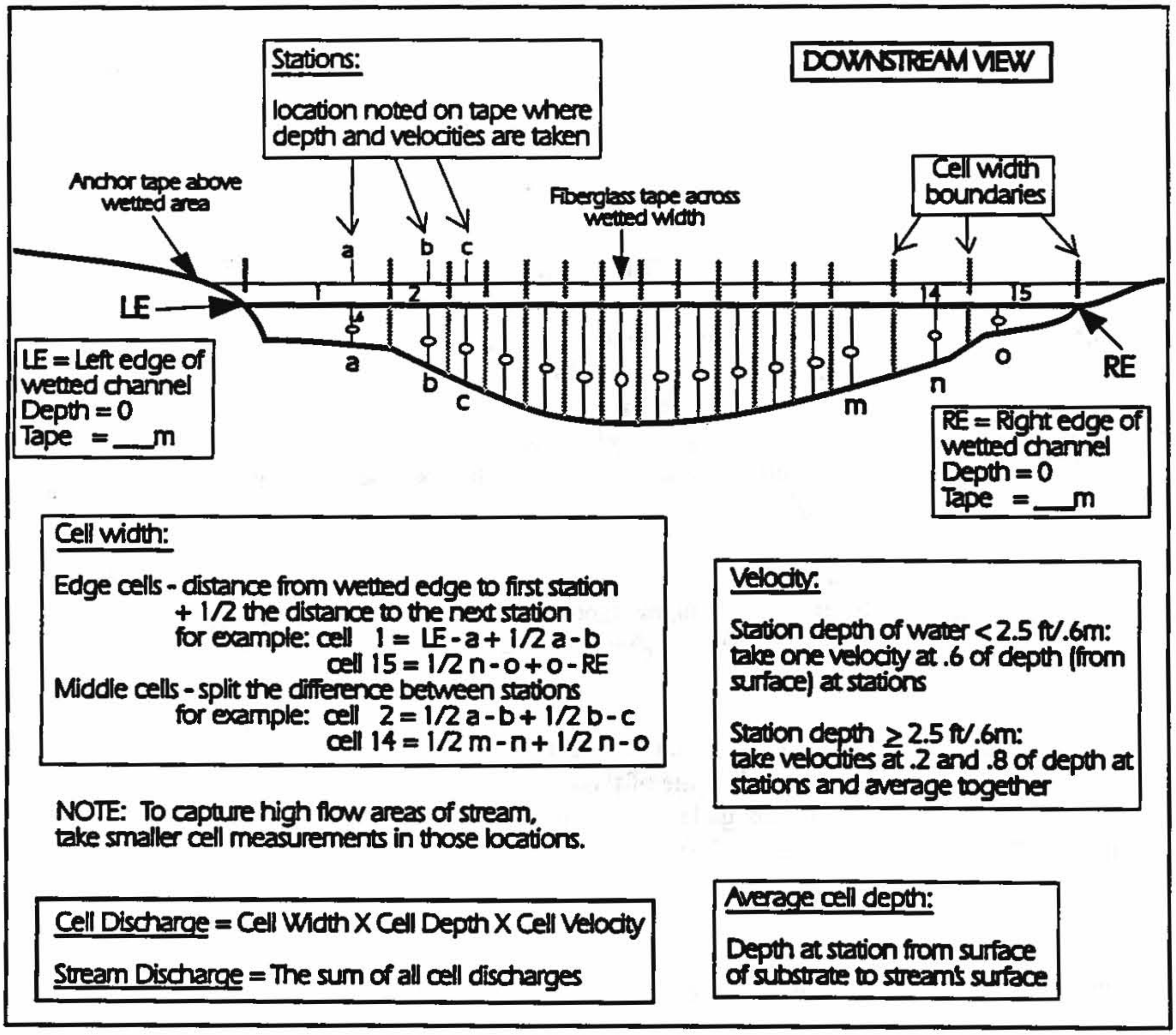

Figure 2. Discharge measurement protocol.

Place the wading rod/flow meter assembly in the center of each cell. Record the distance along the tape at each station where measurements are taken and the width of each cell. Read the water depth from the wading rod and record. Water velocities typically vary with depth, so move the meter assembly on the rod to position the flow meter at the proper depth. If the water depth is less than 2.5 feet, the meter should be placed 0.6 of the distance from the water surface to the stream bottom to properly characterize average velocity. For depths greater than 2.5 feet, two velocity measurements should be taken and averaged. These should be taken at 0.2 and 0.8 of the total depth. Measure and record the velocity in each cell.

To determine the total discharge, calculate the discharge for each cell by multiplying the cell width and water depth to find cross-sectional area. Then multiply cross-sectional area by velocity to get discharge. Sum the discharge measurements for all cells to calculate the total discharge. An example of a completed discharge measurement form is shown in Appendix A. A blank discharge measurement form that can be copied for field use is included in Appendix B. The form also contains a formula for converting cubic feet/second to cubic meters/second.

Identification of Habitat Units

The first step in this procedure is to determine the type of habitat units present (Figure 3). Wetted portions of the main channel and side channels where water is present are assigned to one of four habitat unit types, pool (**P**), tailout (**T**), riffle (**R**) or cascade (**C**). When portions of the channel are not visible, for example when it passes under a massive debris jam or through a long culvert, it is designated obscured (**O**). If it dissipates into a wetland without a distinct channel, it should be designated as a wetland (**W**). If the main channel is dry it should be designated as sub-surface flow (**S**).

Habitat Units		
Pool	=	**P**
Tailout	=	**T**
Riffle	=	**R**
Cascade	=	**C**
Obscured	=	**O**
Wetland	=	**W**
Sub-Surface Flow	=	**S**

Figure 3. List of Habitat Units and single letter codes.

To qualify as a pool, tailout, riffle or cascade, a potential unit must meet a minimum size criteria. The minimum size requirement for a habitat unit varies with channel size, expressed as bankfull width (Table 1). Areas that do not meet the minimum size criteria should be combined with the most similar adjacent unit.

The purpose of the minimum unit size criteria is to provide guidance on when it is appropriate to lump or split small units, in order to improve consistency between observers who tend to lump units and those who tend to split.

Table 1. Minimum unit size by channel bankfull width.

Channel Bankfull width (meters)	Minimum unit size (square meters)
0 - 2.5	0.5
2.5 - 5	1.0
5 - 10	2.0
10 - 15	3.0
15 - 20	4.0
> 20	5.0

Characteristics of Habitat Units

Once the minimum size criteria is met, pools, tailouts, riffles and cascades are distinguished on the basis of depth and gradient characteristics.

Pools- Pools are areas of deep water with low water surface gradients (typically less than 1 %). They are typically created by scour adjacent to obstructions or impoundment of water behind channel blockages and hydraulic controls such as logjams, bedforms or beaver dams. To qualify as a pool, a unit must meet a minimum residual depth requirement that increases with increasing channel width.

Tailouts- Tailouts are areas of moderately shallow water with an even, laminar flow and a lack of pronounced surface turbulence. They are situated on the downstream end of pools, in the transitional area between the pool and the head of the downstream riffle. These units provide deposition sites for fine bedload materials (Lisle 1982). They have a flat, smooth bottom, lacking the scour typically associated with the pool. Because they are located on the upstream side of the riffle crest, they lack the velocity and surface turbulence associated with riffles or cascades located on the downstream slope of the riffle crest. Tailouts are most commonly found in larger, low-gradient channels associated with elongated pools with well-sorted substrate. They are uncommon in small, high-gradient streams with coarse substrate.

Riffles- Riffles are shallow, low gradient areas that do not meet the residual pool depth requirement. They are distinguished from cascades by having a water surface gradient of less than 3.5 percent. Although many riffles exhibit surface turbulence associated with increased velocity and shallow water depth over gravel or cobble beds, the riffle classification also includes shallow areas without surface turbulence that do not meet the minimum pool depth requirement.

Cascades- Cascades are steep areas with a water surface gradient exceeding 3.5 percent. Some cascades are very short and smooth, such as slip-face cascades located on the downstream faces of channel bars or bedrock outcrops. Step-pool cascades occur where boulder or cobble substrate forms stair-steps. They often are very turbulent, and have numerous small pools associated with the cobble/boulder steps.

Using Minimum Residual Pool Depth to Distinguish Pools

Although some pools are quite distinct, in many cases it is difficult to differentiate shallow pools from deep glides or riffles. Considerable divergence occurs in habitat calls made by experienced observers in these situations. To eliminate this problem and provide consistent, replicable survey results, a criteria for minimum residual pool depth has been established. A pool must exceed a minimum residual pool depth criteria that corresponds with channel size, expressed as bankfull width (Table 2).

Table 2. Minimum residual depth criteria for pools by channel bankfull width.

Channel Bankfull width (meters)	Minimum Residual Pool depth (meters)
0 - 2.5	0.10
2.5 - 5	0.20
5 - 10	0.25
10 - 15	0.30
15 - 20	0.35
> 20	0.40

To determine if a potential unit qualifies as a pool, take a residual depth measurement (see section on determining residual pool depth, below), and compare with the minimum value for the appropriate channel size using the average bankfull width computed from the reference point survey form.

If the minimum residual depth requirement is met, the next step is to establish the boundaries of the pool unit and determine if the potential pool meets the minimum unit size requirement. In most cases, pool boundaries extend laterally to the waters edge. However, if there is a distinct riffle or cascade unit adjacent to the pool that meets the minimum unit size criteria, it should be treated as a separate, adjacent unit.

Delineating the upstream and downstream boundaries of pools can be difficult. The variety of situations encountered make a single criteria impractical. Often, the upstream or downstream boundary of a pool is distinguished by a change in water surface gradient. Look for a distinct break between the steeper adjoining riffle or cascade and the nearly flat water surface of the pool.

Distinguishing Tailouts

Once a pool has been identified, the next step is to determine if a tailout unit is present at its lower end. Often, a gradual increase in velocity and decrease in depth occurs in a transitional tailout area below larger, elongated pools. In these situations, the boundary between the pool and the tailout is delineated by examining the bedform of the channel and determining the downstream extent of distinct streambed scour. Where the cross-sectional profile of the bed becomes even and flat, the downstream boundary of the pool has been reached. The area below this boundary is designated as a tailout (Figure 4). The tailout extends downstream to the riffle crest, where the water increases in velocity as it flows down the downstream slope of the bar. This boundary is typically distinguished by surface turbulence associated with the riffle or cascade. Many pools, particularly smaller pools in moderate to high gradient channels, do not have distinct tailouts because the zone of scour extends to the riffle crest. In these cases, extend the pool unit to the riffle crest and do not delineate a tailout unit.

Distinguishing Riffles from Cascades

For the purposes of this survey, areas that do not meet the criteria for pools or tailouts are classified as either riffles or cascades. Riffles and cascades are distinguished on the basis of water surface gradient. Riffles have water surface gradients less than 3.5 percent; cascades have gradients equal to or greater than 3.5 percent.

To measure the water surface gradient of a potential riffle or cascade, observers are positioned at the upstream and downstream boundaries of the potential habitat unit. One person stands at water's edge, with the bottom of their boots at the water surface level, and sights through a hand-held Abney level or clinometer at a stadia rod held with its base at the water surface by the person at the other end of the unit. The Abney level or clinometer is sighted at a point on the stadia rod equal to the observers eye-level and the gradient is read from the instrument (follow manufacturer's instructions).

To identify the boundary between a riffle and cascade, look for a distinct gradient break, where one side is less than 3.5 percent water surface gradient and the other is 3.5 percent or greater.

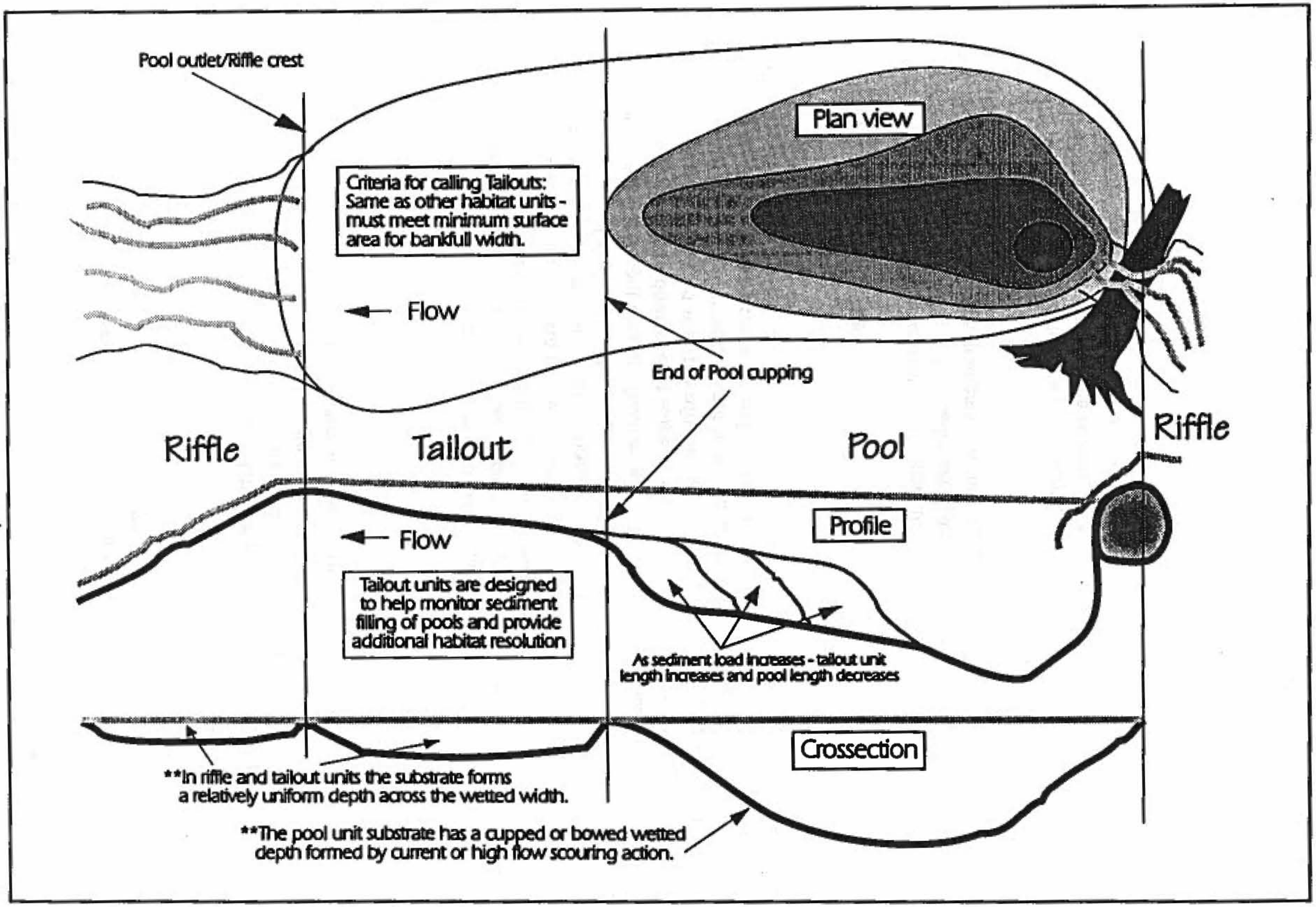

Figure 4. Criteria for Pools and Tailouts.

Distinguishing Small Pools and Riffles within Cascades

Cascades with boulder/cobble stair-steps (step-pool cascades) often contain numerous small pools and occasional riffles, posing the question of whether to split them out as separate units (Figure 5). These small pools and riffles should be examined and classified as separate units if they meet the appropriate minimum unit size requirement (Table 1) and, for pools, the residual pool depth requirement (Table 2). Small pools that occur within riffles should be treated in the same manner. Although the minimum unit size requirement occasionally forces the observer to combine small, distinct areas with adjacent units, using these criteria will improve the repeatability of surveys performed by different observers over time.

Figure 5. Example of small pool unit within a cascade on Willaby Creek.

Sub-Surface Flow, Obscured and Wetland Units

Occasionally, stream reaches will alternate between wet and dry areas, or be completely dry. If the stream is dry because of extreme low flow associated with drought, it is not an appropriate time to conduct a habitat unit survey because the information generated will not be useful for comparative purposes. On the other hand, if intermittent flow is a typical low flow condition, or if it appears to be resulting from changing conditions such as coarse sediment aggradation, then documenting its occurrence is useful.

When intermittent dry areas are encountered in the main channel, they are recorded as sub-surface flow units. Only main channel sub-surface flow areas are counted and recorded, dry side-channels and dry secondary units are not recorded.

Sometimes it is impossible to see habitat units where the stream runs through culverts, or under logjams and piles of debris. When habitat units cannot be seen, record the habitat unit as obscured (**O**). In other cases, the stream channel may spread out into a wetland and become indistinguishable. In these cases, record the habitat unit as wetland (**W**).

Channel Location of Habitat Units

Habitat units are classified in one of three categories, depending on their location and relative significance within the stream channel (Figure 6). The three categories are:

Category 1- Primary units. These are the dominant units in the main channel. They occupy over 50% of the wetted channel width. At any given point along the length of the channel, there can be only one primary channel unit.

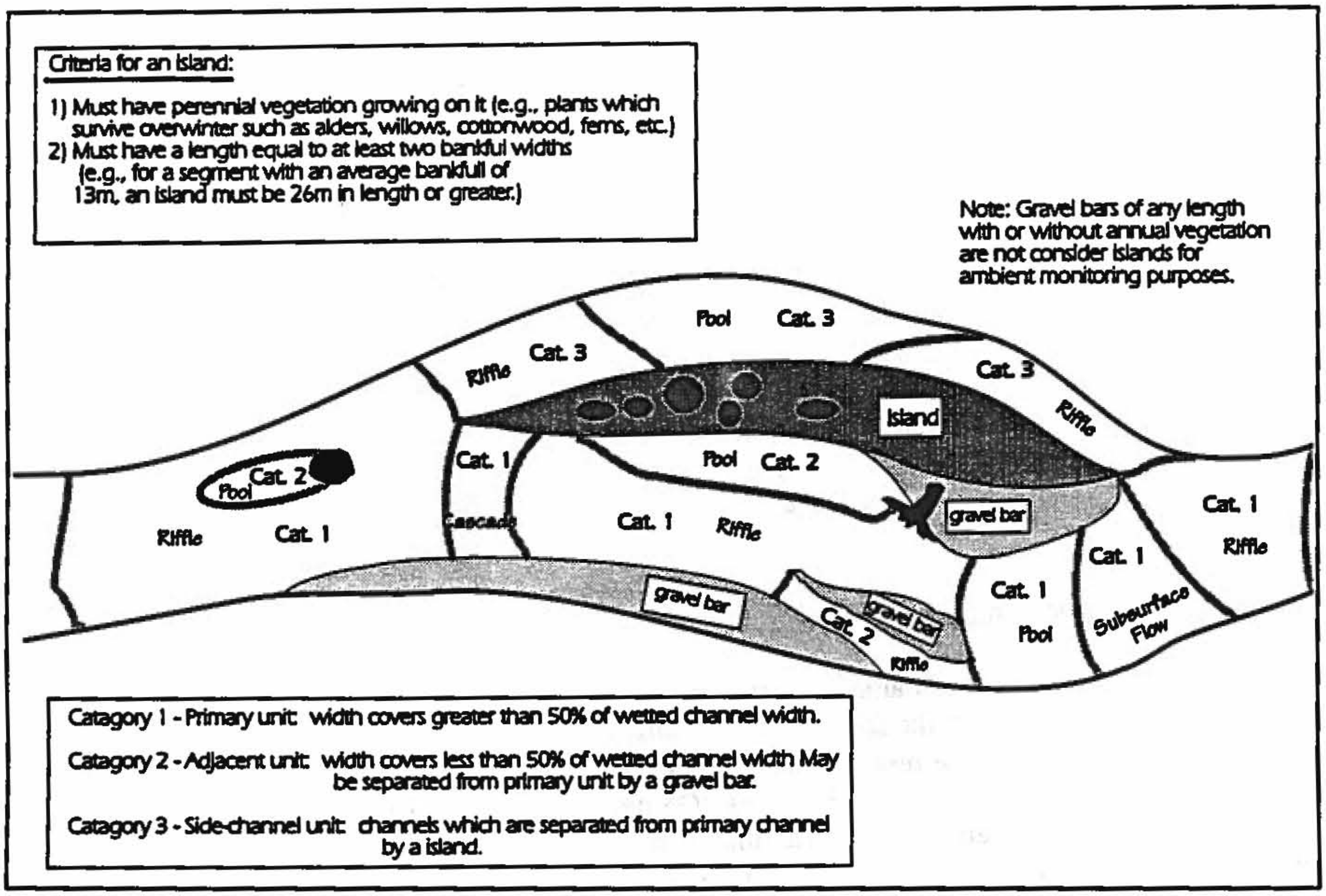

Figure 6. Habitat unit categories

Category 2- Secondary units. These are subdominant units in the main channel that occupy less than 50% of the wetted channel width. They may be either adjacent to a primary unit or lie embedded within and surrounded by a primary unit.

Category 3- Side-channel units. These are found in side-channels that are isolated from the main channel by islands. An island must: a) have a length equal to at least two bankfull widths, and b) be colonized by perennial vegetation. Units separated only by bare gravel bars are treated as adjacent units.

Information on habitat unit location allows determination of the relative abundance of side-channels and main channel habitat during summer low flow conditions.

Measuring Lengths and Widths of Habitat Units

The lengths and widths of habitat units are measured in order to compute the surface area of each habitat unit. During data analysis, the total surface area and relative percentage of each habitat type is calculated.

Measuring Lengths of Pools, Tailouts, Riffles and Cascades

Habitat unit lengths can be measured with a fiberglass tape measure, hip chain, or rangefinder. Habitat unit lengths should be measured from the boundary with the adjacent downstream unit to the boundary with the adjacent upstream unit (Figure 7).

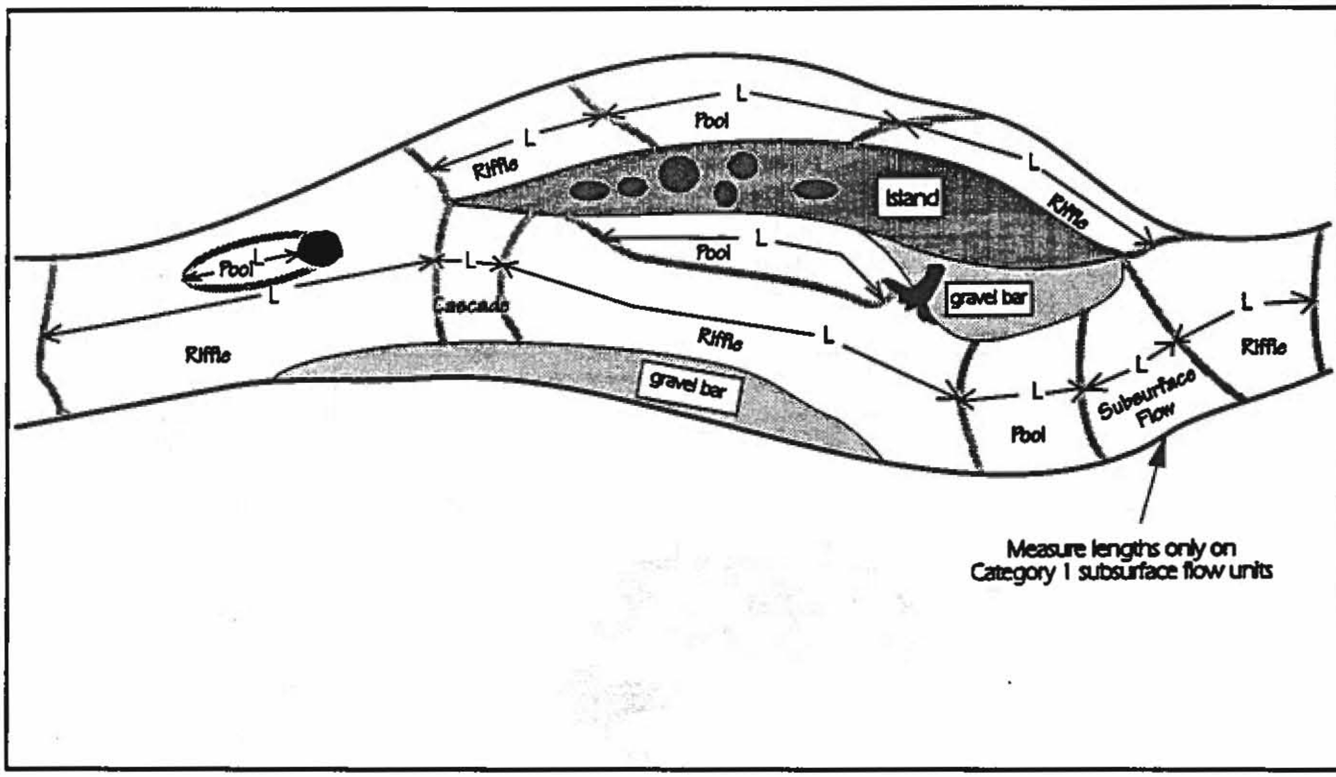

Figure 7. Measuring habitat unit lengths.

Measurements should follow the shape of the unit along the center of its width. For instance, if the unit curves around a bend, the measurement should follow the curve, rather than taking the shortest distance between the upper and lower boundary.

When the boundary between adjacent upstream and downstream units is a straight line perpendicular to the direction of flow, establishing the beginning and ending points for the length measurement is straightforward. Often the boundaries are not perpendicular to the angle of flow. In these cases, measure from a point midway along boundary between the units.

Measuring Lengths of Sub-surface Flow, Obscured and Wetland Units

In areas where the main channel goes dry (sub-surface flow units), length is recorded as the distance between upper end of the adjacent downstream wetted unit and the lower end of the next wetted unit upstream. Follow the curvature of the channel if it can be determined.

Lengths of obscured units should be measured from the point at which the channel is no longer visible to where it re-emerges into view. The length of wetland units is taken from where the channel becomes indistinguishable as it spreads out in the wetland to where it re-emerges as a distinct channel again.

Measuring Average Widths

Average widths are calculated for pool, tailout, riffle and cascade units. Average widths are not measured in sub-surface flow, obscured or wetland units.

The width of units is measured from the waters edge on one side of the stream to the waters edge on the other side, unless there are two adjacent units. Where there are two adjacent units side-by-side, measure from the edge of the stream to the boundary between the adjacent units (Figure 8). When an adjacent unit is embedded within a larger unit, subtract the width of the embedded unit from the total width to calculate the width of the larger unit.

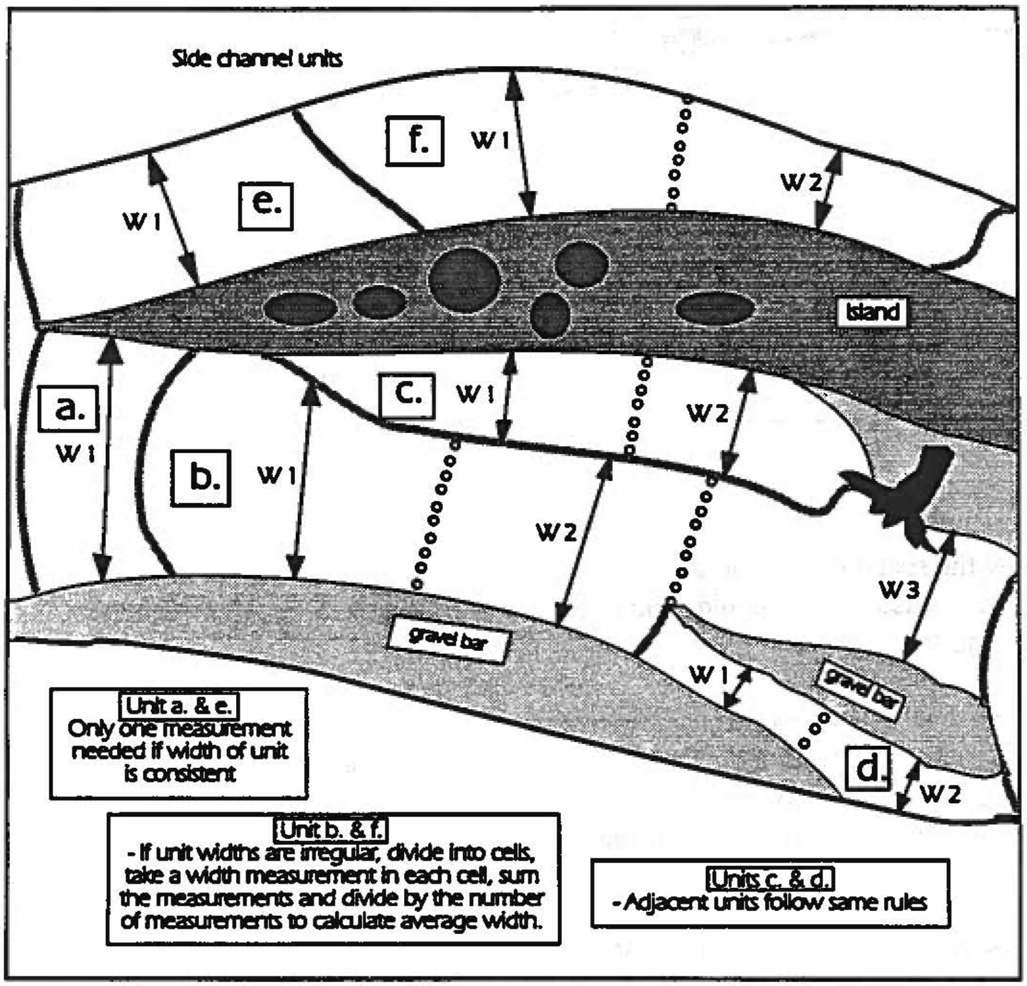

Figure 8. Measuring average habitat unit widths.

Determining the edge of the wetted channel may be difficult, particularly on the margin of gravel bars where there is water between the particles. In these cases, extend the wetted width measurement shoreward to the point where the particles are no longer completely surrounded by water and the water is restricted to isolated pockets. If a dry bar or island is present within the unit, subtract the width of the dry area when measuring width. Protruding objects such as logs or boulders are included in the width measurement.

Determine the average width of the unit. In units with a consistent width, one measurement may suffice to determine average width. Often the width of a habitat unit will vary considerably along its length. In these cases it is necessary to take multiple width measurements and compute the average width. To do this, divide the unit along its length into two or more cells of equal distance, depending on the length of the unit and the amount of variation. Take a width measurement at a representative place in each cell and record the measurements in a field notebook. Sum the width measurements and divide by the number of measurements to compute average width.

Splitting Units at Reference Points

We want to be able to separate habitat unit data into discrete 100 meter reaches separated by the reference points. This will provide an opportunity to randomly or systematically sub-sample 100 meter reaches for future monitoring, instead of re-surveying entire segments. It will also provide the opportunity to document and display variation in conditions throughout the segment in 100 meter increments.

All types and categories of habitat units, primary, secondary, side-channel and subsurface flow, should be split at reference points.

To separate the habitat unit data into 100 meter reaches, identify the units that cross reference points and split them where the reference point intersects the unit. Record separate lengths and average widths for each portion of the unit above and below the reference point boundary (Figure 9). Split units require a separate entry on the form for each portion of the habitat unit. Both entries will share the same habitat unit number, but will have different downstream reference point numbers, indicating that they are in different 100 meter reaches.

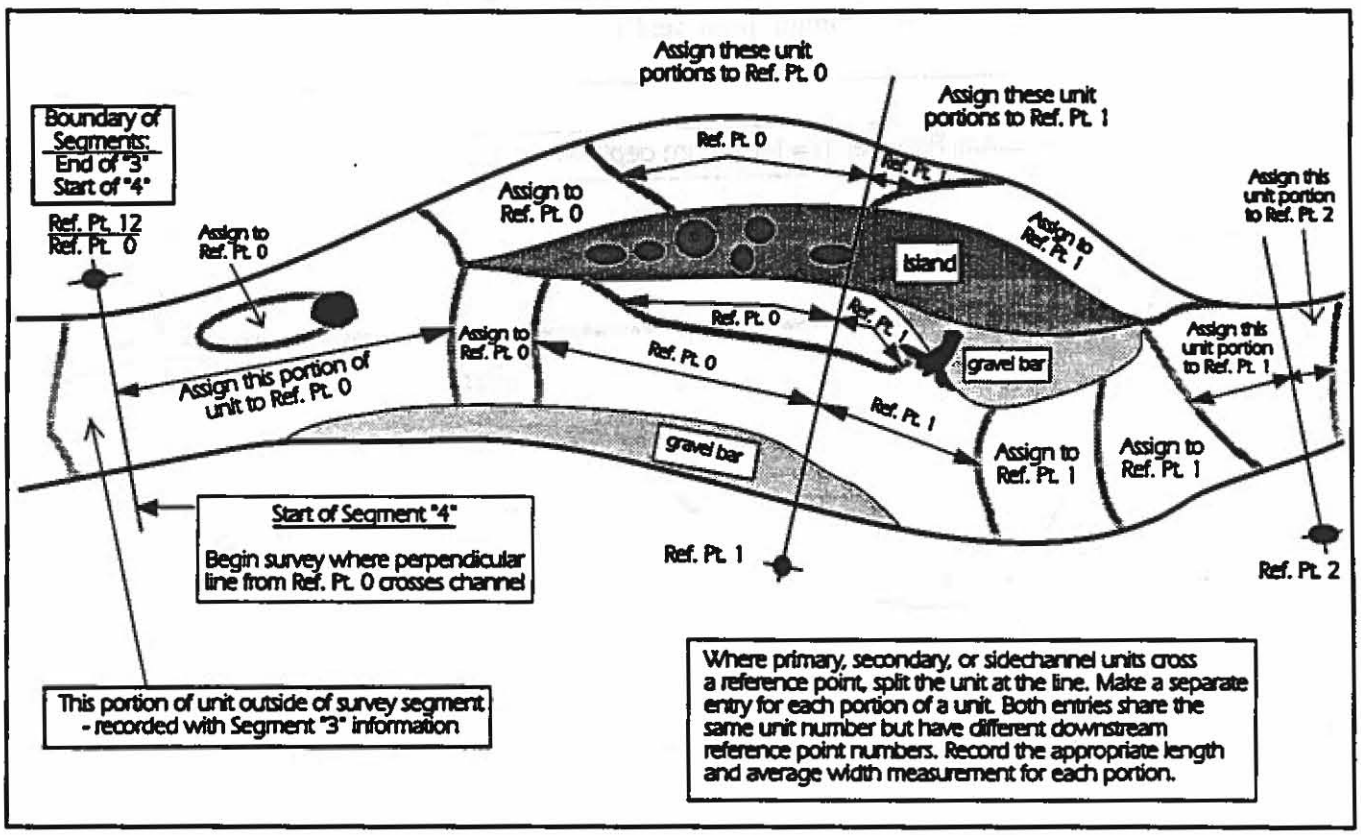

Figure 9. Splitting habitat units at reference points.

Separate lengths and average widths should be recorded for each portion of a split unit. If the unit is a pool, only one entry for maximum depth, outlet depth, and pool forming obstruction should be recorded for the entire unit.

Determining Residual Pool Depth

Residual pool depth is a discharge-independent measure of the depth of a pool relative to the height of the adjacent downstream hydraulic control structure that controls the water depth in the pool, such as a gravel bar or a log It is only measured in pool units. Residual pool depth is used as a criteria for identifying pools and as a means of monitoring the filling of pools with sediment over time.

Residual pool depth represents the difference between the elevation of the deepest point in the pool and the elevation of the crest of the bar immediately downstream. This is determined by calculating the difference between the water depth at the deepest point and the water depth on top of the downstream bar or control structure. To visualize the concept of residual pool depth, imagine what would happen if the water level dropped until it was no longer flowing over the downstream riffle, isolating the pool. The depth of the water that would remain in the pool at its deepest point would be the residual pool depth. See Lisle (1987) for a detailed discussion of residual pool depth.

To determine residual pool depth, two depth measurements are required (Figure 10). First, locate the deepest spot in the pool and measure the distance from the deepest point to the surface of the water. This measurement is the maximum pool depth.

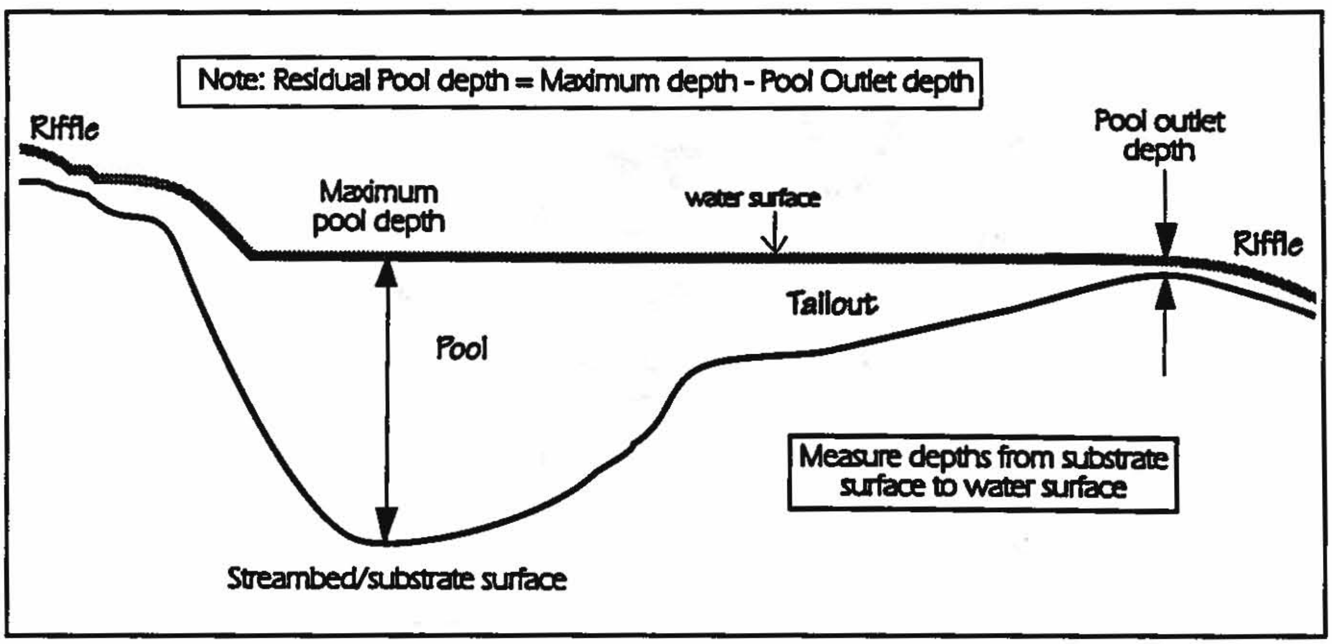

Figure 10. Measuring maximum pool depth and depth of pool outlet.

Next, locate the downstream riffle crest, the point at the outlet of the pool that forms the dam and controls the release of water from the pool. This spot can be tricky to locate. It is often located below the downstream boundary of the pool unit. The correct location to make the measurement is where the thalweg (deepest part) of the channel crosses the top of the bar. It can be visualized as the summit of a mountain pass. The water depth at this location is the pool outlet depth.

In some cases, the downstream hydraulic control may be an obstruction that impounds water, such as a log or a beaver dam, rather than a gravel bar. In these cases, the depth of water flowing over the obstruction would be the pool outlet depth. If the water is not flowing over the downstream hydraulic control, then the pool outlet depth would be zero. During data analysis residual pool depth is calculated by subtracting the pool outlet depth from the maximum pool depth.

Identifying Factors Contributing to Pool Formation

Pools typically form as a result of scour adjacent to channel obstructions or due to impoundment of water behind blockages. Information on the factors contributing to pool formation is collected in order to document changes over time and to provide interpretive information related to current conditions such as percentage of pools and residual pool depth.

Table 3 lists a number of factors that often contribute to pool formation. Record any that appear to be contributing to the scour and/or damming effect forming the pool you are observing. Imagine the pool-forming processes at bankfull flow in order to make this determination. Select more than one factor, if applicable.

Log, Rootwad or Debris Jam: use the TFW Ambient Monitoring Large Woody Debris Survey Module to identify.

Roots of standing tree(s) or stump(s): applies to pools formed by hydraulic scour when the stream's flow is deflected by the roots of live or dead standing trees and stumps.

Rock(s) or Boulder(s): applies to pools formed by hydraulic scour caused by the stream flowing around larger rocks or boulders.

Bedrock outcrop: applies to pools formed by a hydraulic constriction caused by a geologic protrusion of bedrock material.

Channel bedform: refers to situations where the channel bed creates pools, such as where two channels join or where pools form next to bars in the absence of other contributing factors.

Table 3. List of potential factors contributing to pool formation and their codes.

Factors contributing to pool information	Code
Log(s)	1
Rootwad(s)	2
Debris Jam	3
Roots of standing tree(s) or stump(s)	4
Rock or Boulder(s)	5
Bedrock outcrop	6
Channel bedform	7
Scour associated with resistant banks	8
Artificial bank	9
Beaver dam	10
Other	11

Scour associated with resistant banks: applies to pools scoured along banks which resist erosion due to their natural composition (clay, rock, rootmass not covered in #4, etc.).

Artificial bank: applies to pools formed by scour along banks protected by structures of riprap, concrete, etc.

Beaver dam: applies to pools formed by the constriction of flow caused by debris placed in the stream by beavers.

Other: when you observe a factor contributing to pool formation that is not on the list, select "other" and describe the feature in the field notes section.

Filling out the Habitat Unit Survey Form

The TFW Ambient Monitoring Program provides field forms for recording monitoring data. Two options are available for recording information collected in the habitat unit survey. Use the regular habitat unit survey form (Appendix C) to record data if you plan on entering it by hand into a database. Use the scanable version of Form 3 (Appendix D) if you want to have your data scanned into a database at NWIFC. Please measure and record data in metric units. An English/Metric conversion chart is provided in Appendix E.

Background information - Begin by recording the date, the stream name, WRIA and segment number, rivermile and the confinement/gradient category. Record the discharge at the time of the survey. If the discharge is similar on subsequent days, record the same discharge. If the discharge changes, take a new discharge measurement and record this measurement on subsequent forms. Number each page sequentially for the entire segment. For example, if twelve forms are used in a segment, the first one would be 1 of 12, the second would be 2 of 12, and so forth.

Unit number - Each habitat unit should be given a discrete number, beginning with one. Units should be numbered sequentially through the stream **segment** as they are encountered. Begin the numbering sequence over again for each segment surveyed.

Downstream reference point number - Record the number of the nearest downstream reference point for each unit. Remember to split habitat units at reference points.

Recording information for units split at reference points - When a habitat unit is split at a reference point, make two separate entries. Make one entry for the portion of the unit above the reference point and one for the portion below the reference point. Record the same habitat unit number for each entry, since both portions are part of the same unit. Each entry will have a different downstream reference point number, since the upper portion of the unit has crossed a reference point. Record the appropriate unit type and unit category for each portion of the split unit (they should be the same). Record different lengths and average widths for each portion of the unit. Make only one maximum pool depth, pool outlet depth and pool forming obstruction entry for each pool unit, even if the unit is split. Record this information on the first entry for split pool units. See 'splitting units at reference points', above, for more information on this topic.

Unit type - Note the type of unit as a Pool (**P**), Tailout (**T**), Riffle (**R**), Cascade (**C**), Sub-surface flow (**S**), Obscured (**O**), or Wetland (**W**).

Unit category - Record the unit category as Primary (**1**), Secondary (**2**) or Side-channel (**3**). Primary units are over 50% of the wetted width, secondary units are less than 50%, and side-channels are separated from the main channel by an island (over two bankfull widths in length with perennial vegetation).

Length - Record the length of the habitat unit to the nearest tenth of a meter.

Width - Record the average width of the unit to the nearest tenth of a meter.

Maximum pool depth - Record the maximum water depth of each pool to the nearest centimeter. Maximum depth measurements are recorded only for pool units.

Pool outlet depth - Record the pool outlet depth of each pool unit to the nearest centimeter. Outlet depth measurements are recorded only for pool units.

Pool forming obstruction - Record the code number for any factors that are acting to form the pool. See Table 3 or the Field Code Sheet (Appendix F) for the appropriate codes. If the factor causing the pool is not listed, enter #11 and describe the pool forming factor in the field notes section.

Field Code Sheet - All the codes for the habitat unit survey (and the level 2 large woody debris survey) have been compiled on the field code sheet in Appendix F. Copy this sheet on to weather-proof paper and carry it in the field with you for easy reference.

Data Processing and Analysis

After data has been hand entered (by the cooperator) or scanned into the database, it is error checked. Then, habitat unit survey information is summarized in the Stream Segment Summary Report (Appendix G). This report provides habitat information including: the frequency and total surface area of the four habitat unit types, percent pools for use in Watershed Analysis, mean and maximum residual pool depth, and factors contributing to pool formation. A separate Pool Summary Report provides information on the characteristics of all pools surveyed. In addition, cooperators receive a copy of the database on floppy disk for their use. Data is also stored in a statewide database at NWIFC for future TFW-related use.

Training, Field Assistance and Quality Control

This manual is intended as a reference for those collecting monitoring information using the TFW Ambient Monitoring Program habitat unit survey module. Because of the difficulty in relying solely on a manual to learn and implement monitoring methodologies, the TFW Ambient Monitoring Program offers formal training sessions and informal field assistance visits to help cooperators learn and implement the methodologies.

In addition, the Ambient Monitoring Program also provides a quality control service that involves having an experienced crew perform replicate surveys for cooperators. The purpose of these surveys is to identify and correct inconsistencies in application of the methods and to provide documentation that data is being collected in a replicable and consistent manner throughout the state.

We encourage cooperators to utilize these services. Please contact the Northwest Indian Fisheries Commission (1-206-438-1180) for more information concerning the TFW Ambient Monitoring Program.

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APPENDIXES

APPENDIX A

Discharge Measurement Form

Dist. from initial point on tape	Cell Width	Depth	Velocity at point	Cell Discharge
0.5 (wetted perimter)				
1	1.	.3	.05	.015
2	1.	.4	.11	.044
3	.75	.6	.22	.099
3.5	.5	.8	.35	.14
4	.5	1	.40	.2
4.5	.5	1.2	.45	.27
5	.5	1.4	.54	.378
5.5	.5	1.4	.66	.462
6	.5	1.3	.69	.449
6.5	.5	1.2	.56	.336
7	.5	1.1	.48	.264
7.5	.5	1.	.42	.21
8	.75	.6	.22	.099
9	1.	.5	.12	.06
10	1.5	.2	.06	.018
11 (wetted perimeter)				
CONVERSION: Cubic Feet/Second - Cubic Meters/Second CFS CMS 3.044 X .0283 = .086			Cell Discharge Total	3.044

Segment Number 01

Stream Name Deschutes River

Date 7/10, 19 92 Surveyors Smith/Wesson

APPENDIX B

Discharge Measurement Form

Dist. from initial point on tape	Cell Width	Depth	Velocity at point	Cell Discharge
CONVERSION: Cubic Feet/Second - Cubic Meters/Second CFS X .0283 = CMS			**Cell Discharge Total**	

Segment Number____________________

Stream Name ____

Date ___________, **19**___ **Surveyors** ____________________________________

HABITAT UNIT SURVEY

FORM 3A & 3B

TFW - N.W.I.F.C.
Ambient Stream Monitoring 1993

TEMPORARY FORM

Page ____of____

DATE __/__/ STREAM NAME	CONFINMENT/ GRADIENT		W.R.IA. NUMBER			RIVER MILE		DISCHARGE	START NEW SHEET AT BEGINNING OF EACH DAY	
O Creek O River	T/M/L/U	Cat.1-6	O Unlisted	Trib. O O LB RB	Seg #	Beg	End	(cubic meters/sec)	BANKFULL WIDTH	FIELD NOTES:

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.	FIELD NOTES:
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12	

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.	FIELD NOTES:
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12	

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.	FIELD NOTES:
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12	

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.	FIELD NOTES:
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12	

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.	FIELD NOTES:
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12	

APPENDIX C

Version 7/10 AP

HABITAT UNIT SURVEY

FORM 3A & 3B (cont.)

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12

FIELD NOTES:

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12

FIELD NOTES:

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12

FIELD NOTES:

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12

FIELD NOTES:

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12

FIELD NOTES:

UNIT NUMBER	DOWNSTREAM REF. PT. #	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	MAX DEPTH (POOL)	OUTLET DEPTH (POOL)	POOL OBS.
		P/R/C/S/O/W	1-3	(meters)	(meters)	(meters)	(meters)	1 - 12

FIELD NOTES:

N.W.I.F.C. 6730 Martin Way E, Olympia, WA 98506
Contact:: Scott Hall (206)438-1180

TFW Ambient Monitoring

HABITAT UNIT SURVEY

FORM 3A

1. Use this form when beginning a survey of a new confinement/gradient segment OR as the first form used 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.

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

STREAM NAME

DATE: MO. | DAY | YEAR

CONF./ GRAD. (C, M, U)

W.R.I.A. NUMBER — ◯ UNLISTED — W.R.I.A. NUMBER | UNLISTED TRIB (LT, RT) | SEGMENT NUMBER

DISCHARGE (CMS)

BEGINNING RIVER MILE

ENDING RIVER MILE

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS	UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
		P R C T S O W	1 2 3								P R C T S O W	1 2 3					

APPENDIX D

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rev. 8/92

Continue on back of form.

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

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	P R C T S O W	1 2 3	0 1 2 3 4 5 6 7 8 9 (×5)	0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3; 0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3 4 5 6 7 8 9 (×2)

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	P R C T S O W	1 2 3	0 1 2 3 4 5 6 7 8 9 (×5)	0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3; 0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3 4 5 6 7 8 9 (×2)

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	P R C T S O W	1 2 3	0 1 2 3 4 5 6 7 8 9 (×5)	0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3; 0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3 4 5 6 7 8 9 (×2)

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	P R C T S O W	1 2 3	0 1 2 3 4 5 6 7 8 9 (×5)	0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3; 0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3 4 5 6 7 8 9 (×2)

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	P R C T S O W	1 2 3	0 1 2 3 4 5 6 7 8 9 (×5)	0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3; 0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3 4 5 6 7 8 9 (×2)

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	OUTLET DEPTH POOL (m)	MAX DEPTH POOL (m)	POOL OBS
0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	P R C T S O W	1 2 3	0 1 2 3 4 5 6 7 8 9 (×5)	0 1 2 3 4 5 6 7 8 9 (×4)	0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3; 0 1 2 3 4 5 6 7 8 9 (×3)	0 1 2 3 4 5 6 7 8 9 (×2)

TFW Ambient Monitoring

HABITAT UNIT SURVEY (CONT'D)

1. Date is carried from FORM 3A.
2. Refer to code reference sheet and field manual for codes and procedures.

FORM 3B

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.	CONF./ GRAD.	BEGINNING RIVER MILE	ENDING RIVER MILE	DISCHARGE	W.R.I.A. NUMBER	UNLISTED TRIB	SEGMENT NUMBER

6/25/93 MKG

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS	UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS
		P R C T S O W	1 2 3								P R C T S O W	1 2 3					

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS	UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS
		P R C T S O W	1 2 3								P R C T S O W	1 2 3					

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rev. 8/92

Continue on back of form.

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

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS	UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS	UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS

UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS	UNIT NUMBER	DOWN-STREAM REF. POINT	UNIT TYPE	UNIT CAT.	LENGTH (m)	WIDTH (m)	MAX DEPTH POOL (m)	OUTLET DEPTH POOL (m)	POOL OBS

APPENDIX E

Conversion Formulas:

Cubic Feet/Sec. (CFS)
Cubic Meters/Sec (CMS)

CFS (x) .0283 = CMS
CMS (x) 35.315 = CFS

Metric Conversion Chart

Symbol	When You Know	Multiply By	To Find	Symbol
		Length		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		Area		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000m2)	2.5	acres	
		Temperature (exact)		
°C	Celsius temp.	9/5 (÷32)	Fahrenheit temp.	°F
		Temperature (exact) to Metric		
°F	Fahrenheit temp.	−32 5/9 of remainder	Celsius temp.	°C
		Length		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		Area		
in^2	square inches	6.5	sq. centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	sq. kilometers	km^2
	acres	0.4	hectares	ha

APPENDIX F

TFW AMBIENT MONITORING CODE SHEET

HABITAT UNIT CODES

Unit type

P = pool
T = tailout
R = riffle
C = cascade
S = sub-surface flow
O = obscured
W = wetland

Unit Category

1 = primary unit
2 = secondary unit
3 = side-channel unit

Factors contributing to pool formation

Log(s)	1
Rootwad(s)	2
Debris Jam	3
Roots of standing trees or stumps	4
Rock(s)/boulder(s)	5
Bedrock outcrop	6
Channel bedform	7
Scour-resistant banks	8
Artificial bank protection	9
Beaver dam	10
Other	11

LARGE WOODY DEBRIS CODES

Piece type

L = log
R = rootwad

Wood Type

C = conifer
D = deciduous
U = unknown

Stability

R = rootwad
B = buried
P = pinned

Pool forming function

Y = yes
N = No

Wood location zone

1 = Zone 1
2 = Zone 2
3 = Zone 3
4 = Zone 4

Pool forming function

Y = Yes
N = No

Bankfull width (meters)	Minimum unit size (square meters)	Minimum residual pool depth (meters)
0 - 2.5 m	0.5	0.10
2.5 - 5.0 m	1.0	0.20
5 - 10 m	2.0	0.25
10 - 15 m	3.0	0.30
15 - 20 m	4.0	0.35
> 20 m	5.0	0.40

APPENDIX G

TFW Ambient Monitoring Stream Segment Summary 1992

Stream Segment Identification

(FileID: CC)

Stream name: DESCHUTES R. WAU name: WAU #:
WRIA number: 13.0028 Segment number: 18
River mile: 35.3 to 36.6

Stream Segment Characteristics

Gradient category: 2 Confinement: U Stream order: 4
Avg bankfull width: 20.2 M Avg bankfull depth: 0.4 M Width / depth: 46.66
Segment length: 2615.0 M Upper elevation: 550 F Lower elevation: 510 F

Resource Condition Indice Summary

Percent pools = 51.8% rated as a GOOD (>=50%) habitat condition
In-channel LWD pieces / bankfull width = 3.11 rated unkwn target value of
Average canopy closure: 23 %

Habitat Unit Summary Information

Habitat Units per Kilometer = 40.54

	Freq	% Total	Total Area (M^2)	% Total	Mean RPD (M)	Maximum RPD (M)
Pools	50	47.2	18120.1	51.8	0.61	2.70
Riffles	40	37.7	15011.7	42.9		
Cascades	15	14.2	1748.6	5.0		
Tailout	1	0.9	109.1	0.3		
Total	106		34989.4			

Factors Contributing to Pool Formation

Factor	Description	Freq	% Total	Area (M^2)	%Total Area
1	Log(s)	4	8.0	892.0	4.9
2	Rootwad(s)	15	30.0	3597.3	19.9
3	Debris jam	10	20.0	3888.5	21.5
4	Roots of standing trees or stumps	2	4.0	673.2	3.7
5	Rock(s) or boulder(s)	1	2.0	519.1	2.9
6	Bedrock outcrop	4	8.0	1205.5	6.7
7	Channel bedform	0	0.0	0.0	0.0
8	Scour associated with resistant banks	8	16.0	3371.2	18.6
9	Artificial bank protection	0	0.0	0.0	0.0
10	Beaver Dam	0	0.0	0.0	0.0
11	Other	0	0.0	0.0	0.0

	Freq	Length
Subsurface flow	0	0.0
Obscured flow	0	0.0
Wetland	0	0.0
Total	0	0.0

	Freq	Length
Main channel	76	2615.0
Secondary ch	16	443.9
Side channel	14	321.1
Total	106	3380.0

Timber-Fish-Wildlife
Ambient Monitoring Program

LARGE WOODY DEBRIS SURVEY MODULE

July 1993

Dave Schuett-Hames
Jim Ward
Martin Fox
Allen Pleus
Jeff Light

Northwest Indian Fisheries Commission

LARGE WOODY DEBRIS SURVEY MODULE

Contents

Acknowledgements

Thanks to Larry Dominguez, Paul Faulds, Mark Mobbs and Mindy Rowse for comments and suggestions used in the development and refinement of this module.

Cover, photographs, illustrations and hand entry field forms by Allen Pleus unless noted.

LARGE WOODY DEBRIS SURVEY MODULE

Figure 1. CSS Field Tech. Joe Apfel surrounded by a large debris jam on West Fork Taneum Creek.

Introduction

Large woody debris (LWD) is an important component of stream channels in the Pacific Northwest. It plays an integral role in the formation of channel morphology and fish habitat (Figure 1). Logs and rootwads enter stream channels due to bank cutting, blowdown, and mass wasting. Once in the channel, the effect of LWD is related to the size, stability and longevity of the individual pieces, and to the tendency of wood to collect in large accumulations known as debris jams.

Large woody debris influences channel morphology in several ways. Pools often form in association with LWD, due to adjacent scouring or impoundment of water behind channel-spanning pieces. Large woody debris often traps and stores sediment, having a moderating affect on sediment transport rates. In steeper, smaller channels, it often forms distinct steps that capture sediment on the upstream side and dissipate energy as the flow drops over the step.

Large woody debris plays an important biological role in Pacific Northwest streams, creating and enhancing fish habitat in streams of all sizes (Bisson et al., 1987). Pools formed in association with LWD often provide deep, low velocity habitat with cover. This habitat is beneficial for a variety of salmonid species and life history stages, particularly those that over-winter in stream channels. Large woody debris also functions to retain spawning gravel in high energy channels and provides thermal and physical cover.

The nature and abundance of large woody debris in a stream channel reflects past and present recruitment rates. This is largely determined by the age and composition of past and present adjacent riparian stands. Activities that disturb riparian vegetation, including timber removal in riparian areas, can reduce LWD recruitment. In addition, current conditions also reflect the past history of both natural and management-related channel disturbances, such as flood events, debris flows, splash damming, and stream cleanout.

Our understanding of the function of large woody debris in stream channels is still developing. To help increase the state of knowledge regarding LWD distribution and characteristics in Washington streams, Peterson et al. (1992) recommend expanding the type and amount of information collected in LWD monitoring and inventory surveys.

Purpose of the Large Woody Debris Survey Module

The purpose of the large woody debris survey module is to:

1. Provide a means of accurately documenting the current abundance and characteristics of large woody debris in stream channels.

2. To provide a repeatable methodology that can be used to monitor changes in the status of large woody debris over time.

3. To provide information on the abundance, size and function of large woody debris that is suitable for use in the Watershed Analysis cumulative effects assessment procedure.

4. To improve our knowledge of the distribution and characteristics of large woody debris in Pacific Northwest streams.

Large Woody Debris Survey Methodology

This section describes procedures for identifying and measuring large woody debris and large debris jams. Two options are provided. The less intensive Level 1 option does not require measurement of individual pieces of wood, however it provides information on abundance and size class suitable for Watershed Analysis Level 1. The more intensive Level 2 method requires measurement of each piece of wood and provides detailed information on diameter, length, volume and channel location suitable for Watershed Analysis Level 2. Please record all measurements in metric units to reduce confusion and streamline data processing.

Information and Equipment Needed

In order to complete the Ambient Monitoring large woody debris survey, it is necessary to have previously identified a survey segment (see stream segment identification module). It is also desirable to have established reference points (see the reference point survey module) so that large woody debris and debris jams can be associated with permanent reference locations.

You will need the following equipment:

Large Woody Debris survey forms (separate forms provided for the Level 1 and Level 2 methods)
Large Debris Jam survey forms
Number 2 pencils
Clip board or form holder
Fiberglass tape (metric)
Rangefinder (metric)
Calipers (metric)
Stadia rod or measuring stick (metric)
Field notebook
Field guide to tree identification (to help distinguish coniferous and deciduous species)
Hip boots or waders
First aid supplies

FIELD NOTE: It is important to make a copy of this list and use it before each daily survey.

Identifying Large Woody Debris

For the purposes of the large woody debris survey module, there are three types of LWD; logs, rootwads and large debris jams. Somewhat different information is collected for each type, so the first step is to identify the type of piece being observed.

How to Identify a Log

To qualify as a log, a piece of wood must (Figure 2a):

1. be dead (or imminently dying with no chance of survival);

2. have a root system that is wholly or partially detached and is no longer capable of supporting the log's weight;

3. have a diameter of at least 10 cm for at least 2 meters of its length, and;

4. intrude into the bankfull channel.

This criteria is based on the definition of LWD used by Bilby and Ward (1989; 1991), and is compatible with the Watershed Analysis LWD assessment procedure. Pieces that meet the minimum length and diameter criteria above are classified as logs regardless of whether or not they have roots attached. Individual stems that have grown in a cluster and meet at the base may be counted as separate pieces if they meet the minimum length and diameter criteria. Branches that are attached to the trunk of the tree should not be counted regardless of their size.

How to Identify a Rootwad

Rootwads are pieces of wood with a root system that do not meet the minimum length criteria for a log. To qualify as a rootwad, a piece (Figure 2b);

1. must be less than 2 meters long (except for old-growth stumps) and have a root system attached;

2. must be at least 20 cm diameter at the base of the stem where it meets the roots;

3. must have roots that are either wholly or partially detached from the soil so the rootwad has the ability to fall over, and;

4. must intrude into the bankfull channel.

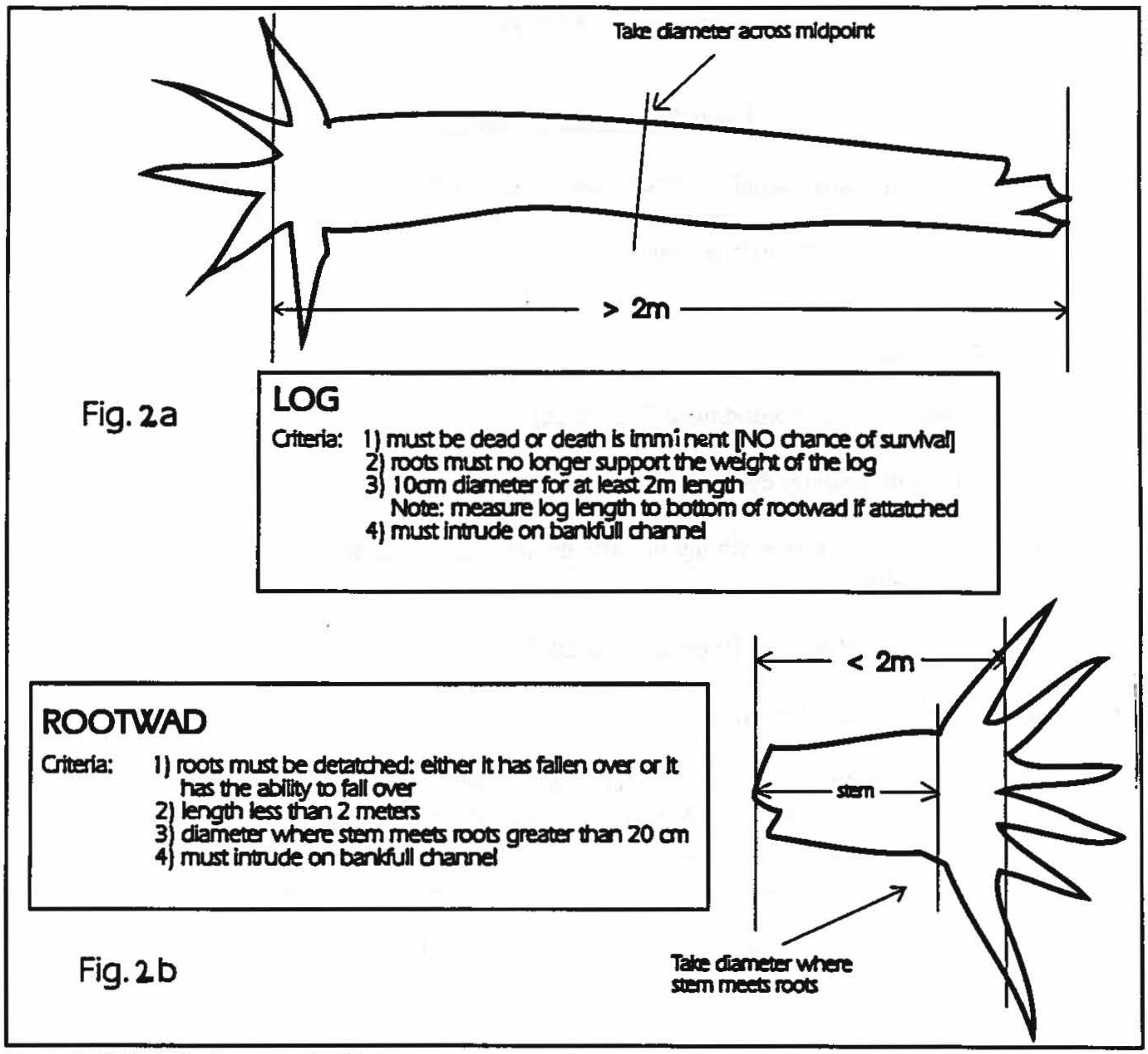

Figure 2. Criteria for large woody debris.

Old stumps are often found along the banks of stream channels running through areas that were harvested in the past. Often the stream has cut into the bank, exposing the roots of these standing stumps. The exposed roots are within the bankfull channel, and may have an influence on channel morphology. However, to maintain consistency with Bilby and Ward (1989; 1991), stumps with root systems that are still anchored in the ground are not counted as rootwads unless the stem (above the roots) has fallen into the bankfull channel (see section on length and channel location, below).

How to Identify a Large Debris Jam

Large debris jams are defined as accumulations of 10 or more qualifying logs or rootwads that are in contact with one another (Figure 3). Each qualifying piece must meet the minimum size criteria (defined above) and must intrude into Zone 1, 2 or 3. While smaller accumulations may sometimes function as debris jams, for our purposes they are not counted as "large debris jams". Only limited information is collected on individual pieces of wood in large debris jams (see section on large debris jams, below).

Figure 3. Lyman Bullchild on top of a large debris jam in the headwaters of Charley Creek, 1991

Collecting Information on Logs, Rootwads and Large Debris Jams

Two options are provided for collecting information on logs and rootwads. The Level 1 method is least intensive and does not require measurement of individual pieces of wood. It is designed to collect a minimal amount of information on LWD rather rapidly and generate information on the abundance and size class of LWD suitable for Watershed Analysis Level 1. The more intensive Level 2 method involves taking measurements on individual pieces of wood. This method is more time consuming, however it provides detailed information on attributes such as diameter, length, volume, channel location, wood type and stability that is suitable for Watershed Analysis Level 2.

The Level 1 Large Woody Debris Method

Use the Level 1 Large Woody Debris Survey Form (Appendix A) to record information collected using the Level 1 LWD survey method. Fill out the survey date, stream name, WRIA and segment identification numbers, and beginning and ending river miles.

Begin the survey at the start of the stream segment (see the TFW Ambient Monitoring Stream Segment Identification Module). If reference points have been established in the segment, determine the segment length from the reference point survey form. If you are not planning on establishing reference points prior to the Level 1 LWD survey, then you will need to measure the length of the survey segment by running a tape or hip chain down the center of the bankfull channel. This can be done before or during the Level 1 LWD survey.

Walk the channel, counting the number of qualifying pieces encountered (see identifying large woody debris, above). Logs and rootwads that occur in accumulations of 10 or more pieces are treated separately as large debris jams and recorded on the Large Debris Jam survey form. In the Level 1 LWD survey, qualifying pieces are assigned to one of the following four categories (Figure 4):

***Small** Log:	10-20 cm diameter at midpoint
***Medium** Log:	20-50 cm diameter at midpoint
***Large** Log:	greater than 50 cm diameter at midpoint
***Rootwad**:	20 cm or greater at base of stem

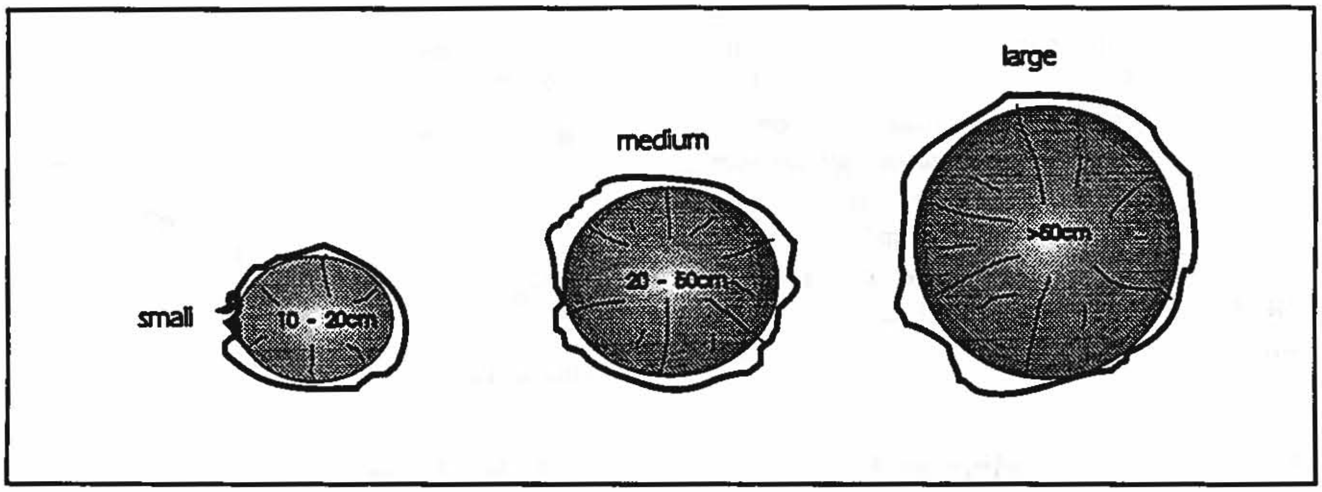

Figure 4. Log diameter categories used in the Level 1 LWD survey.

Next, determine the maximum extent to which the piece intrudes into the channel and assign the piece to either channel location zone 1 or 2. If a portion of the piece intrudes into the water at low flow, it is assigned to Zone 1. If it does not intrude into the water at low flow but would be partially submerged at bankfull flow, it would be assigned to Zone 2. See the section on length and channel location in the Level 2 LWD method (below) for a detailed discussion of the channel location zones.

Once the size category and channel location have been determined, tally the piece in the appropriate column (size category) and row (channel location zone) in the matrix on the Level 1 form. Each piece should only be tallied once. At the end of the survey add up all the tally marks in each cell of the matrix and record the total at the bottom of each cell. The sum of the totals for all cells equals the count of individual pieces in the segment. Add this number to the total number of pieces counted in large debris jams to calculate the total number of LWD pieces surveyed.

The Level 2 Large Woody Debris Method

The following information is collected on qualifying logs and rootwads during the Level 2 survey and is recorded on the Level 2 large woody debris survey form (Appendix B and C). This type of information is not collected for logs or rootwads that occur in accumulations of 10 or more pieces; they are treated separately as large debris jams (see large debris jams, below).

Association with Reference Points

Each log or rootwad should be assigned to a 100 meter reach delineated by established reference points (see reference point survey module). Locate the mid-point along the log or rootwad, and record the number of the nearest **downstream** reference point (Figure 5).

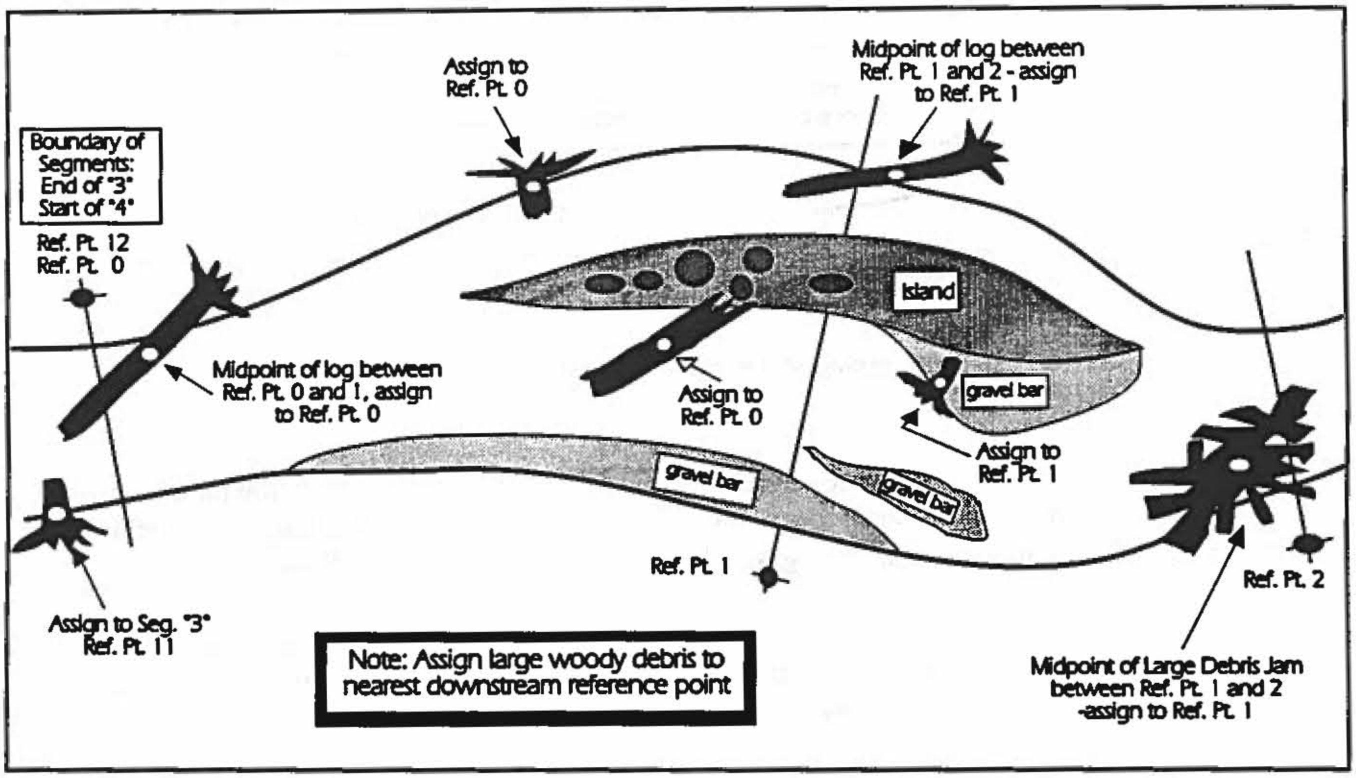

Figure 5. Assigning large woody debris to reference points.

Diameter

Diameter information is useful in determining the relative size and volume of individual logs. Diameter (to the nearest centimeter) is measured at the mid-point along the length of each log with a caliper or measuring stick. If a log cannot be measured, for example if the water is too deep or part of the log is suspended above the channel, estimate the diameter. If the log is divided into several large branches at the mid-point, making an accurate diameter measurement impossible at that location, measure the diameter immediately below the point where the branches fork. The diameter of rootwads is measured on the stem just above where the roots begin.

Length and Channel Location

Information on the length of logs and rootwads is useful in determining their relative size and volume. In conjunction with the length measurement, information on the channel location of the piece is collected. The system used to describe channel location (based on Robison and Beschta, 1991) consists of four location zones or categories (Figure 6).

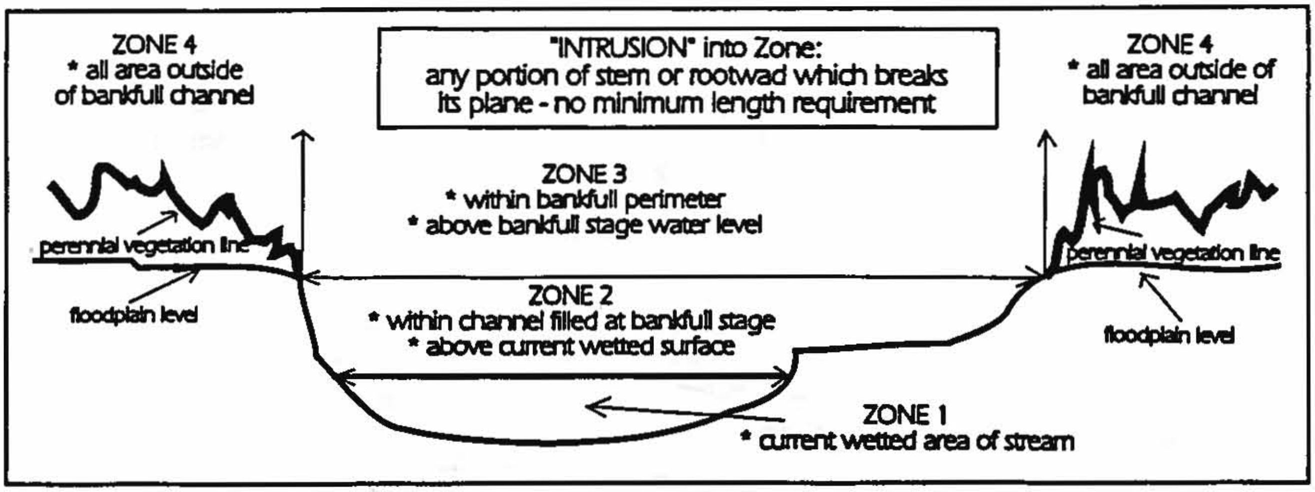

Figure 6. Description of LWD zones in stream channel.

Zone 1 is the wetted low flow channel, defined as the area under water at the time of surveys done during the low flow period.

Zone 2 is an area within the influence of the bankfull flow. This zone is within the perimeter of the bankfull channel and below the elevation of the water at bankfull flow (excluding areas defined as Zone 1). Zone 2 includes areas such as gravel bars that are exposed at low flow.

Zone 3 is an area within the perimeter of the bankfull channel but above the water line at bankfull flow. This zone includes pieces that extend out over the channel but are suspended above the elevation of the water at bankfull flow;

Zone 4 is the area outside of the bankfull channel perimeter. This zone includes the upper banks and riparian areas.

To measure length and channel location, first determine which zones the log or rootwad passes through. To define the location of the zones, it is necessary to determine the point on each bank that represents the high water mark at bankfull flow.

A variety of methods have been used by geomorphologists to establish the outer boundaries of the bankfull channel, however many require discharge records or surveying techniques. For ambient monitoring purposes, use bank form and vegetation indicators to identify the perimeter of the bankfull channel. See the reference point survey module for a detailed discussion on determining bankfull channel dimensions. In channels with natural (un-diked) riparian areas and frequently inundated floodplains, the boundary of the bankfull channel corresponds with the top of the low banks between the active channel and the floodplain. For confined channels without a floodplain the line of perennial non-aquatic vegetation is the best indicator of the bankfull channel boundary. Examples include channels that have been artificially diked and channelized, or channels that are incised into terraces that are not regularly inundated.

The outer boundary of the bankfull channel can be used to separate Zone 4 from Zones 2 and 3. Zone 4 lies outside the bankfull channel. To separate Zones 2 and 3, extend an imaginary horizonal line across the channel connecting the bankfull boundary points, representing the estimated water surface when the channel is at bankfull stage.

Once the zones have been determined, measure the length of the log (Figure 7) or rootwad along its main stem (Figure 8) in each of the four zones. The boundary line between two zones often passes through the log at an angle. In these situations, start with the lowest zone and measure to the furthest extent that the log influences that zone. At the point where the entire log has left the first zone, measure to the furthest extent that the log influences the second zone. Often the bottom of a log is the last portion to leave Zone 1 or 2.

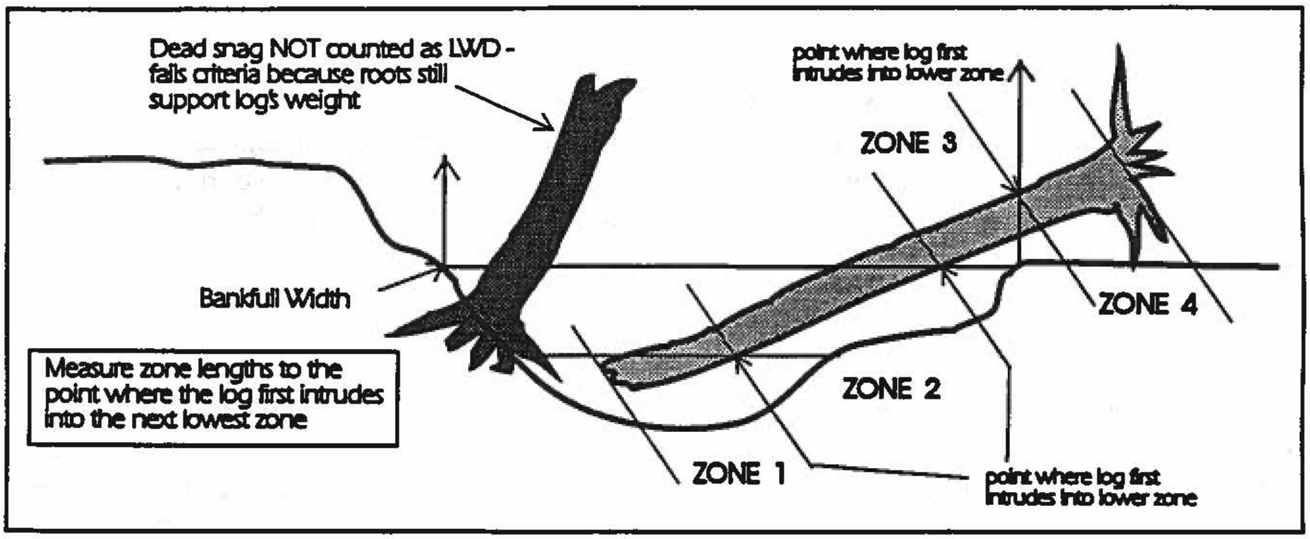

Figure 7. Assigning portions of logs to stream channel zones.

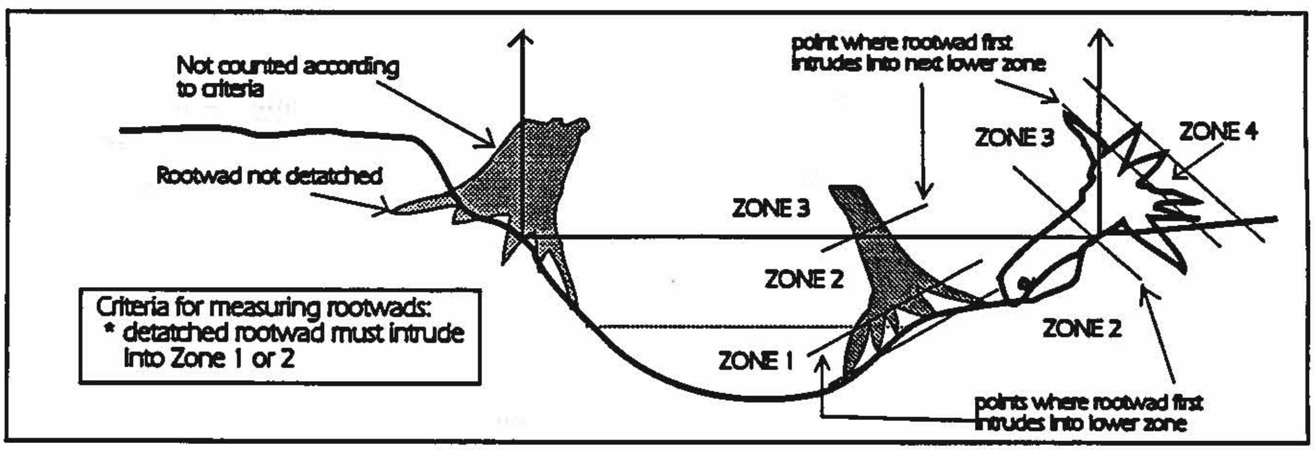

Figure 8. Assigning portions of rootwads to stream channel zones.

If part of a piece that is within Zone 1 or 2 also extends into Zone 3 or 4, measure and record the length in Zone 3 and/or 4. If a piece lies entirely within Zone 3 and/or 4 it is not counted in the survey.

Extend the length measurement from the base of the attached root-ball, if present, to the end of the log, even if the end is less than the minimum diameter. If a portion of a log is buried and the entire length cannot be determined, measure only the exposed portion of the log. When a piece of wood forks into numerous small branches, such as the branches at the top of a tree, measure to the point where the main stem is no longer distinctly larger than the branches forking off of it.

Cooperators may also want to count and measure pieces of debris that are suspended or bridged over the channel in Zone 3. To do this, also enter data for qualifying pieces that intrude into Zone 3 but do not enter Zone 1 or 2. These pieces will not be included in the regular wood count but will be reported in a separate category.

Type of Wood

Logs are classified in one of three categories based on the species of tree. The three categories are Coniferous (**C**), Deciduous (**D**) or Unknown (**U**). This provides information on the type of material that is entering the channel and its potential longevity, since conifers resist rot and persist longer than deciduous pieces. Characteristics of the bark, wood fiber, and branching pattern can often be used to identify the type of wood. A tree identification guide may be useful to help identify various species. If unsure about the type of wood, enter Unknown (**U**).

Stabilizing Factors

Note if the piece has a Root system (**R**), is partially Buried (**B**), or is Pinned (**P**). Buried is defined as having increased stability at bankfull flow due to complete burial of either end or lateral burial of 50% or more of the piece. Pinned is defined as having increased stability at bankfull flows due to having another piece on top of it, or due to being wedged between other logs, standing trees or bedrock.

Pool Forming Function

Note if the log or rootwad is associated with pool formation, contributing to either scour or impoundment of water. Imagine the pool-forming processes at bankfull flow to make this determination, because pieces outside of the wetted perimeter at low flow may contribute to pool formation at bankfull flows.

Large Debris Jams

Large debris jams consist of accumulations of ten or more qualifying pieces (either logs or rootwads) that are touching. Pieces must be wholly or partially within Zones 1, 2 or 3 to be counted in debris jams.

The following information is collected on logs and rootwads that are found in large debris jams and is recorded on the Large Debris Jam Survey Form (Appendix D and E). Walking on top of large debris jams can be difficult and dangerous, so this information is intended to be collected while walking around the outside of the debris jam and does not involve actual measurement of individual pieces of wood.

Associating Large Debris Jams with Reference Points

Each debris jam should be associated with a 100 meter reach delineated by established reference points (see the Reference Point Survey Module). Locate the mid-point along the length of the debris jam, and record the number of the nearest **downstream** reference point (see Figure 5).

Number and Size of Visible Pieces

Walk around the debris jam and count the visible pieces that meet the minimum size criteria for logs and rootwads. Because it is often not possible to see both ends of logs that go through the middle of large jams, it may be difficult to know if you are counting the same piece twice. Take your time and do your best! Assign each piece that you count to one of four categories, based on a visual estimate of the diameter. The categories are:

***Small** Log:	10-20 cm diameter at midpoint
***Medium** Log:	20-50 cm diameter at midpoint
***Large** Log:	greater than 50 cm diameter at midpoint
***Rootwad**:	20 cm or greater at base of stem

Determine the Size of the Debris Jam

The purpose of this information is to obtain an estimate of the dimensions of the debris jam to characterize its relative size. Determining the dimensions of a debris jam may be difficult because debris jams often have irregular shapes with individual logs that protrude from the pile. Imagine the debris jam as a rectangular shape with the smaller protruding pieces pushed into the pile or trimmed off, and record the average length, average width and average height.

Channel Location

Use the system of channel location zones described in the section on collecting information on logs (above). Note the furthest channel zone into which the debris jam intrudes. To determine this, imagine the debris jam with the protruding individual pieces trimmed off, as when determining the size of the debris jam.

Pool Forming Function

Note if the debris jam is associated with pool formation, contributing to either scour or impoundment of water. Imagine the pool-forming processes at bankfull flow to make this determination. It is possible that debris jams outside of the wetted perimeter at low flow contribute to pool formation at bankfull flows.

Filling Out the Level 2 Large Woody Debris Survey Form

The TFW Ambient Monitoring Program provides field forms for recording monitoring data. Two options are available for recording information collected in the Large Woody Debris Survey. Use the regular Level 2 LWD survey form (Appendix B) to record data if you want to enter it by hand into the database. Use the scan-able version (Appendix C) to record your data if you want the data scanned directly into the database. This section describes how to enter information on the forms.

Background information - Begin by recording the Date the survey was done. Begin a new sheet on each subsequent day if the segment takes more than one day to survey. Record the Stream name, WRIA and Segment ID number, and the beginning and ending River mile. This information can be taken from the segment summary form.

Piece number - Make one entry on the Level 2 form for each qualifying piece of wood (except those in large debris jams). Assign each piece a unique piece number, beginning with 001 and continuing in sequence to the last piece in the stream segment, and record it in the piece number column.

Downstream reference point number - Record the number of the nearest downstream reference point from the mid-point of the log or rootwad in the downstream reference point column.

Piece type - Determine if the piece is a log (greater than 2 meters in length, with or without roots) or a rootwad (less than 2 meters with roots attached). Record **(L)** for Log or **(R)** for Rootwad in the piece type column.

Diameter - Record the diameter measurement (to the nearest centimeter) in the diameter column.

Length - The form has separate columns for each of the channel location zones. Record the length of the portion of the log or rootwad assigned to each zone in the appropriate column. Lengths are measured to the nearest 0.1 meter. Total length will be computed during data processing by adding the lengths in each of the individual zones.

Wood type - Record the type of wood in this column using **(C)** for Conifer, **(D)** for Deciduous or **(U)** for Unknown.

Stability - Use this column to record all of the applicable stability factors for the piece using **(R)** for Root system, **(B)** for Buried, and **(P)** for Pinned.

Pool forming function - After determining if the log or rootwad is associated with a pool, use this column to record **(Y)** for Yes and **(N)** for No.

Filling Out the Large Debris Jam Survey Form

Two options are available for recording information collected on large debris jams. Use the regular Large Debris Jam Survey Form (Appendix D) if you plan on entering data by hand into the data-base. Use the scan-able version (Appendix E) if you want to have the data scanned directly into the database by NWIFC. Scan-able forms are available from NWIFC. The following section describes how to record data on this form.

Background information - Begin by recording the date the survey was done. Begin a new sheet on each subsequent day if the segment takes more than one day to survey. Record the stream name, WRIA and segment ID number, and the beginning and ending river mile. This information can be taken from the segment summary form.

Large debris jam number - Make one entry on the Large Debris Jam Survey Form for each qualifying large debris jam (10 or more interconnected qualifying pieces of wood). Assign each large debris jam in the segment a unique number beginning with 1, and record in this column.

Downstream reference point number - Record the number of the nearest downstream reference point from the mid-point along the length of the debris jam.

Visible pieces - Record the total number of visible pieces in each of the size categories in the appropriate column.

Length, width and height - Record the length, width and height (in meters) of the debris jam in these columns.

Channel location zone - Record the zone number (**1** or **2**) corresponding with the greatest intrusion of the debris jam into the channel.

Pool forming function - After determining if the debris jam is associated with a pool, use this column to record (**Y**) for Yes or (**N**) for No.

Data Processing and Analysis

After data has been hand entered (by the cooperator) or scanned into the database, it is error checked. Then, an in-channel Large Woody Debris summary report is generated (Appendix F). This report provides information on LWD for the segment including: the frequency, average diameter, length and volume by channel location zone of logs and rootwads; frequency and volume by species type; and the size and composition of debris jams. In addition, cooperators will receive a copy of the database on floppy disk for their use. Data is stored in a statewide database at NWIFC for future TFW-related use.

Training, Field Assistance and Quality Control

This manual is intended as a reference for those collecting information using the TFW Ambient Monitoring Program Large Woody Debris Survey Module. Because of the difficulty in relying solely on a manual to learn and implement monitoring methodologies, the TFW Ambient Monitoring Program offers formal training sessions and informal field assistance visits to help cooperators learn and implement the methodologies.

In addition, the Ambient Monitoring Program also provides a quality control service that involves having an experienced crew perform replicate surveys for cooperators. The purpose of these surveys is to identify and correct inconsistencies in application of the methods and to provide documentation that data is being collected in a replicable and consistent manner throughout the state.

We encourage cooperators to utilize these services. Please contact the Northwest Indian Fisheries Commission (1-206-438-1180) for more information concerning the TFW Ambient Monitoring Program.

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APPENDIXES

Appendix A.
LWD Form 4 Level 1

Appendix B.
LWD Form 4 Level 2 - Hand entry

Appendix C.
LWD Form 4 Level 2 - Scan entry

Appendix D.
LWD Form 5 Level 2 - Hand entry

Appendix E.
LWD Form 5 Level 2 - Scan entry

Appendix F.
LWD Summary Report - example

LARGE WOODY DEBRIS SURVEY

FORM 4 LEVEL 1

TFW - N.W.I.F.C.

Ambient Stream Monitoring 1993

TEMPORARY FORM

DATE / / STREAM NAME ○ Creek ○ River	CONFINMENT/ GRADIENT T/M/L/U Cat.1-6	W.R.IA. NUMBER ○ Unlisted Trib. ○ LB ○ RB Seg #	RIVER MILE Beg End	DISCHARGE (Optional) (cubic meters/sec)	START NEW SHEET AT BEGINNING OF EACH SEGMENT FIELD NOTES:

TOTALS PER SEGMENT

Beg. Ref Pt.	
End Ref Pt.	

	ROOTWAD >20cm	LOG 10-20cm	LOG 20-50cm	LOG >50cm
ZONE 1	Total	Total	Total	Total
ZONE 2	Total	Total	Total	Total
ZONE 3	Total	Total	Total	Total

APPENDIX A

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Contact: Scott Hall (206) 438-1180

Version 7/17 AP

LARGE WOODY DEBRIS SURVEY

FORM 4 LEVEL 2

TFW - N.W.I.F.C.

Ambient Stream Monitoring 1993

TEMPORARY FORM

Page ____ of ____

DATE __/__/__ STREAM NAME	CONFINEMENT/ GRADIENT		W.R.I.A. NUMBER			RIVER MILE		DISCHARGE (Optional)	*START NEW SHEET AT BEGINNING OF EACH DAY*
O Creek O River	T/M/L/U	Cat.1-6	O Unlisted	Trib. O LB O RB	Seg #	Beg	End	(cubic meters/sec)	FIELD NOTES:

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
							O Y O N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
							O Y O N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
							O Y O N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
							O Y O N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
							O Y O N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/U	POOL FORM FUNC.
							O Y O N

APPENDIX B

Version 7/17 AP

LARGE WOODY DEBRIS SURVEY

FORM 4 (cont.) LEVEL 2

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
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PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

PIECE No.	DWNSTRM REF. PT.	PIECE TYPE R/L	LOG DIA. (CM)	LENGTH (in meters) ZONE (circle for rootwad) 1 2 3 4	WOOD TYPE C/D/U	STAB. R/B/P/O	POOL FORM FUNC.
							○ Y ○ N

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TFW Ambient Monitoring

LARGE WOODY DEBRIS SURVEY

LEVEL II

FORM 4

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

Page ______ of ______ .

STREAM NAME (CIRCLE ONE ↓) CREEK / RIVER	BEGINNING RIVER MILE	ENDING RIVER MILE	CONF./ GRAD.	DATE (MO. / DAY / YR.)	DISCHARGE (OPT.)	W.R.I.A. NUMBER (UNLISTED TRIB / SEGMENT NUMBER)
	.	.		0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	LT RT; 0 1 2 3 4 5 6 7 8 9

PIECE NUMBER	DOWNSTREAM REF. PT.	PIECE TYPE	DIAMETER (CM)	LENGTH (METERS) 1	2	3	4	WOOD TYPE	STABILITY FACTOR	POOL FORMING FUNCTION
0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	L R	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	C D U	R B P U	Y N

APPENDIX C

PIECE NUMBER	DOWNSTREAM REF. PT.	PIECE TYPE	DIAMETER (CM)	LENGTH (METERS) 1	2	3	4	WOOD TYPE	STABILITY FACTOR	POOL FORMING FUNCTION
0 0 0 0 … 9 9 9 9	0 0 0 … 9 9 9	L R	0 0 0 … 9 9 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	C D U	R B P U	Y N

PIECE NUMBER	DOWNSTREAM REF. PT.	PIECE TYPE	DIAMETER (CM)	LENGTH (METERS) 1	2	3	4	WOOD TYPE	STABILITY FACTOR	POOL FORMING FUNCTION
0 0 0 0 … 9 9 9 9	0 0 0 … 9 9 9	L R	0 0 0 … 9 9 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	C D U	R B P U	Y N

PIECE NUMBER	DOWNSTREAM REF. PT.	PIECE TYPE	DIAMETER (CM)	LENGTH (METERS) 1	2	3	4	WOOD TYPE	STABILITY FACTOR	POOL FORMING FUNCTION
0 0 0 0 … 9 9 9 9	0 0 0 … 9 9 9	L R	0 0 0 … 9 9 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	0 0 . 0 … 9 9 . 9	C D U	R B P U	Y N

LARGE LOG JAM SURVEY

FORM 5 (cont.)

Version 7/17 AP

N.W.I.F.C. 6730 Martin Way E. Olympia, WA 98506
Contact: Scott Hall (206) 438-1180

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

LOG JAM No.	DOWNSTRM REF.PT.	VISIBLE PIECES		RTWD >20CM	LENGTH	WIDTH	HEIGHT	ZONE	POOL FORM FUNC
		10-20cm	20-50cm	>50 cm	meters	meters	meters	1-4	
									O Y O N

TFW Ambient Monitoring

LARGE LOG JAM SURVEY

LEVEL II

FORM 5

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.	CONF./ GRAD.	W.R.I.A. NUMBER	BEGINNING RIVER MILE	ENDING RIVER MILE	DISCHARGE
			.	.	.	.

LOG JAM NUMBER	DOWNSTREAM REF. PT.	VISIBLE PIECES & ROOT WADS: VISIBLE PIECES 10-20 CM	20-50 CM	>50 CM	ROOT WADS >20 CM	LENGTH	WIDTH (METERS)	HEIGHT	ZONE	POOL FORMING FUNCTION
0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	① ② ③ ④	Ⓨ Ⓝ

LOG JAM NUMBER	DOWNSTREAM REF. PT.	VISIBLE PIECES & ROOT WADS: VISIBLE PIECES 10-20 CM	20-50 CM	>50 CM	ROOT WADS >20 CM	LENGTH	WIDTH (METERS)	HEIGHT	ZONE	POOL FORMING FUNCTION
0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	① ② ③ ④	Ⓨ Ⓝ

APPENDIX E

Printed in U.S.A. Mark Reflex® by NCS MM91385:32 A4200

LOG JAM NUMBER	DOWNSTREAM REF. PT.	VISIBLE PIECES & ROOT WADS: VISIBLE PIECES 10-20 CM	VISIBLE PIECES 20-50 CM	VISIBLE PIECES >50 CM	ROOT WADS >20 CM	LENGTH (METERS)	WIDTH (METERS)	HEIGHT (METERS)	ZONE	POOL FORMING FUNCTION
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 2 3 4	Y N
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		
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		
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		
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		
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		

LOG JAM NUMBER	DOWNSTREAM REF. PT.	VISIBLE PIECES & ROOT WADS: VISIBLE PIECES 10-20 CM	VISIBLE PIECES 20-50 CM	VISIBLE PIECES >50 CM	ROOT WADS >20 CM	LENGTH (METERS)	WIDTH (METERS)	HEIGHT (METERS)	ZONE	POOL FORMING FUNCTION
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 2 3 4	Y N
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		
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		
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		
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		
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		

LOG JAM NUMBER	DOWNSTREAM REF. PT.	VISIBLE PIECES & ROOT WADS: VISIBLE PIECES 10-20 CM	VISIBLE PIECES 20-50 CM	VISIBLE PIECES >50 CM	ROOT WADS >20 CM	LENGTH (METERS)	WIDTH (METERS)	HEIGHT (METERS)	ZONE	POOL FORMING FUNCTION
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 2 3 4	Y N
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		
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		
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		
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		
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		

APPENDIX F

TFW Ambient Monitoring In-Channel Large Woody Debris Summary

Stream Segment Identification (FileID: CC)

Stream name: DESCHUTES R. WAU name: WAU #:
WRIA number: 13.0028 Segment number: 18
River mile: 35.3 to 36.6
Segment length: 2615.0 M Bankful Width: 20.2 Depth: 0.4 Width/Depth: 46.66

Individual Pieces Intruding into Zones 1 and/or 2

	Freq	per Km	Average Diam.(cm)	Average Total Length (M)	Total Volume (M^3)	Tot. Volume(M^3) by Zone 1	2	3	4
Rootwads	7	2.7	59.4	1.4	2.8	1.4	0.6	0.8	2E-2
Logs	128	48.9	27.7	6.4	98.2	34.7	26.5	19.9	17.1
Total	135	51.6			101.1	36.2	27.1	20.7	17.1

Composition of individual pieces

	Freq	%Freq	Total Volume (M^3)	%Total Volume
Coniferous	52	38.5	78.6	77.8
Deciduous	34	25.2	9.3	9.2
Unknown	49	36.3	13.2	13.1
Total	135		101.1	

Stability of individual pieces

	Freq	% Total
Root system	29	21.5
Buried	37	27.4
Pinned	14	10.4
Undetermined	58	43.0

Debris jam information

	Freq	per Km	Pieces with Diameter 10-20	20-50	>50 cm	Root wads	Total Pieces	Average Size (M) Length	Width	Height	Zone 1	Freq 2
Debris Jams	8	3.06	113	111	34	10	268	22.5	5.4	2.1	7	1

Total of in-channel LWD including individual pieces and pieces in debris jams*

	No. of Pieces	* Average Diameter (cm)	Average Length (M)	Average Volume(M*3)	Total Volume (M*3)
Rootwads	17	20.0	1.4	0.03	0.5
Logs 10-20 cm	175	13.9	6.1	0.10	17.0
20-50 cm	164	31.7	5.8	0.51	84.4
> 50 cm	47	76.8	10.0	5.00	234.8
Total	403				336.7

Average pieces per Km: 154.1 Average volume per Km: 128.7

* Note: Where no measured pieces exist in Zones 1 or 2, the following are used:

	Rootwads	Logs: 10-20	20-50	>50 cm
Average diameter (cm)	20.0	15.0	35.0	50.0
Average length (M)	1.0	1.0	1.0	1.0

Timber-Fish-Wildlife
Ambient Monitoring Program

SALMONID SPAWNING GRAVEL COMPOSITION MODULE

July 1993

Dave Schuett-Hames
Bob Conrad
Mike McHenry
Phil Peterson
Allen Pleus

Northwest Indian Fisheries Commission

SALMONID SPAWNING GRAVEL COMPOSITION MODULE

Contents

Acknowledgements

Thanks to Jeff Cederholm, Jim Matthews, Doug Morrel, and Mark Teske for providing data and assistance in the development of the salmonid spawning gravel module.

Cover: Dave Schuett-Hames on Thurston Cr. Photo by Allen Pleus.
Module illustrations and photographs by Allen Pleus unless noted.

SALMONID SPAWNING GRAVEL COMPOSITION MODULE

Introduction

The development of salmonid eggs and alevin typically occurs in the gravel substrate of freshwater rivers and streams. Mature females choose sites where substrate and flow conditions are favorable and deposit their eggs in nests (redds) they excavate in the substrate. After the eggs hatch, the alevins continue to reside within the streambed gravel, subsisting on nutrients from an external yolk-sac. When the yolk-sac has been absorbed they emerge from the gravel and begin active feeding.

The eggs and alevin require a stable streambed and an adequate supply of water while developing to prevent dehydration, supply oxygen and carry away metabolic waste. Mortality during intra-gravel development is highly variable, depending on hydrologic, geomorphic and biotic conditions. Mortality has been attributed to a variety of causes including disease, predation, suffocation, dehydration, mechanical disturbance and freezing (McNeil, 1969).

How Fine Sediments Affect the Incubation Environment

Salmonid eggs require an abundant supply of dissolved oxygen to ensure survival to emergence and proper development (Alderdice et al., 1958). Oxygen reaches the eggs through a three-step process involving dissolution of oxygen from the atmosphere into stream water, transport of oxygenated water to the stream bottom, and interchange of oxygenated water from the stream to the pores between gravel in the egg pocket (Vaux, 1962). Fine sediment (fine sand, silt or clay) that lodges in the interstitial spaces between gravel particles reduces permeability and slows the rate of flow through the gravel substrate (McNeil and Ahnell, 1964; Johnson, 1980). Numerous studies (Chapman, 1988, Everest et al., 1987; Iwamoto et al. 1978) have associated high levels of fine sediments with elevated mortality rates and reduced fitness of surviving fish (Koski, 1975). These effects are due to increased stress and mortality associated with oxygen deprivation (Alderdice et al., 1958), the accumulation of toxic metabolic by-products (Bams and Lam, 1983), and entombment of emerging fry (Chapman, 1988).

Natural and Management-Related Sources of Fine Sediments

Concentrations of fine sediments in stream channels vary in space and time (Adams and Beschta, 1980). The amount of fine sediments present at a particular location depends on the nature and magnitude of erosional processes that produce fine sediments and introduce them to the stream channel, as well as the geomorphic factors that control the transport and storage of sediments, such as stream gradient and hydrology. In addition, spawning salmonids tend to remove fine sediments from the substrate during redd construction, however the persistence of this effect is not well understood (Everest et al. 1987). During the incubation period, fine sediments moving through the stream channel may intrude into the redd. The severity and significance of fine sediment intrusion is related to the size and amounts of transported sediment, and the depth of intrusion (Lisle, 1989). Fine sediment levels are higher in watersheds where the geology, soils, precipitation or topography create conditions favorable for erosional processes that produce fine sediments (Duncan and Ward, 1985). Fine sediments are typically more abundant where land-use activities such as road-building or land-clearing expose soil to erosion and increase mass wasting (Cederholm et al., 1981; Swanson et al., 1987; Hicks et al., 1991).

Purpose of the Spawning Gravel Composition Module

The purpose of this module is to provide a standard method of sampling potential salmonid spawning habitat to characterize gravel composition and fine sediment levels on a stream segment scale. The intent is to ensure replicable data that allows comparisons to be made through time and between stream segments. The information generated on the condition of potential spawning habitat is suitable for use as a management indicator. The module does not attempt to document or predict actual survival to emergence, because that objective would require research of an intensity impractical for management purposes. Nor is it oriented towards the requirements of any particular salmonid species, as species may vary within and between stream segments around the state.

The information generated using this methodology is suitable for:

* evaluating the composition and characteristics of spawning gravel;
* estimating the percentage of fine sediments less than 0.85 mm for Watershed Analysis;
* comparing spawning gravel composition among stream segments, watersheds and eco-regions;
* monitoring trends in spawning gravel composition over time.

The Spawning Gravel Sampling Methodology

Information and Equipment Needed

Map delineating stream segments
McNeil sampler with plunger
Plastic buckets (5 gallon) with lids- typically one per sample
Backpack carrier for buckets (optional)
Squirt bottle
Write-in-the-rain paper (for tags)
Field notebook
Pencils
Hip boots or chest waders
Rain gear
Flagging
Permanent markers
Fiberglass tape (50 m or 100 m, depending upon channel width)

*Note: The equipment needed for processing samples depends upon the method used. The equipment requirements of each processing method are discussed separately in the sections on "volumetric processing" and "gravimetric processing".

Site selection and sampling strategy

Prior to collecting samples, it is necessary to define the sampling reach, identify potential sampling sites, and select sampling sites in a non-biased manner.

Identifying a Sampling Segment

Partition the river system into stream segments based on tributary junctions, gradient and valley confinement per the TFW Ambient Monitoring Stream Segment Identification Module.

Once the river system has been divided into segments, the criteria used to select appropriate monitoring segments should include salmonid use (current, historic, or future potential) and appropriate gradient. This methodology is best suited for segments with gradients less than two percent. It can be applied on segments in the two-to-six percent range, but is unsuitable for segments with gradients over six percent (Figure 1). Finally, the substrate particles must be of a suitable size for sampling. The McNeil sampling technique does not work well in substrates with particles greater than ten cm (four inches) in diameter.

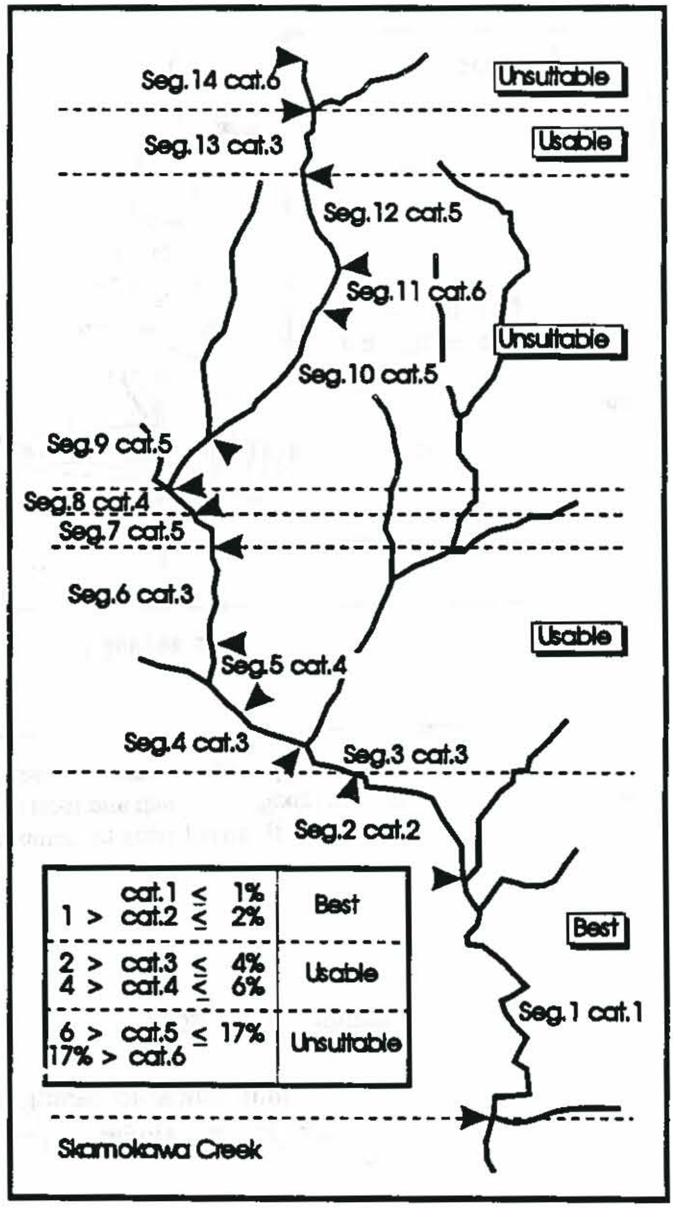

Figure 1. Suitability of gravel sampling by segment and gradient.

Defining a Logistically Feasible Sampling Area

Once a segment has been chosen for sampling, the next step is to identify portions of the segment suitable for sampling and to eliminate areas where sampling is logistically impractical (Figure 2). Ideally, sampling sites should be distributed throughout the entire segment. However, due to the size and weight of the sampler and the gravel samples, proximity to vehicle access is a legitimate consideration in determining what portions of a stream segment are feasible to sample, unless other means of transport such as helicopters or boats are available. In addition, terrain features such as bedrock canyons make some areas inaccessible.

Examine the segment and identify potential access roads and trails, and terrain features that impede

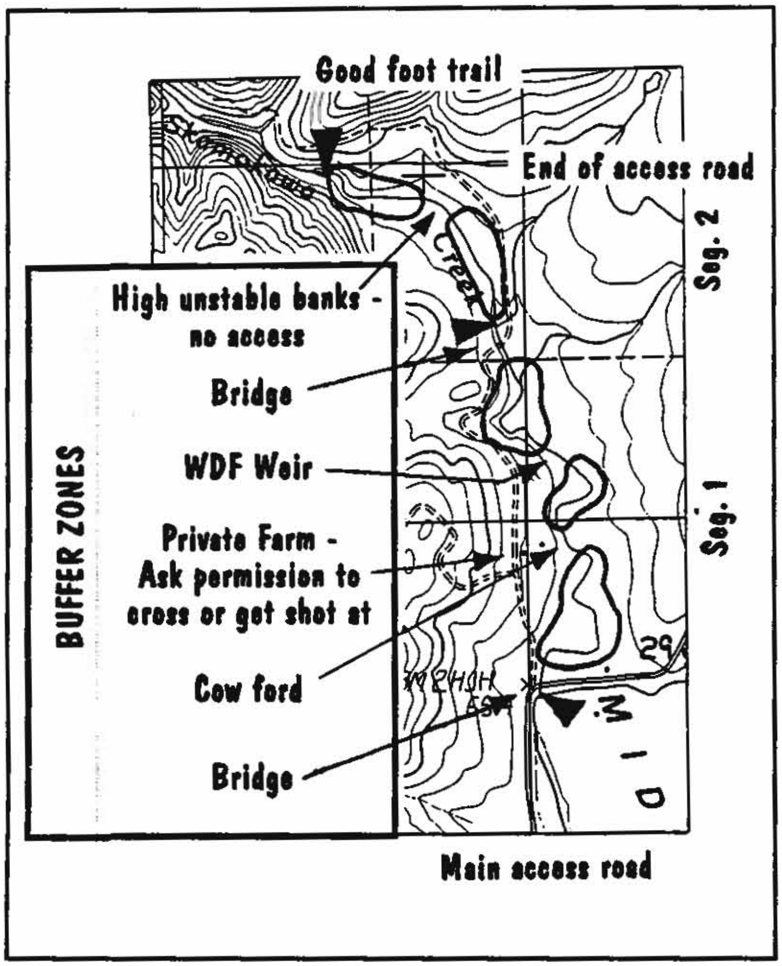

Figure 2. Determining and finalizing potential sampling areas in segment reaches 1 and 2 based on topographic map and local knowledge. The circular areas are the finalized areas for sampling.

access. Then determine how far it is feasible to transport equipment and samples to the access points. This will depend on the terrain and the physical strength and endurance of those transporting the samples. Transporting samples for distances greater than 0.75 - 1.0 kilometer is probably not practical in most cases.

Eliminating Areas in the Vicinity of In-stream Structures

Human structures and disturbance in the stream channel such as bridges, culverts, weirs, dams, bank protection, fords, etc., locally alter hydraulic conditions in stream channels, affecting sediment deposition patterns. Samples taken in the vicinity of these structures or disturbances reflect the local effects of the structure and mask the overall effect of watershed conditions on the stream channel. Avoid sampling within the immediate influence of these features. The length of affected stream channel will vary, however as a general guideline do not collect samples within 50 meters of instream structures.

Finalizing the Potential Sampling Reach

Once areas that are logistically impractical to sample or are in the immediate vicinity of instream structures have been eliminated, the remainder of the segment is available for sampling and is referred to as the sampling reach.

Identifying Potential Sampling Sites Within the Sampling Reach

The next step is to identify specific potential sampling sites within the sampling reach. To promote consistent and reproducible sampling, samples are taken at a specific geomorphic feature, the riffle crest, as in Tripp and Poulin (1986). Riffle crests are located at the upstream end of riffles, typically forming the boundary between pool tailouts on the upstream side and the riffle on the downstream side (Lisle, 1987.) Riffle crests were chosen as sampling sites for the following reasons:

1) Riffle crests are distinct geomorphic features that can be identified and located by different observers in a wide variety of streams. This reduces observer bias in site selection and increases our ability to replicate and compare data on a statewide basis.

2) Riffle crests are located at the transition between the two areas most heavily utilized for spawning by salmonids, pool tailouts and riffles. The riffle crest is utilized by nearly all salmonids for spawning, and is often the first area in the stream selected by salmonids for spawning.

3) Sampling riffle crests avoids the confusion associated with using species-specific criteria to identify sites (particularly in areas used by multiple species), and eliminates potential bias associated with the effect of run-size when using actual spawning sites selected by salmonids.

How to Identify Riffle Crests

The term "riffle crest" refers to a specific feature of the streambed. The riffle crest is located at the high point of the bar that typically occurs below many pools. Viewed in longitudinal profile, the channel bottom slopes down in both an upstream and downstream direction at the riffle crest (Figure 3). Riffle crests typically act as hydraulic control structures that impound water in the upstream pool. They can be located by finding the boundary between the smooth, laminar flow of water leaving the pool and the surface turbulence of the riffle associated with increased velocity and decreased depth as water flows over the downstream slope of the bar. See Habitat Unit Survey Module for a more detailed description.

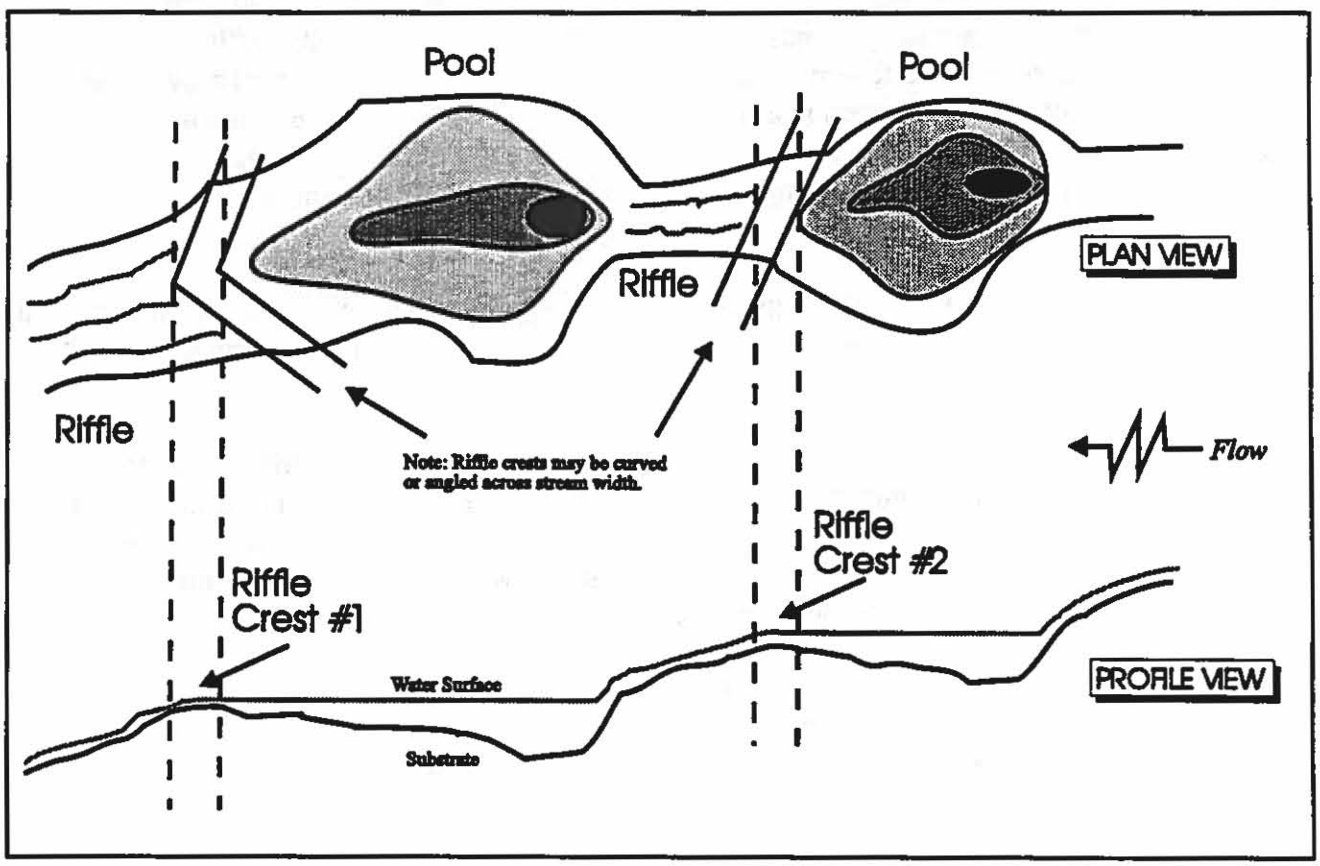

Figure 3. Plan and profile views of a stream reach identifying the location of riffle crests.

Inventorying Riffle Crests to Identify Potential Sampling Sites

Inventory all the riffle crests in the sampling reach to make a list of potential sampling sites. Walk the entire length of the sampling reach, identifying riffle crests. Evaluate each riffle crest as a potential sampling site. If the average diameter of the substrate is 10 cm (4 inches) or more, it will be too difficult to sample with the McNeil cylinder and should be eliminated. Be sure to eliminate riffle crests that have been disturbed by human activities as described above.

Riffle crests that appear suitable for sampling are assigned a riffle crest (RC) number. Begin at the downstream end of the sampling reach and assign the RC numbers sequentially. Record the number assigned to each suitable riffle crest and note its location relative to a reference point or landmark in a field notebook. Mark each suitable riffle crest with flagging showing the RC number. The complete set of suitable riffle crests identified within the sampling reach constitutes the sampling population from which actual sampling sites will be selected.

Systematic Sampling Strategy

This standard sampling strategy is designed to characterize spawning gravel composition on a segment scale in streams where there is no prior data available on variation in gravel composition to guide sample design. (For streams with existing data, it may be preferable to develop custom sampling strategies based on segment-specific variation). This method was developed by examining four existing large data sets from Washington State to determine variation within and among riffles. It uses a two-stage sample design with riffle crests as the primary sample units and samples within riffle crests as the secondary sample units. Systematic sampling of riffle crests (with a random starting point) is recommended to avoid potential clustering, because fine sediment may systematically increase in a downstream direction as gradient decreases. Based on the existing data we examined, a coefficient of variation of less than 20% can be achieved by collecting a minimum of three samples per riffle crest and sampling as many riffle crests as possible, but no fewer than 10% of the total riffle crests in each segment.

The following recommendations for sampling riffle crests are based on the number of riffle crests in the stream segment, and seek to maximize the number of riffle crests sampled within the logistical constraint of keeping the total number of samples per segment under 20.

To determine the number of riffle crests to sample, refer to your inventory of riffle crests for total number of riffle crests in the segment. In the left hand column of Table 1, locate the appropriate row corresponding with the segment total. The second column on that row will state the percentage of riffle crests to be sampled. For example, if 17 riffle crests were inventoried, then the third row (13 - 18) would be selected so 33% of the riffle crests should be sampled.

Next, select a random starting number using a random number generator, die, or a random number table (provided in Appendix A). Use the third column in Table 1 to determine the appropriate range of random numbers to select from. Then find the appropriate box in Table 2 to determine the sequence of riffle crests to sample.

Table 1. Recommendations for sampling riffle crests (RC's).

Total No. of RCs	Percent of RCs sampled	Choose random number between	Total Samples
0 - 6	100%	-	3 - 18
7 - 12	50%	1-2	9 - 18
13 - 18	33%	1-3	12 - 18
19 - 24	25%	1-4	12 - 18
25 - 30	20%	1-5	12 - 18
> 30	12.5%	1-8	9 +

Table 2. Selection of systematic sampling sequences.

Random No.	50%	33%	25%	20%	12.5%
1	1,3,5,7 9,11	1,4,7,10,13,16	1,5,9,13,17,21	1,6,11,16,21,26	1,9,17,25,33, 41 etc.
2	2,4,6,8 10,12	2,5,8,11,14,17	2,6,10,14,18,22	2,7,12,17,22,27	2,10,18,26,34, 42 etc.
3		3,6,9,12,15,18	3,7,11,15,19,23	3,8,13,18,23,28	3,11,19,27,35, 43 etc.
4			4,8,12,16,20,24	4,9,14,19,24,29	4,12,20,28,36, 44 etc.
5				5,10,15,20,25,30	5,13,21,29,37, 45 etc.
6					6,14,22,30,38, 46 etc.
7					7,15,23,31,39, 47 etc.
8					8,16,24,32,40, 48 etc.

Determining Specific Points to Collect Samples

Identifying Sampling Points at Riffle Crests

At each riffle crest selected for sampling, samples are taken on a line extending across the channel along the riffle crest. If the riffle crest extends diagonally across the channel, the line should follow the riffle crest. Begin by extending a fiberglass tape across the wetted channel at the riffle crest. Three samples should be taken at each riffle crest (Figure 4). To determine these locations, identify the mid-point of the line across the riffle crest and take a sample. Take another sample two-thirds of the way between the mid-point of the cross-section and the wetted perimeter on the left bank, and the third two-thirds of the way to the wetted perimeter on the right bank. If the spot selected is on a dry bar or in still water, go to the nearest suitable location along the line. If you are unsuccessful taking a sample at a selected location because of substrate conditions, try sampling laterally along

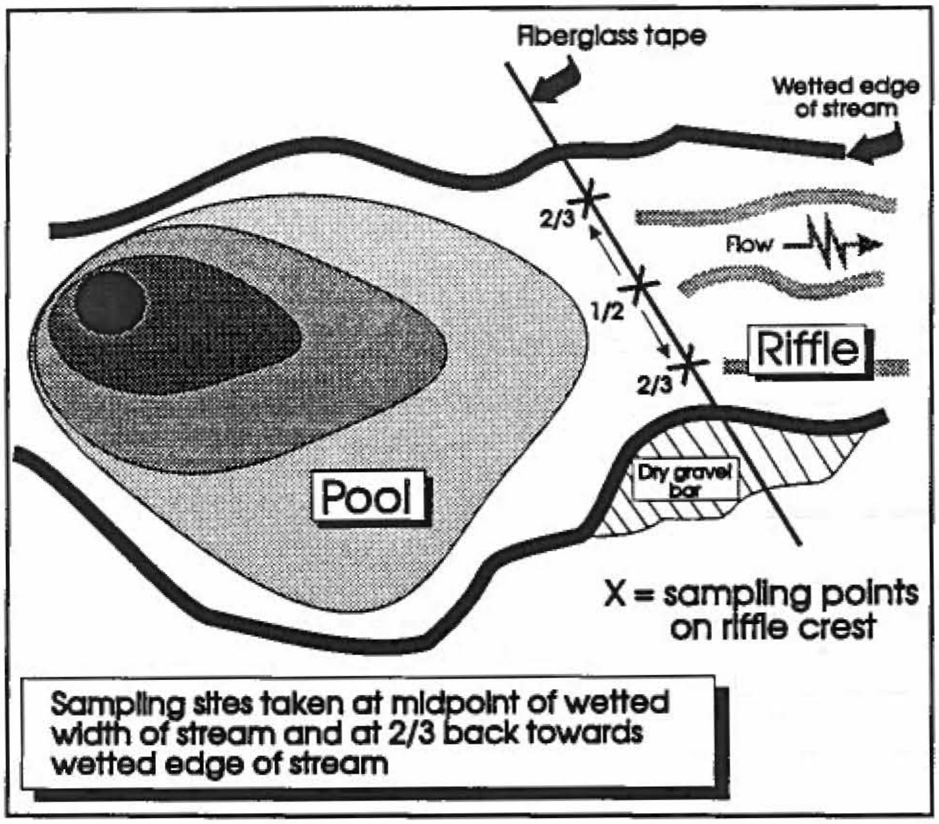

Figure 4. Sampling points at riffle crests.

the transect, remaining as close to the original point as possible.

Occasionally, it may prove to be impossible to sample a riffle crest. For example, the substrate concealed under the surface layer is occasionally much larger than the visible particles. In situations where you are unsuccessful in collecting samples from a riffle crest, randomly select either the upstream or downstream adjacent riffle crest and collect the samples at this location. Be sure to note this change in your field notebook.

Identifying Sampling Points in other Situations

In some cases, particularly when channel gradient is greater than two percent, or in streambeds predominately composed of large particles, spawning gravel may occur in small patches associated with woody debris or boulders, rather than in association with channel features such as riffle crests. In these situations identify and number each patch of spawning gravel greater than two square meters in size in the sampling reach. Take one sample in the center of each patch.

Collecting Samples with the McNeil Gravel Sampler

The McNeil sampler was selected to collect samples of potential spawning gravel for analysis as recommended by Peterson et al. (1992). It was chosen for the following reasons:

1) it is a reliable sampling device that is simple to operate;

2) although bulky, it is relatively portable and requires little auxiliary equipment;

3) it has been used in Washington State for survival to emergence studies that were the basis of the Forest Practices Board cumulative effects threshold values for spawning gravel fine sediments.

The McNeil gravel sampler is designed to take a core sample of the gravel substrate. A schematic diagram of the sampler is shown in Figure 5. The bottom of the sampler consists of a 15 cm (6 inch) diameter stainless steel coring cylinder with an open bottom and top. The coring cylinder is designed to penetrate into the streambed gravel to a depth of 25 cm (10 inches). The top of the coring cylinder extends up through the bottom of the larger (35 cm diameter) collection basin, where gravel from the core is temporarily stored during excavation of the core. The collection basin is open on the top. A horizonal steel rod attached across the top of the collection basin acts as a handle.

There is also a plunger, inserted into the coring cylinder to retain sediment-bearing water after extraction of the sample. The plunger consists of two metal disks, just slightly smaller in diameter than the inside of the coring cylinder, attached to the end of a long handle. Between the metal disks is a piece of neoprene that is slightly larger than the inside of the coring cylinder and acts as a seal. A hole through the disks with a one-way flapper valve allows the plunger to be inserted without forcing the water down into the streambed, but prevents water from escaping when the sampler is lifted. When fully inserted, the plunger comes to rest on a small stop-ring on the inside of the coring cylinder.

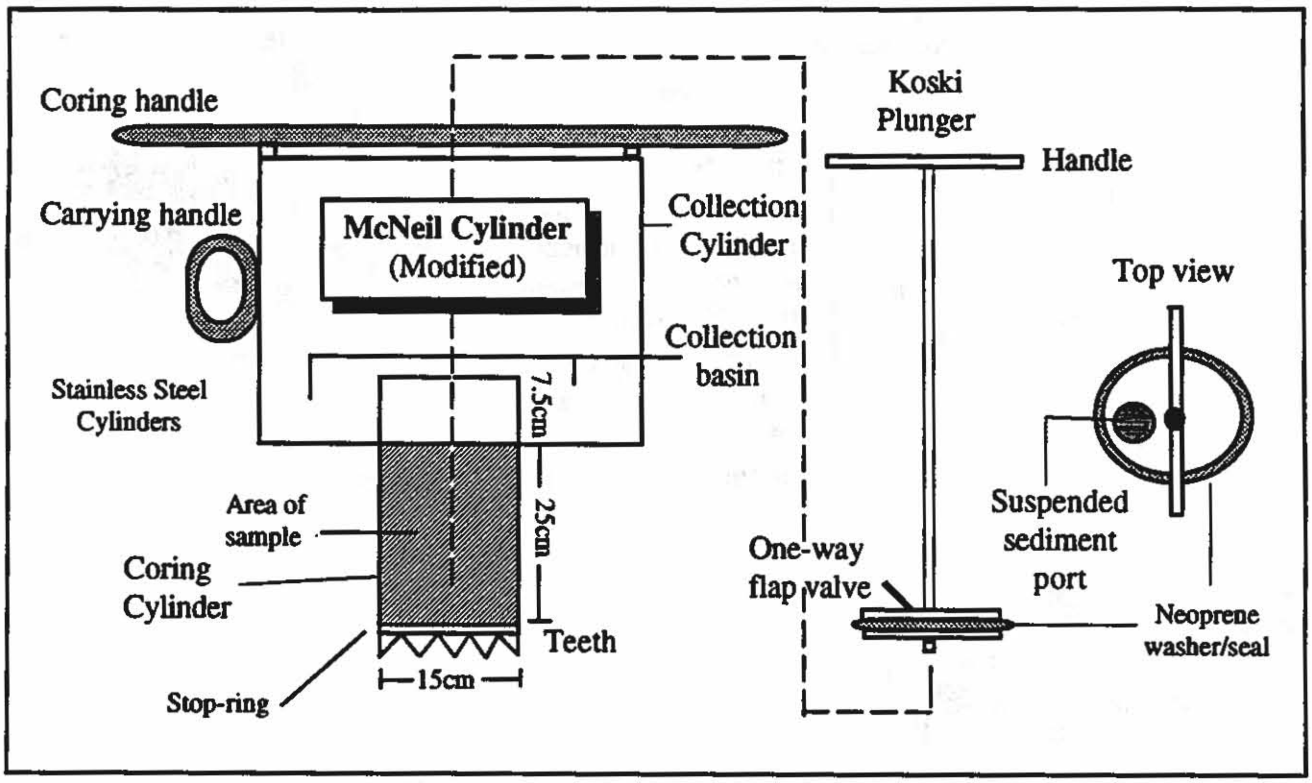

Figure 5. Schematic diagram of a modified McNeil Cylinder.

Taking a Sample with the McNeil Gravel Sampler

Step 1. Before taking a sample, rinse the sampler to insure it is free of sediment. Approach the sampling site from the downstream side to avoid disturbance prior to sampling. Place the bottom of the coring cylinder on the surface of the substrate. Grasp the handle on top of the collection basin, placing one hand on each side of the rod outside of the basin (Figure 6). Twist the handle back and

Figure 6. Grasp handles.

Figure 7. Forcing cylinder into gravel.

forth, alternately pushing one arm forward away from your body and pulling the other back towards you. As you twist the sampler in this manner, hunch your shoulders over it, using the weight of your upper body to force the sampler straight down into the gravel (Figure 7). The combined grinding and pressing action should force the sampler down into the substrate, however the rate of progress will depend on the size of the particles and the degree of compaction. Avoid side to side and up and down agitation which causes fine sediment particles to filter down throught the large particles, changing the composition of the sample (Figure 8). If you encounter resistance, do not raise and lower the cylinder. The only time you should lift the coring cylinder is when you want to remove the sampler and try a different site.

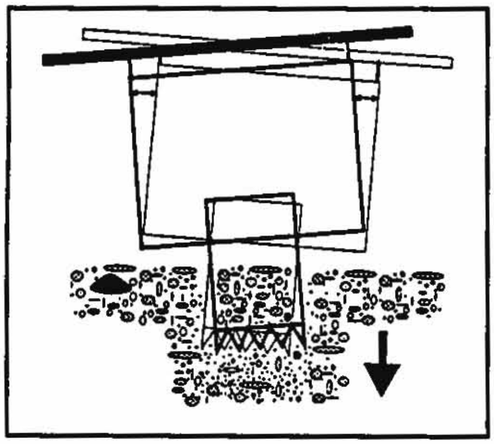

Figure 8. Avoid side to side and up and down movement while inserting cylinder.

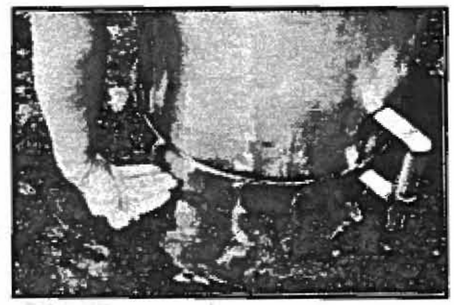

Figure 9. Use your hand to check if cylinder is fully inserted.

The sampler is fully inserted when the bottom of the collection basin is resting on the streambed (Figure 9). Sometimes large particles, wood, or bedrock will prevent the sampler from being fully inserted. In these cases, remove the sampler, rinse it out, and try another undisturbed location in the immediate vicinity.

Figure 10. Remove gravel matrix with hand.

Step 2. After the sampler is successfully inserted, carefully remove the gravel/sand matrix from the coring cylinder with your hand (Figure 10). Excavate the gravel slowly, layer by layer, using your hand as a scoop (Figure 11), so that both gravel- and sand-sized materials are removed together. As much as possible, avoid plucking out the larger particles and allowing the finer material to continually settle to the bottom of the excavation. Place the excavated material in the collection basin around the coring cylinder (Figure 12). As you dig, occasionally run your fingers along the inside of the cylinder, feeling for the protruding stop-ring. When you locate the stop-ring, level the excava-

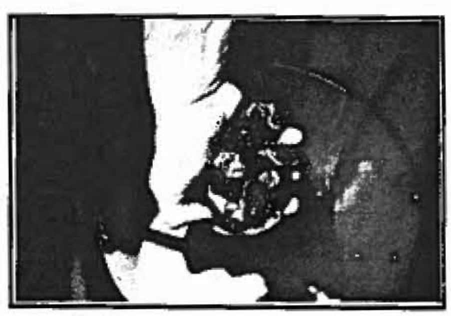

Figure 11. Use hand as scoop.

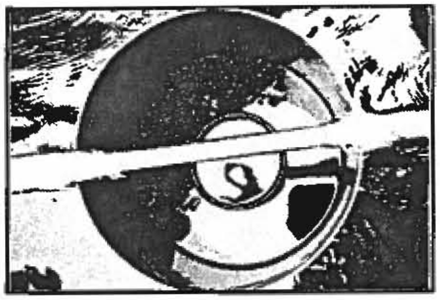
Figure 12. Collection Basin.

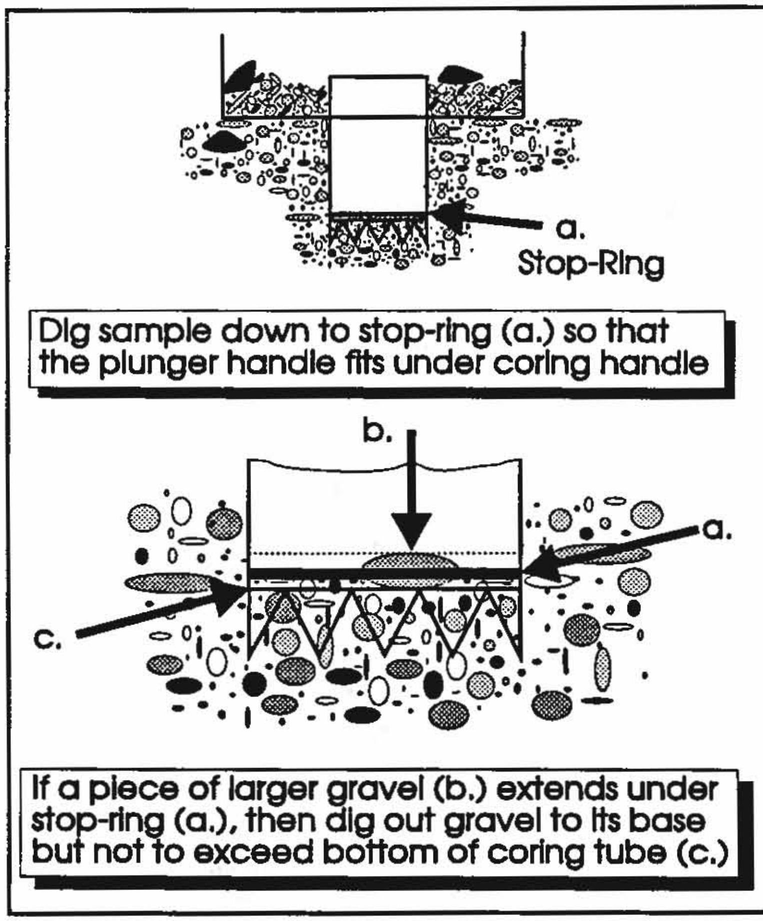

Figure 13. Stop-ring protocol.

tion off just below the top of the ring (Figure 13). The removal of the sample is now complete. Occasionally a larger particle will partially protrude above the ring. In these cases, the particle should be removed, along with the surrounding material to avoid bias. In this case the excavation will go below the top of the ring, however it should not exceed the depth of the coring cylinder. If the protruding particle extends below the bottom of the coring cylinder, it will be necessary to start over with a new sample.


Figure 14. Rinse arms and hands.

Step 3. After you complete digging, rinse the fine particles clinging to your hand and arm into the collection basin with the rinse bottle (Figure 14). Then, insert the clean plunger into the top of the coring cylinder (Figure 15) and slowly push the plunger down into the cylinder. Don't push the plunger too rapidly or water will not have time to pass through the one-way valve as the plunger is lowered and silty water will be forced down into the substrate (Figure 16). If this occurs, you will often notice a turbid cloud emerging from the substrate just downstream of the sampler. When the plunger comes to rest on the stop-ring near the base of the coring cylinder the sampler is ready to be removed (Figure 17). The sampler is designed so that when the plunger is fully inserted and resting against the stop-ring, the plunger handle fits under the handle of the sampler.


Figure 15. View of plunger.

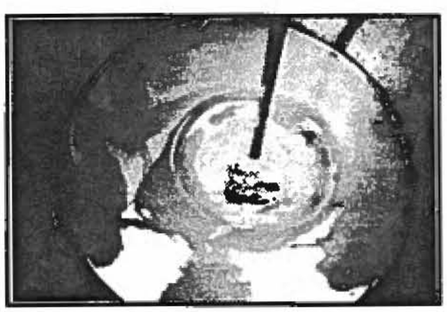
Figure 16. Insert plunger slowly.

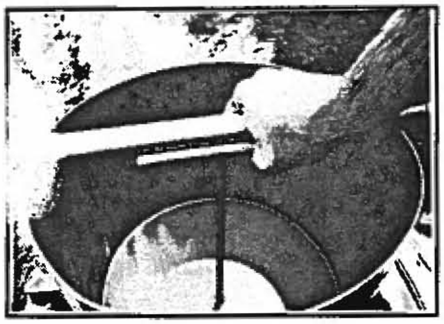

Figure 17. Plunger fully inserted.

Figure 18. Pour sample into clean bucket.

Step 4. Lift the sampler out of the substrate and carefully pour the gravel and water from the sampler into a clean plastic bucket (Figure 18). A five gallon bucket will usually hold a sample, however samples taken in deep areas contain more water and may require two buckets. After pouring the sample into the bucket, carefully rinse out the sampler with the rinse bottle, taking care to insure that fine particles that were inside the sampler end up in the bucket, while any on the outside of the sampler do not (Figure 19).

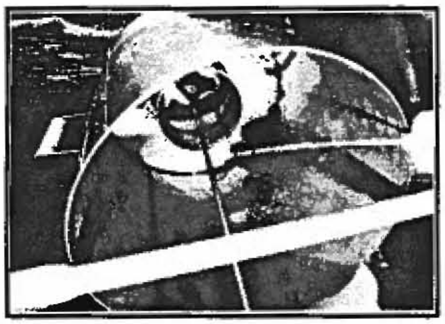

Figure 19. Rinse cylinder into bucket.

Step 5. Finally, fill out a label on waterproof paper with the date, stream name, segment number, riffle-crest number, bucket/sample number, and crew names (Figure 20). Appendix B provides a page of sample labels that can be copied on waterproof paper. The outside of the bucket and its lid should have a discrete number, inscribed or marked with permanent marker. Seal the bucket with a tight-fitting lid, placing the label in the bucket with a corner under the rim of the lid, so the label is inside the bucket above water level. Record the information in your field notebook or data sheet.

Date: ______________________________
Stream: ____________________ Seg.# ______
Riffle Crest #: ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient
Monitoring
Gravel Sample

Figure 20. Gravel sample label for bucket identification.

Appropriate Times to Collect Samples

Spawning gravel composition (particularly fine sediment levels) in a stream reach can vary over the course of the year. In western Oregon streams, substrate composition was relatively stable from early summer to early fall, and was most variable during the winter storm season when peak flows mobilized the substrate and the processes of fine sediment infiltration were most active (Adams and Beschta, 1980). In order to provide a management indicator of substrate composition that can be used to compare stream reaches and determine trends over time, sampling should be conducted during moderate to low flow conditions outside of the winter-spring high runoff period. The actual timing of the high runoff period will vary depending on the hydrologic regime of the system. If you are unfamiliar with the system to be sampled, consult with people familiar with the system or refer to USGS stream flow records to determine an appropriate sampling period.

Collecting spawning gravel samples during extremely low flow conditions is also to be avoided, because only a small portion of the potentially available spawning habitat will be wetted. This may introduce bias into site selection. We do not recommend sampling areas that do not have water flowing over them such as dry, exposed bars because the potential effect this may have on the sampling process or the composition of the sample is unknown.

It is usually ideal to sample in the late summer/early fall low flow period when conditions are similar to those encountered by salmonids when they begin to spawn. Avoid working in the channel during spawning or when there are eggs in the gravel, to prevent unnecessary disturbance and mortality to salmonid populations.

Methods for Processing Spawning Gravel Samples

Two options are provided for processing spawning gravel samples. The **volumetric method** determines particle size distribution based on the volume of material in various size classes, measured while damp. The **gravimetric method** calculates the particle size distribution based on the weight of material that has been oven-dried. There are advantages and disadvantages to both methods. The greater labor and more elaborate equipment required by the gravimetric method make it more expensive, but the procedure eliminates many potential sources of inaccuracy and provides data meeting geology and engineering standards. The volumetric method is faster and requires less equipment, reducing processing costs, but it provides greater potential for inaccuracies. The choice of methods is left to the cooperator, depending on data needs and the time and equipment available. During data anaylsis, gravimetric data will be converted to volumetric equivalents and vice-versa.

The Volumetric Processing Method

The volumetric method of processing spawning gravel originated with Dr. William McNeil's studies of pink and chum salmon spawning grounds in southeast Alaska in the late 1950's (McNeil and Ahnell, 1960). This method has been used, with refinements, in many additional studies of spawning gravel in Washington State (Cederholm and Lestelle, 1974; Tagart, 1976). The procedure involves washing the gravel sample through a series of sieves and measuring the volume of material collected on each sieve to characterize the composition of the sample.

The recommended sieve sizes provide a geometric progression of categories adequate to characterize the overall particle size-distribution of the sample, and include the 0.85 mm size-class that has been correlated with survival to emergence of salmonids. In some cases, cooperators may not have all of the suggested sieves, or may have a set with somewhat different sizes. At a minimum, it is essential to have the 0.85mm sieves and at least three sieves smaller than 0.85mm and four sieves larger than 0.85mm at geometrically spaced intervals.

Equipment Needed

Sieves- 12" diameter- one each of the following sizes:

64.0 mm
32.0 mm
16.0 mm
8.0 mm
4.0 mm
2.0 mm
1.0 mm
0.85 mm
0.5 mm
0.25 mm
0.125 mm

1-Sieve holder
1-Catch basin
1-Stand
1-Hose connected to pressurized water supply
1-Nozzle that can be used to control water usage
4-Graduated cylinders, modified to attach with flexible tubing to the bottom of the catch basin
1-Flexible tubing
1-Displacement flask, with rubber tubing on outlet and clip to control flow
1-Graduated cylinder- 1000 ml
1-Graduated cylinder- 500 ml
1-Graduated cylinder- 100 ml
1-small cup
3-kitchen timers
1- sturdy table
1-level (2 or 4 ft)
Forms for recording data
Pencils
Rain gear

Processing Samples

Setting Up the Processing Laboratory

The lab should provide protection from the weather, but must be capable of handling water on the floor. An enclosed room with heat, electricity, a water faucet and a concrete floor with a drain is ideal for volumetric processing in all weather and temperature conditions.

The stand that holds the sieves and the catch basin should be placed on a level surface, so that it will remain stable and withstand jostling. It should be elevated to allow water to drain from the catch basin into a graduated cylinder. Volumetric measurements are made on a table ideally located in the same room as the stand holding the sieves, but out of the way to avoid being bumped by people working around the stand. The table should be level to ensure accurate readings. Check the surface of the table with a level and use small shims of wood under the legs to level it.

Washing Samples Through the Sieves

Once the lab has been set up, you are ready to begin processing samples.

Step 1. Begin by filling out a spawning gravel composition data form each day. Appendix C contains a copy of this form that can be copied on waterproof paper. Use a separate form for each stream segment. Record the steam name, WRIA number, segment number, the date of processing, date the sample was collected, and the name and affiliation of the person(s) processing the samples. Note the processing method used. Record the sieve sizes (in descending order) in the column on the left hand side of the form. Don't forget to include a row for the material captured in the graduated cylinder attached to the bottom of the catch basin. Label this row "less than" the smallest sieve size (for example, <.125mm).

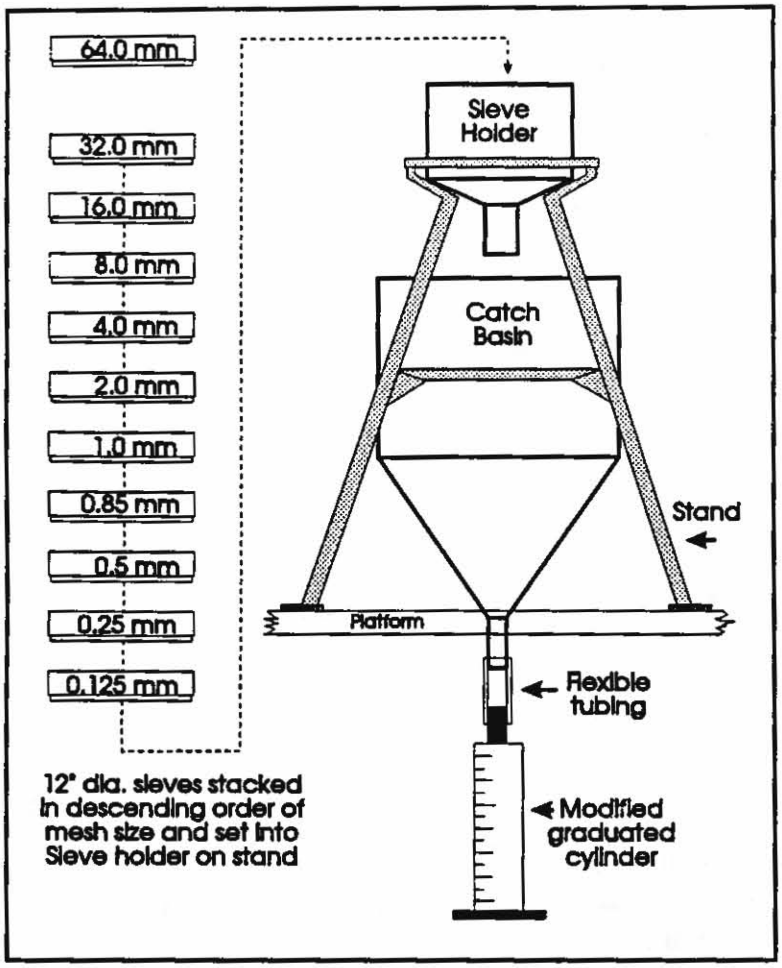

Figure 21. Diagram of a volumetric gravel processing station.

Step 2. Next, rinse out the catch basin and place it in the stand (Figure 21). Use a short piece of tight-fitting flexible tubing and hose clamps to attach a specially modified graduated cylinder to the outlet of the catch basin. These cylinders must have a plumbing fitting glued into the top that allows them to be attached to the rubber hose without leaking.

Before beginning to sieve samples, it is imperative to check and make certain that a graduated cylinder has been attached to the bottom of the catch basin (Figure 22). Forgetting to attach one will result in irretrievable loss of the finest sediments, and the sample must be disgarded.

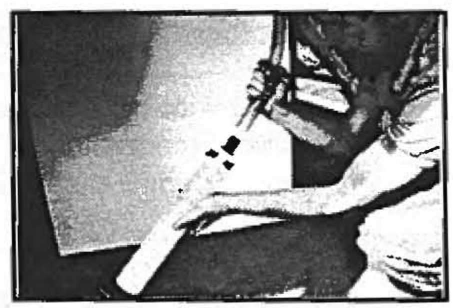

Figure 22. Graduated cylinder attatched to bottom of catch basin.

Step 3. Place the sieve holder in the top of the stand. Stack the sieves one on top of another in order of descending mesh size, so that the one with the largest mesh size is on the top and the one with the smallest mesh size is on the bottom. Place the tightly nested stack of sieves in the sieve holder. It is important to have the sieves in perfect descending order, otherwise the material will not be properly sorted and the sieve that is out of order will become clogged.

Step 4. Open the plastic bucket containing the sample and remove the tag. Record the sample number and riffle crest number off the tag at the top of the appropriate column of the gravel sample composition data form.

Step 5. Lift the bucket to the top of the stack of sieves, and carefully pour the contents into the top sieve without spilling gravel or water (Figure 23). Using the hose and nozzle, carefully rinse any particles remaining in the bucket, or on the inside of the lid, into the sieves (Figure 24). The entire

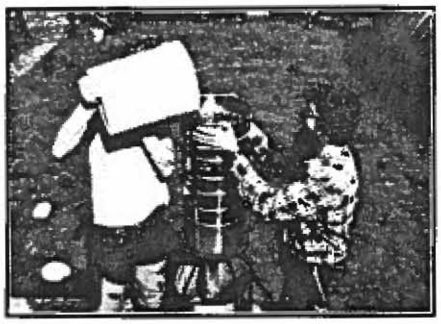

Figure 23. Pour contents of bucket into top sieve.

contents of a bucket should empty into the sieves at one time, because the water in the sample washes the finer particles down into the stack of sieves. However, if the top sieve becomes full, stop and shake the material down before continuing to empty the sample bucket.

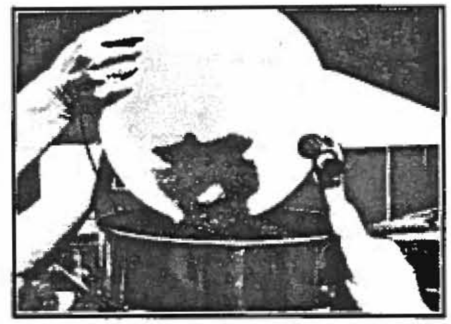

Figure 24. Rinse sample bucket thoroughly.

Step 6. Shake and wash the particles through the sieves. It is important to be thorough so that the material is accurately sorted by size class. Failure to thoroughly wash material through the sieves will result in inaccurate results because the volume of the smaller particle size-classes will be underestimated.

To force the material through the sieves, use a combination of shaking and washing. Begin by grasping the outside of the sieves and forcefully shaking them back and forth. Be careful not to shake material out of the top sieve onto the floor, or to dislodge sieves from the stack or the sieve holder. When you no longer hear particles rattling down through the sieves, use a fine spray from the nozzle to carefully rinse the material in the top sieve (Figure 25).

Figure 25. Shaking and washing sieves.

The goal is to wash all particles small enough to pass through the screen into the next sieve. It often helps to jostle the sieve stack while washing. Make sure the stream of spray from the nozzle is not too powerful and is directed downward, or it may drive fine particles out of the sieve and onto the floor. When all the smaller particles have been washed down into the next sieve, remove the top sieve (Figure 26) and lean it up at a 45 degree angle to drain while you work on the other sieves. Repeat the procedure on each successive sieve until all sieves have been carefully washed and set to drain (Figure 27).

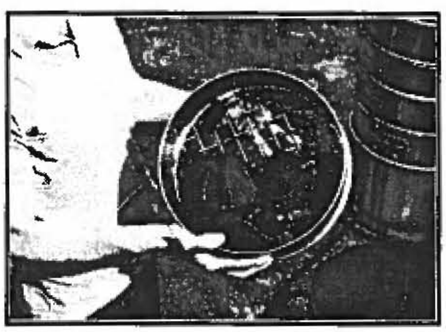

Figure 26. View of top sieve after all finer particles have passed through mesh.

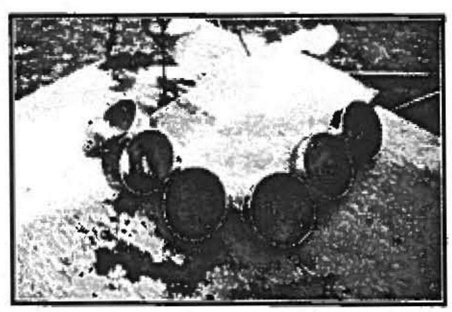

Figure 27. Set sieves at 45° angle to drain.

Working with fine materials on the small-mesh sieves is challenging because there is little difference in diameter between the size-classes. The particles are layered on top of one another and cling together, and it is difficult to force them through the small openings. Concentrate and work carefully, using the spray from the nozzle to move the particles around the screen (Figure 28). All particles must come in contact with the screen and have an opportunity to be washed through. Use an adequate amount of water during processing to ensure good results. However, there is a limit to the amount of water that can be held by the catch basin without causing an overflow. Monitor the water level in the catch basin to avoid overfilling it. If the catch basin overflows and suspended fine sediments are lost, the sample should be disgarded.

Figure 28. Concentrate and work carefully.

Step 7. While the sieves are being washed, water passing through them drains into the catch basin, carrying clay and silt particles fine enough to pass through the smallest screen. The wash water is captured in the catch basin, and the fine sediment particles settle to the bottom and slide down the steep sides of the catch basin into the graduated cylinder. Make sure the rubber hose connecting the graduated cylinder is not twisted or pinched, so flow of sediment into the cylinder is not obstructed. In order to ensure consistent results, adequate time must be provided for sediment to settle into the graduated cylinder. Wait 20 minutes from the time you finish washing sieves before removing the graduated cylinder from the bottom of the catch basin. Use this time to begin volumetric measurement of the contents of the sieves.

Measuring the Volume of Material in the Sieves

Measure the volume of material in each sieve. Begin with the sieve having the largest mesh size and work down in the same order that the sieves were washed. This helps to ensure that each sieve drains for a similar amount of time. It is important to allow time for water to drain from the spaces between the particles because water mixed with the particles will create additional displacement, resulting in an overly high volume measurement. Some inaccuracy is unavoidable because water will be held between the smaller particles by capillary action. This is an inherent disadvantage of the wet-volume method. To minimize this problem, all sieves should drain for 15 minutes.

Step 1. Check and make sure the sample number and riffle crest number are recorded on the data form.

Step 2. Before measuring the volume of material for a set of sieves, fill the displacement flask with water to a level above the outlet tube. Then, use the control valve to open the outlet hose and allow the excess water to drain. When no additional water comes out, close the outlet tube (Figure 29). The displacement flask is now ready.

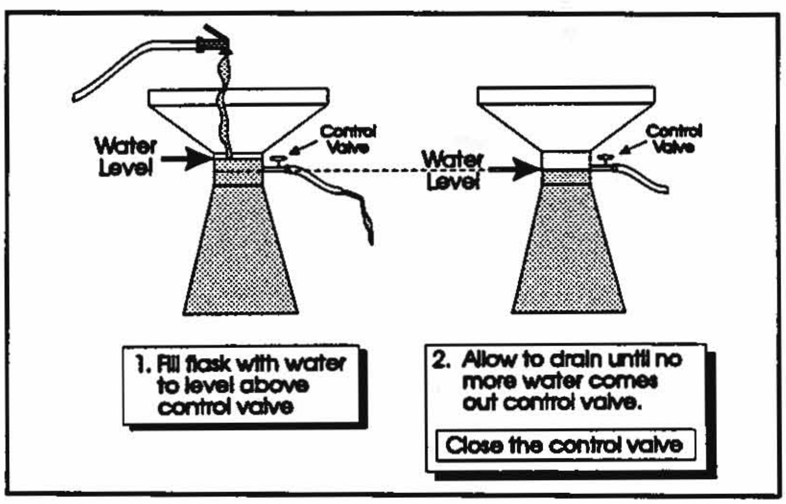

Figure 29. Displacement flask preparation.

Step 3. Empty the material from the first (largest diameter)

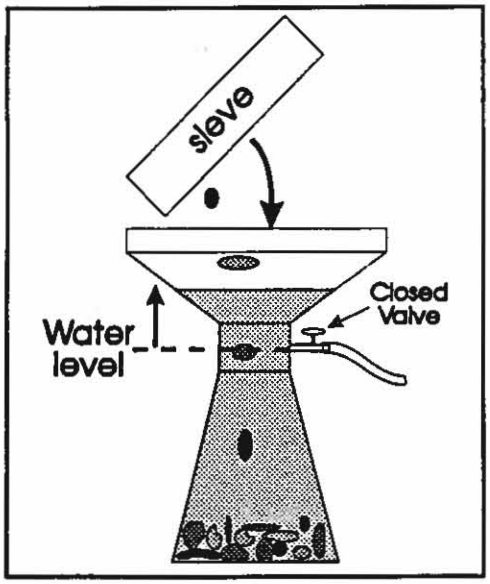

Figure 30. Empty sieve material into flask. Make sure valve is closed.

sieve into the displacement flask (Figure 30). Before putting material from the sieve into the displacement flask, always make sure the outlet tube is closed. Hold the sieve over the displacement flask and carefully pour the particles out of the sieve into the displacement flask, taking care not to splash water out. Be thorough and remove all material from the sieve. It is difficult to remove small particles from sieves with fine screens. It helps to use a small cup to dip water out of the displacement flask and wash sediment from the screen into the displacement flask (Figure 31). Be very careful to spill no water because all the water that is dipped out of the displacement flask must return to the flask or the measurement will be inaccurate.

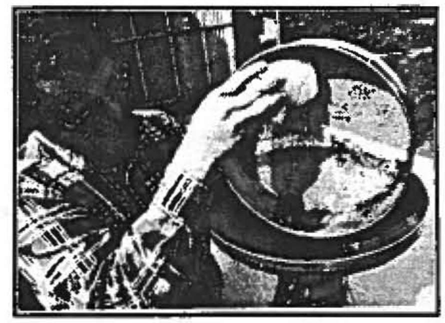

Figure 31. Use cup to wash fine particles from screen into collection pan.

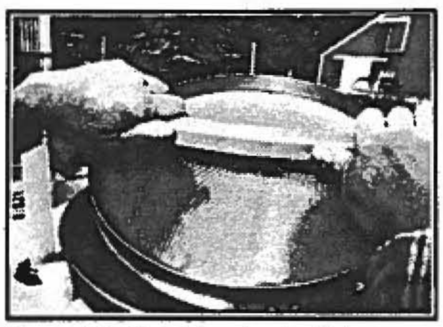

Figure 32. Brushing back of sieve screen to remove embedded particles.

Tap the excess water out of the cup into the displacement flask when you are done washing the screen. Brushing or scraping the back of the screen will help to remove particles that are lodged in the screen (Figure 32). Although it may be impossible to remove all particles from the mesh of some of the screens, they should be thoroughly clean before the measurement is taken.

When you are done cleaning the sieve, use the cup to dip water from the flask and rinse all the particles from the surface of the collection pan into the water (Figure 33). Tap the excess water out of the cup into the displacement flask when you are done.

Figure 33. Rinse collection basin with flask water.

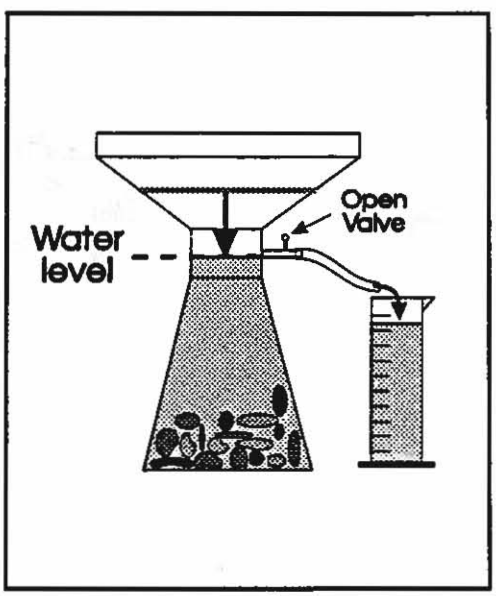

Figure 34. Place graduated cylinder under outlet tube and open valve to record volume displaced.

Step 4. After the water in the flask has become still, open the valve on the outlet tube and drain the excess water into a graduated cylinder (Figure 34). Choose the smallest cylinder that will hold the water. After a little experience you will be able to judge the size of cylinder needed from the amount of material in the sieve. If you underestimate, close the valve on the tube before the cylinder overflows and get a larger one. Close the valve after water stops coming out. Set the graduated cylinder on the table, read the line on the graduated cylinder corresponding with the top of the water (Figure 35) and record the volume in milliliters under the appropriate column on the form. Take care because the various sizes of graduated cylinders use different scales. It is also a good idea to check calibration among cylinders for manufacturing error at the start of a season or when replacing a cylinder.

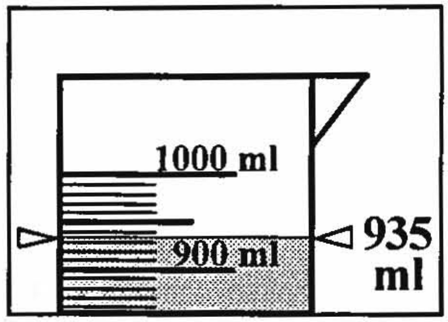

Figure 35. Read volume of water in graduated cylinder.

Step 5. Record the volume measurement (in milliliters) in the appropriate column on the spawning gravel data composition form.

Step 6. Continue to measure and record the volume of material captured on each successive sieve using the same procedure. The displacement flask should have adequate capacity so that it will not have to be emptied until the set of sieves is done.

Step 7. After all the sieves in the stack have been done, remove the graduated cylinder from the bottom of the catch basin, allowing the additional water to evacuate from the basin. Put the cylinder on the table, with a tag identifying the sample number, and set the timer for 60 minutes (Figure 36). When the timer rings, record the amount of sediment that has settled out in the bottom of the cylinder. In the meantime, clean out and reset the displacement flask, rinse out the catch basin, attach another clean cylinder, and begin processing another sample.

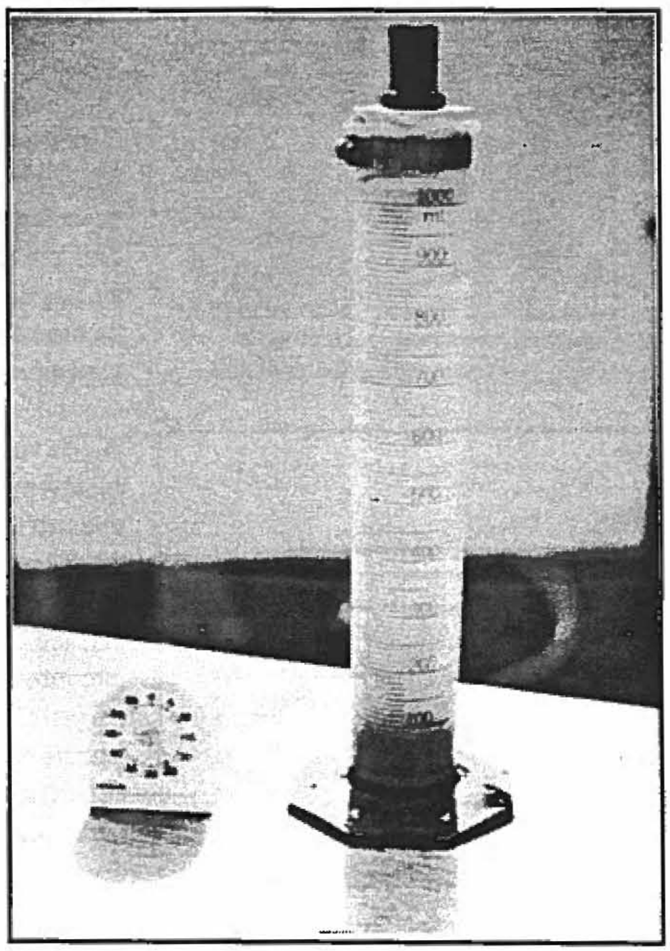
Figure 36. Clay and silt sediments must settle for 60 minutes before recording the volume they displace.

The Gravimetric Processing Method

The dry or gravimetric method of processing spawning gravel samples has its foundation in the engineering (materials testing) and soil sciences. Outside of Washington, fisheries biologists have increasingly used this methodology (Lotspeich and Everest, 1981, Shepard et al., 1984, Platts et al., 1989). Although the cost of equipment makes the gravimetric technique more expensive, it has a decided advantage in terms of precision. The analysis procedure is conceptually similar to that of the volumetric method, with the main differences involving drying of samples and weighing of individual sample size.

Equipment Needed

11- Sieves (300 mm dia)- one each of the following sizes:

64.0 mm
32.0 mm
16.0 mm
8.0 mm
4.0 mm
2.0 mm
1.0 mm
0.85 mm
0.5 mm
0.25 mm
0.125 mm

1- Drying oven (Gilson BO-550). Note: Many options available here, check with various scientific supply companies. Regular domestic ovens will also work.
1- Triple beam balance (20 kg capacity)
6- Drying pans (stainless steel, 52.5 x 32.2 x 10.1 cm)
11- Weighing pans (34.29 cm diameter, 8.9 cm height)
1- Mechanical shaker
1- Sample splitter (necessary if sieves become overwhelmed by fines)
Filter masks
Forms for recording gravel composition data (Appendix C)
Pencils

Lab requirements for gravimetric processing are similar to those for the volumetric method. A dry, dust-resistant room, with a concrete floor, good lighting and ample electrical outlets is necessary. Because the shaking process is noisy, try to locate the lab away from other co-workers. A sturdy table to place the balance and record data is also nice. It is recommended that the mechanical shaker be bolted to a secure base, as vibration and movement of the unit can be significant.

Processing

Field collected samples (previously stored in individual, labelled 5-gallon buckets) must be dried prior to processing. Sample buckets should be left undisturbed for 48 hours to allow the suspended fraction to drop out. Carefully open the lids of the sample buckets to be processed. Inspect the volume of water in each gravel sample. If there is significant water in your sample, carefully siphon or pump away excess supernatant (clear water) to within five cm of the gravel layer.

Place samples in individual drying trays making sure that the bucket is cleaned of remaining sediment particles. Be sure to include the metal identification tag as well. Drying trays should be large enough to contain the entire McNeil sample. Oven dry your sample for 12-24 hours at between 50-105 degrees centigrade. Experience will dictate the time and temperature setting for efficient processing of your samples. If you are sampling in geologies dominated by clay, use a lower temperature setting, as some researchers have reported fracturing of gravel and rubble particles.

Once your samples have been dried and cooled, they can be sieved. Check to see that the sieves are in descending order. Place them into the shaker frame, and add the gravel sample to the sieve stack. Place the shaker lid over the largest sieve, then adjust and tighten the adjustment bolts and set the shaker timer for five minutes. In clay geologies a longer shaking time may be necessary. If using the recommended Phi-series of sieves it will be necessary to shake each sample through 11 sieves. Because standard shakers hold only 6 sieves, the investigator must shake the sample through the larger 5 sieves, then again through the final 6 small sieves. Once the samples have been shaken, remove each size sieve and place the sample portion into individual weighing pans.

As sieve size decreases, the sieves will become increasingly "clogged" with sediment. Be sure to thoroughly clean each sieve with the appropriate brush. It is a good idea to pre-mark each weighing pan to a corresponding size class and to clearly mark the tare weight of the pan. Samples can then be weighed on the balance. The total weight of the sample/pan minus the tare weight equals the sample weight. Record the weight of material in each sieve on the form in Appendix C.

Data Analysis

Data analysis will be provided by the Ambient Monitoring Program for spawning gravel composition data collected by cooperators using the spawning gravel composition module. Forms are provided for recording spawning gravel composition data. Cooperators will have their data entered into a database where it will be analyzed and will receive a data summary sheet and a copy of their database on floppy disk.

Spawning gravel composition has been characterized in a variety of ways by different investigators. Young et al. (1991) evaluated 15 different measures of substrate composition. They determined that geometric mean diameter (Dg) was the most sensitive measure of survival to emergence and the percentage of particles less than 0.85mm was the most sensitive indicator of changes to substrate induced by land management activities. They concluded that no single measure would be adequate to describe both potential survival to emergence and alteration of substrate due to land management activities.

Consequently, substrate samples will be analyzed using both measures. The percentage of particles less than 0.85mm (volumetric equivalent) will be calculated for each individual sample and the segment average will be provided for use in Watershed Analysis. In addition, the geometric mean diameter (gravimetric equivalent) will also be provided. The results of the data analysis will be contained in a spawning gravel fine sediment segment summary report provided to cooperators.

Data Analysis for Individual Samples

Information on the amount of material retained on each sieve will have been recorded in either grams or milliliters depending on the processing method used. This information will be entered into the database and a conversion factor will be used to calculate equivalent gravimetric values for volumetric data or volumetric equivalents for gravimetric data.

The amount of material retained on each sieve, the percentage of the total it represents, and the cumulative percentage less than the next sieve size will be calculated separately for both the volumetric and gravimetric values. The cumulative percent less than the next largest sieve size will be calculated for each sieve size by summing the amount of material on that sieve and all smaller size classes and dividing this figure by the total material in the sample.

Similarly, the percentage of fine sediments less than 0.85mm will be calculated by summing the total amount of material in the size classes less than 0.85mm and dividing by the total amount of material in the sample. The geometric mean diameter will be calculated with the formula used by Young et al. (1991) from Lotspeich and Everest (1981).

Information on the amount and percentage of material retained on each sieve, in both volumetric and gravimetric equivalents, will be reported for each sample in the spawning gravel fine sediment segment summary report. The cumulative percentage less than each sieve size, the percentage of material less than 0.85mm, and the geometric mean diameter for each sample will also be reported.

Data Analysis by Stream Segment

The mean percentage of fine sediments less than 0.85mm (and standard deviation) and the mean value for geometric mean diameter will be calculated and reported for each segment in the segment summary report. The average value for geometric mean diameter is calculated by summing the individual geometric mean diameter values for all the samples in the segment and dividing by the total number of samples. The average value for percentage of fine sediments less than 0.85mm is calculated by summing all the individual sample values for percent fine sediment values less than 0.85mm and dividing by the total number of samples from the segment.

In addition, individual samples within the segment will be sorted into three categories utilized in Watershed Analysis. The categories are based on the percentage of fine sediment less than 0.85mm and include: samples with less than 12% fine sediment, samples with 12-17% fine sediment, and samples with greater than 17% fine sediment. The number and percentage of individual samples falling in each category will be calculated and displayed in graphic form in the segment summary report.

Training, Field Assistance and Data Processing

This manual is intended as a reference for those collecting information on spawning gravel composition in conjunction with the TFW Ambient Monitoring Program and Watershed Analysis. It is difficult to rely solely on a manual to learn and implement the methodology, so the TFW Ambient Monitoring Program offers formal training sessions and informal field assistance visits to help cooperators learn the methodology. In addition, the Ambient Monitoring Program also provides a quality control service to identify and correct inconsistencies in application of the methods and to ensure replicable and consistent data is being collected throughout the state.

We encourage cooperators to utilize these services. Please contact the Northwest Indian Fisheries Commission (1-206-438-1180) for more information concerning the TFW Ambient Monitoring Program.

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APPENDIXES

Appendix A.
Random Number Table

Appendix B.
Labels for Sample Buckets

Appendix C.
Forms for Recording Gravel Composition Data

APPENDIX A

TABLE A.1. 2500 Random Digits

	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50
1	38742	24201	25580	18631	30563	11548	08022	62261	74563	54597
2	01448	28091	45285	81470	09829	49377	88809	59780	46891	29447
3	34768	23715	37836	17206	26527	21554	62118	78918	30845	78748
4	89533	67552	74970	68065	50599	85529	20588	59726	84051	44388
5	74163	13487	64602	07271	03530	88954	66174	68319	25323	05476
6	92837	06594	01664	43011	27981	81256	75467	28245	29149	70357
7	69008	55983	22496	55337	74159	11283	13316	27479	63079	34060
8	92404	00156	38141	06269	51599	11371	24120	88150	99649	54740
9	45369	68854	67952	06245	32056	67900	84670	50098	29179	47904
10	16929	17418	70611	53752	39997	53621	67393	24891	53738	77251
11	95400	57951	64492	52389	86037	52586	42206	74681	82599	24606
12	36981	75140	26771	67681	54042	26121	70479	50295	43593	08220
13	37705	05124	60924	24374	99850	12414	13982	83219	26396	93876
14	67830	54660	89150	92919	90913	49560	49845	98239	78807	87479
15	32789	25115	44030	86301	61900	17173	34870	37043	40625	17954
16	60127	17491	59011	37625	03435	77178	08520	49910	34898	34345
17	17115	42174	81592	04300	68875	30353	48630	86132	55173	05788
18	27760	36661	85617	06242	09725	10642	44142	29625	49415	98360
19	04494	95805	16053	37126	54750	12617	09310	94021	38471	57427
20	34753	89545	33847	78318	41551	18705	64107	18200	56834	74584
21	63319	12471	56242	06344	94606	89207	26550	93261	17931	79259
22	98802	54600	92170	51425	74130	10301	08763	56046	00093	03793
23	82661	67501	01368	91079	54810	68160	11860	84288	27053	00917
24	99251	10088	48345	72786	81066	54353	17546	31595	77246	40514
25	72756	52088	29291	46169	14636	26380	35201	07490	28845	02341
26	96723	05193	38941	33288	13923	46860	12385	94973	43259	85010
27	96169	16158	24345	78561	46611	66869	17678	38209	24023	56259
28	96678	41518	88402	17882	79991	00083	29337	39994	06328	06476
29	97329	58496	55229	90839	93840	67032	77411	57137	06172	11036
30	38143	94319	58015	71878	42332	28120	80481	41745	68085	88776
31	83510	94405	93811	02145	74541	29582	24535	21485	54519	93320
32	98898	39140	50371	20646	07782	63276	66375	88305	77405	74749
33	04406	76609	46544	55985	72507	98678	48840	16601	44598	50487
34	55997	34203	29784	12914	37942	86041	48431	11784	28492	28049
35	95911	19810	65733	05412	18498	79393	37322	75911	92047	61599
36	67151	13303	12466	08918	27140	22886	61210	67131	52278	95829
37	59368	23548	60681	09171	18170	62627	48209	62135	44727	12937
38	75670	78997	76059	83474	15744	71892	52740	22930	92624	93036
39	94444	45866	42304	85506	26762	24841	47226	34746	90302	70785
40	73516	82157	24805	75928	02150	84557	12930	63123	11922	76960
41	89059	45446	56541	62549	21737	78963	30917	37046	81184	83397
42	94958	71785	47469	29362	91492	80902	80586	66162	74551	87221
43	21739	80710	61346	04257	09821	17188	80855	76589	36971	41982
44	93859	78783	46343	03715	12473	48553	02762	45114	75502	42382
45	14263	52552	17964	20078	82454	35167	35631	81815	18879	93676
46	22894	01894	47934	54594	43739	51301	22511	39456	51031	58121
47	29316	85620	09294	67074	77403	82789	22212	52358	69310	57604
48	31889	40095	98007	15605	93206	86857	29784	63937	83545	50407
49	60096	11744	74086	65948	37934	35941	25731	30787	68848	14320
50	42450	70020	43245	05233	21149	85898	73527	55648	65388	55211

APPENDIX B

Master for gravel sample bucket labels -
Copy onto "Rite-In-Rain" paper

Date: ______________________________
Stream: ____________________ Seg.# ________
Riffle Crest # : ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient Monitoring Gravel Sample

Date: ______________________________
Stream: ____________________ Seg.# ________
Riffle Crest # : ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient Monitoring Gravel Sample

Date: ______________________________
Stream: ____________________ Seg.# ________
Riffle Crest # : ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient Monitoring Gravel Sample

Date: ______________________________
Stream: ____________________ Seg.# ________
Riffle Crest # : ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient Monitoring Gravel Sample

Date: ______________________________
Stream: ____________________ Seg.# ________
Riffle Crest # : ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient Monitoring Gravel Sample

Date: ______________________________
Stream: ____________________ Seg.# ________
Riffle Crest # : ______________________
Bucket/Sample # ____________________
Crew: ______________________________

Close Lid Rim here

TFW Ambient Monitoring Gravel Sample

g:\apleus\sedapx2.cdr

TFW Ambient Monitoring
SPAWNING GRAVEL COMPOSITION DATA FORM

Stream: ______________________

W.R.I.A.#: ______________________

Segment #: ______________________

Date of Sample Collection: __________

Date of Sample Processing: __________

Name: ______________________

Affiliation: ______________________

Processing Method:

☐ Volumetric data (ml)

☐ Gravimetric data (gm)

Sieve Size (mm)	Sample # ___ RC # ___	Sample # ___ RC # ___	Sample # ___ RC # ___	Sample # ___ RC # ___	Sample # ___ RC # ___	Sample # ___ RC # ___
64						
32						
16						
8						
4						
2						
1						
0.85						
0.5						
0.25						
0.125						
< 0.125						

g:\apleus\sed3.pm4

Timber-Fish-Wildlife
Ambient Monitoring Program

STREAM TEMPERATURE MODULE

July 1993

Ed Rashin
Dave Schuett-Hames
Jim Matthews

Northwest Indian Fisheries Commission

STREAM TEMPERATURE MODULE

Contents

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Cover: Richard Miller, Tulalip Water Quality Lab Coordinator, taking temperature readings. Photo by Tony Meyer, NWIFC.

STREAM TEMPERATURE MODULE

Introduction

Water temperature is a critical factor affecting the survival and growth of salmonid fishes that reside in freshwater streams during the summer low flow period. Lantz (1970) provides the following summary of the relationship between water temperature and salmonids:

1. Water temperature is one of the most important environmental factors affecting fish because they are cold-blooded and their internal body temperature must adjust to the temperature of the external environment.

2. Salmon and trout have a lower level of thermal tolerance than many less desirable species have.

3. Fish have lower and upper lethal temperature limits. These limits are specific for each species, but may vary at different stages in their life history.

4. Within the lethal thermal limits, other environmental factors (such as diseases, toxic materials, etc.) can operate in conjunction with temperature to reduce survival. The total impact of such interactions may be greater than the sum of their individual effects.

5. Fish are able to acclimatize themselves to seasonal temperature changes and to minor fluctuations in temperature. They acclimatize more readily to an increase than to a decrease in tem perature.

6. Growth is an indicator of the well-being of an animal. The most efficient utilization of food resources for growth occurs at lower temperatures.

7. Migratory behavior patterns of adults and juveniles can be altered by temperature changes.

8. The scope for activity of cold-water fishes is greatest at moderately low temperatures, which correspond closely to the fishes preferred temperatures."

The optimal temperature range for most salmonid species is approximately 12-14 degrees C. Increased stream temperature may have a beneficial effect on salmonids when it results in greater food production and increased growth but does not exceed the optimal temperature range (Beschta et al., 1987). Lethal levels for adult salmonids will vary according to factors such as the acclimation temperature and the duration of the temperature increase, but they generally are in the range of 23-29 degrees C (Bjornn and Reiser, 1991). Bjornn and Reiser (1991) caution that, "although some salmonids can survive at relatively high temperatures, most are placed in life-threatening conditions when temperatures exceed 23-25 degrees C, and they usually try to avoid such temperatures by moving to other areas". The egg and juvenile life history stages are the most sensitive to high temperatures (MacDonald et al., 1991). In some cases, the extent of temperature changes may be more critical than the maxima.

Sub-lethal effects of above optimal water temperatures often appear to be more critical than direct mortality. Examples of sub-lethal effects include: a) reduced survival of eggs and progeny when adults spawn in warm water (Lantz, 1970); b) increased virulence of many of the diseases most significant in the Pacific Northwest including kidney disease, furunculosis, vibriosis and columnaris (Lantz, 1970); c) avoidance of warm waters, resulting in changes in distribution or migration patterns (Beschta et al., 1987); d) increased metabolic activity that results in reduced growth rate when temperatures exceed the optimum level (Lantz, 1970; Beschta et al., 1987); e) change in timing of development and life history stages (Holtby, 1988); and f) reduced ability to compete with other species (Beschta et al., 1987).

How Forest Practices Effect Stream Temperature

The principal source of heat for small mountain streams is the solar radiation that directly strikes the surface of the stream (Brown, 1971). The amount of sunlight reaching the stream depends on the surface area of the stream and the shade provided by vegetation and topography. Wide, shallow streams receive more solar radiation relative to the volume of water than narrow, deep ones (Brown, 1971). For a given rate of solar radiation input, temperature change is directly proportional to surface area and inversely proportional to discharge (Sullivan et al., 1990). Vegetation typically provides substantial shade to streams and other water bodies in forested areas. Reduction in vegetative cover along streams from human or natural causes increases incident solar radiation reaching the stream. This results in higher maximum summer temperatures and larger diurnal fluctuations, especially in small streams (Sullivan et al., 1990). Other factors affecting water temperature include: extent of ground water inputs, air temperature, water depth and channel form (width:depth ratio). Heat is transported downstream with flowing water. As water moves downstream, its temperature seeks an equilibrium with air temperature although it responds to local environmental factors such as shading, ground water inputs and tributary inflow (Sullivan et al., 1990).

The effects of logging on stream temperature can be reduced by designing timber harvest units to maintain adequate shade. In Washington State, post-harvest shade requirements necessary to meet water quality standards are estimated with a screening tool based on the elevation of the site. Alternately, a predictive temperature model with additional site-specific factors can be used (Doughty et al., 1991). Rashin and Graber (1992) tested the effectiveness of the 1988 riparian management zone regulations and recommended periodic review and update of the temperature screen as new stream temperature data becomes available.

Purpose of the TFW Stream Temperature Module

The objectives of the TFW Stream Temperature Module are as follows:

1. Determine the maximum temperature regime of a stream reach or specific location in a stream (Levels 1, 2 and 3);

2. Provide data that can be used to test and improve the TFW temperature screen (Levels 2 and 3);

3. Provide data that can be used to test and improve the empirical relations in the TFWTEMP model and allow a more complete assessment of factors influencing stream temperature (Level 3, only).

Methodology

The Stream Temperature Module provides a three-level approach that allows you to choose the protocol that meets your monitoring objectives. Objectives must be fully defined in order to decide which parameters and protocols are appropriate to your monitoring project.

Equipment Needed

For Level 1:

- Min-Max Thermometers or Recording Electronic Thermograph
- Locking steel box and chain (or other enclosure) to protect thermograph from weather, theft, and/or vandalism
- Stakes and fasteners (wires or plastic ties) to set probes/thermometers in stream.
- Calibration thermometer
- Water bath or 5 gallon bucket of sand for calibration
- Aerial photos of site
- Field notebook and pencils

For Level 2:

- Equipment listed for Level 1; and
- Densiometer
- Tape measure or hipchain
- Topographic map of site (USGS 7.5 minute, if available)

For Level 3:

- Equipment listed for Levels 1 and 2; and
- Map wheel or digitizer
- Air temperature probe or Min/Max thermometer for air
- Stadia rod or measuring stick
- Clinometer
- Flowmeter
- Camera

The Level 1 Method

The Level 1 method is designed to determine the maximum temperature regime of a stream reach or a specific location in a stream. Either recording thermographs or min-max thermometers may be used to measure temperature. Both types of instruments are discussed in the following section.

Protocols

1. Select a monitoring site.

It is often preferable to establish a site that is near the downstream end of a thermal reach, so as to characterize that reach rather than local conditions. A thermal reach is a reach that has similar (relatively homogeneous) stream and riparian conditions for a sufficient distance to allow the stream temperature to reach equilibrium with those conditions. The length of reach required to reach equilibrium will depend on stream size (especially water depth) and morphology. A deep, slow moving stream responds more slowly to heat inputs and requires a longer thermal reach, while a shallow, faster moving stream will generally respond faster to changing riparian conditions, indicating a shorter thermal reach. As a rule of thumb, it takes about 600 meters (2000 feet) of similar conditions to establish a equilibrium thermal reach, although that may be reduced to as little as 300 meters for a small stream under certain conditions. If in doubt about the length of the thermal reach, use 600 meters. Aerial photos will help in the assessment of stream reach conditions.

If the reach above your monitoring site has highly variable riparian or stream channel conditions (such as significant tributary input within 600 meters, or major changes in riparian vegetation), you can still determine the temperature at that site. Keep in mind that you will be characterizing localized temperature conditions as opposed to conditions of a representative reach. In other words, the stream temperature at that site could be in a state of flux, either increasing or decreasing in order to come into equilibrium with changing conditions.

2. Determine the monitoring period.

For determining maximum equilibrium temperature (i.e. maximum annual temperature) of the reach, monitoring should be conducted between July 15 and August 15, although the period may be extended until August 30 in some areas, particularly in Eastern Washington. Late June and early July may also be important high temperature periods in some areas. Use local knowledge to determine the best monitoring period, but include the July 15 - August 15 period. Monitoring should be conducted for at least 14 consecutive days during this period. Longer monitoring periods may improve your ability to characterize the temperature regime, but will also increase the risk of losing or damaging your equipment due to floods, animal damage, or vandalism.

3. Calibrate instruments.

Before installing thermographs or thermometers, conduct a calibration check to ensure reliability.

Calibration of recording thermographs. If thermographs consist of data loggers with separate temperature probes, each data logger and probe should be marked with a unique identification code. Data loggers and probes should be paired for calibration in the same combinations as they will be deployed for monitoring. Place all probes in a stable water bath, along with a reliable reference thermometer. (Note: In order for the water bath to be stable, it should be water that has had plenty of time to come into equilibrium with room temperature, or it should be iced so its temperature will not fluctuate rapidly during calibration). If fluctuating temperatures make a stable water bath difficult to obtain, a five gallon bucket filled with sand can be used. Allow the sand bucket to stabilize for a day prior to calibration. After a couple minutes of equilibration time, record the reading from each instrument and the reference thermometer. You may want to do this each minute for ten minutes or so. If any instruments are more than one-half degree celsius off, adjust the data from these instruments, or qualify the data as accurate to +/- *x* degrees. If the error is biased in a consistent direction, based on multiple checks with a reliable reference thermometer, an adjustment can be made to the thermograph results if desired.

Any instruments off two or more degrees C should not be considered reliable until the problem is corrected. This is a minimum calibration procedure. It may be improved by running calibration checks in two different water baths (e.g. one iced and one at room temperature). If the instrument you are using allows you to obtain an instantaneous reading after it is installed in the stream, then field checks with a hand held thermometer are also a good idea. Even if you can't obtain an instantaneous reading in the field, it's a good idea to do a field check with a hand held thermometer, record the time of the reading, and compare it to recorded data as a check on thermograph performance. It is also a good idea to perform calibration checks at the completion of monitoring as added insurance of reliability.

<u>Calibration of maximum/minimum thermometers.</u> Mark each thermometer with a unique identification number or code. Place the thermometers in a stable water bath along with a reliable reference thermometer. After approximately five minutes, record the readings from both the maximum and minimum sides of the thermometer. When taking measurements from maximum/minimum thermometers, try to keep them at least partially submerged in the water bath so air temperatures do not alter the readings. Continue to take <u>at least</u> two more readings at five minute increments. Then slide a magnet downward along the thermometers to "zero out" the maximum and minimum marker pins. Record the temperature at the maximum marker pin placement. Add a substantial amount of ice to the bath to bring the water temperature down to near 0 degrees C. Gently mix the water bath to achieve a uniform water temperature. After approximately 20 minutes of equilibration time, with some ice still present, record the readings from the thermometers and reference instrument. Record the maximum marker pin placement to determine if it has changed from the initial measurement. In addition, record the minimum marker pin placement. This will be the initial minimum marker placement. Let the water bath sit over night and again take readings from both the maximum/minimum thermometers and the reference thermometer. Also, record the minimum marker pin position and compare to the initial reading.

Maximum/minimum thermometers can be manually adjusted to the same reading as the reference thermometer by loosening the set screws. Alternately, the recordings from the maximum/minimum thermometers can be adjusted during data analysis by taking the difference from the reference thermometer. If a maximum/minimum thermometer is off by more than 2 degrees C, does not track uniformly with the reference thermometer during calibration, or the maximum or minimum marker pins are found to wander during calibration, do not use the instrument.

4. Install instruments.

When installing the temperature probe or max-min thermometer, choose a location in the stream that is representative of the overall morphology of the reach. If pool habitat is common in the reach, choose a location in a representative pool. The instrument should be set in the stream so that it is not too near the bottom so as to be unduly influenced by groundwater inflow or stratification. Ensure it is deep enough so that it will not be exposed as the water level drops during the low flow period. MacDonald et al. (1991) recommend areas with turbulent mixing in order to obtain a representative temperature.

Installation of recording thermographs. It is often best to set the probe at about one-half of water depth, near the center of the cross-section. Attach the probe securely to a stake or rock to keep it where you set it. Install the probe at a location where it will be shaded from direct sunlight; shade can be from the canopy or some other feature such as large woody debris. If no shaded locations are available, then it may be necessary to construct a shade for the probe (e.g. using a section of large diameter plastic pipe).

Several measures can be taken to reduce the potential for loss or damage of data loggers:

1. Place data loggers outside of the mean high water line to prevent loss during a freshet;

2. Some data loggers must be housed in a waterproof metal or plastic box that can be locked and chained to a tree, and;

3. Data logger box and cables can be covered with rocks, moss and wood to hide equipment from passersby.

Installation of maximum/minimum thermometers. It is important that the thermometer is protected from excessive movement due to turbulent flow that can cause the marker to move. Build a rock cairn with a height of approximately 8-15 cm (3-6 inches) above the stream substrate to house the maximum/minimum thermometer. Locate the cairn near the thalweg where uniform flows will give reliable temperature readings. The site must be deep enough in the water column to insure that the thermometer will not become de-watered during the monitoring period. Place the maximum/minimum and a reference thermometer in the stream and wait a minute to allow the instruments to adjust to the water temerature. This is critical, otherwise the first maximum reading will likely be that of the air. Record the initial water temperatures from the maximum/minimum thermometers. "Zero out" the maximum and minimum marker pins with a magnet and lay the thermometer in the cairn with the top of the instrument slightly elevated. Place a single layer of rocks on top of the thermometer. If the stream may experience high, scouring flows, anchor the thermometer with string or wire to a large rock or stable material on the bank.

5. Data collection and checking.

Thermographs. If using recording thermographs, set to record maximum and average temperature at one hour intervals. The site should be visited periodically to make sure the instruments are in working order. Once the field monitoring is completed and the results are transferred to a spreadsheet, the data must be checked. Recording thermographs may begin to drift after a period of time, even if they calibrated all right, or direct sunlight hitting a probe or thermometer can cause a spike that does not reflect actual water temperature. The best way to detect spurious data is to prepare an X-Y graph of the results. Field checks can also be used to detect gross errors. Spurious data (spikes or drift that cannot be explained) should be censored before maximums, minimums, or averages are calculated.

Maximum/minimum thermometers. If using min-max thermometers, record data and reset thermometers every one to three days, preferably at the same time each day. By resetting them often, you will be able to establish how often high temperatures are reached, and also will be able to characterize the diurnal temperature range. If, however, your objective is only to determine the maximum temperature that is reached over the monitoring period and you aren't concerned with how often it is reached, you may leave the min-max thermometer out for longer periods without reading or resetting it.

Min-max thermometers should always be read and reset while in the water, so that air temperature doesn't influence the marker pins. Also, it is best to reset them in the morning when air temperatures are somewhat near the daily mean. Record the information and lay the thermometer back in the cairn. Wait a minute to ensure the thermometer is back at equilibrium and then "zero out" the marker pins with the magnet. At the end of the monitoring period, record the final temperatures and take a reading with a reference thermometer to gauge if the maximum/minimum thermometer is still performing properly.

The Level 2 Method

The Level 2 method is designed to: 1) determine the maximum temperature regime of a stream reach; **and** 2) provide data that can be used to test and improve the Temperature Screens used to design RMZs.

Protocols

1. Monitor stream temperature as described for Level 1.

2. Determine canopy closure/shade level.

Use a spherical densiometer at evenly spaced intervals to determine average canopy closure for the thermal reach above the monitoring site. See the TFW Ambient Monitoring Reference Point Survey Module for a discussion on taking canopy closure measurements. Take the canopy closure measurements at 50 meter intervals throughout the thermal reach. The thermal reach extends 300-600 meters above the site, depending on stream size (see selecting a monitoring site, above). If the percent canopy closure varies by more than 20% between measurements, then take additional measurements at 25 meter intervals to more accurately determine the average percent canopy closure for the reach. (In order to save time, it may be preferable to determine canopy closure at 25 meter intervals from the start, thus avoiding the need to back-track in cases where the variability exceeds 20%). In addition to calculating the average canopy closure, keep track of the percent canopy closure at each plot and note plot locations on a map or sketch of the reach to document how the shade level varies through the reach. At each plot, stand in the center of the low flow channel and measure canopy closure four times facing upstream, right bank, downstream, and left bank, and average these to obtain canopy closure for the plot. Depending on whether the canopy is primarily open or closed, it may be easier to count openings and determine percent skyview, and then convert this to canopy closure.

3. Determine reach elevation.

Determine the elevation at the midpoint of the thermal reach from a topographic map.

4. Determine Water Quality Standard Classification of the reach.

The classification of streams is established by the provisions of Sections 120 and 130 of Chapter 173-201A WAC (the State Water Quality Standards). The stream you are monitoring may be specifically classified in Section 130, or its classification may be determined by the downstream water it is tributary to or its location (e.g. all streams within national forests, national parks, or wilderness areas are Class AA). A copy of the water quality classification list is included in Appendix A.

5. Determine temperature region.

Determine whether the site is located in the Coastal, Western Washington, or Eastern Washington temperature region (Figure 1). These regions generally correspond to ecoregion boundaries.

The Level 3 Method

The Level 3 method is designed to: 1) determine the maximum temperature regime of a stream reach; 2) provide data that can be used to test and improve the Temperature Screen used to design RMZs; and 3) provide data that can be used to test and improve the empirical relations in the TFWTEMP model used to determine shade requirements in RMZs. The additional information will also allow a more complete assessment of factors influencing stream temperature.

Protocols

1. Monitor stream temperature as described for Level 1, and determine canopy closure, elevation, Water Quality Class, and temperature region as described for Level 2.

2. Determine distance from divide.

Measure the stream distance from the monitoring site up the drainage network (longest tributary) to the drainage divide on a topographic map using a map wheel or digitizer (Figure 2). This parameter is needed to run the TFWTEMP model, and the model uses this distance to approximate water depth and groundwater inflow rate based on empirical relationships.

3. Monitor air temperature.

Using procedures similar to those described for stream temperature, install a thermograph/ thermometer in the riparian zone, near the stream bank, about 1 meter off the ground. Make sure it is shaded from direct sun. Set recording thermographs to record average rather than maximum hourly temperature.

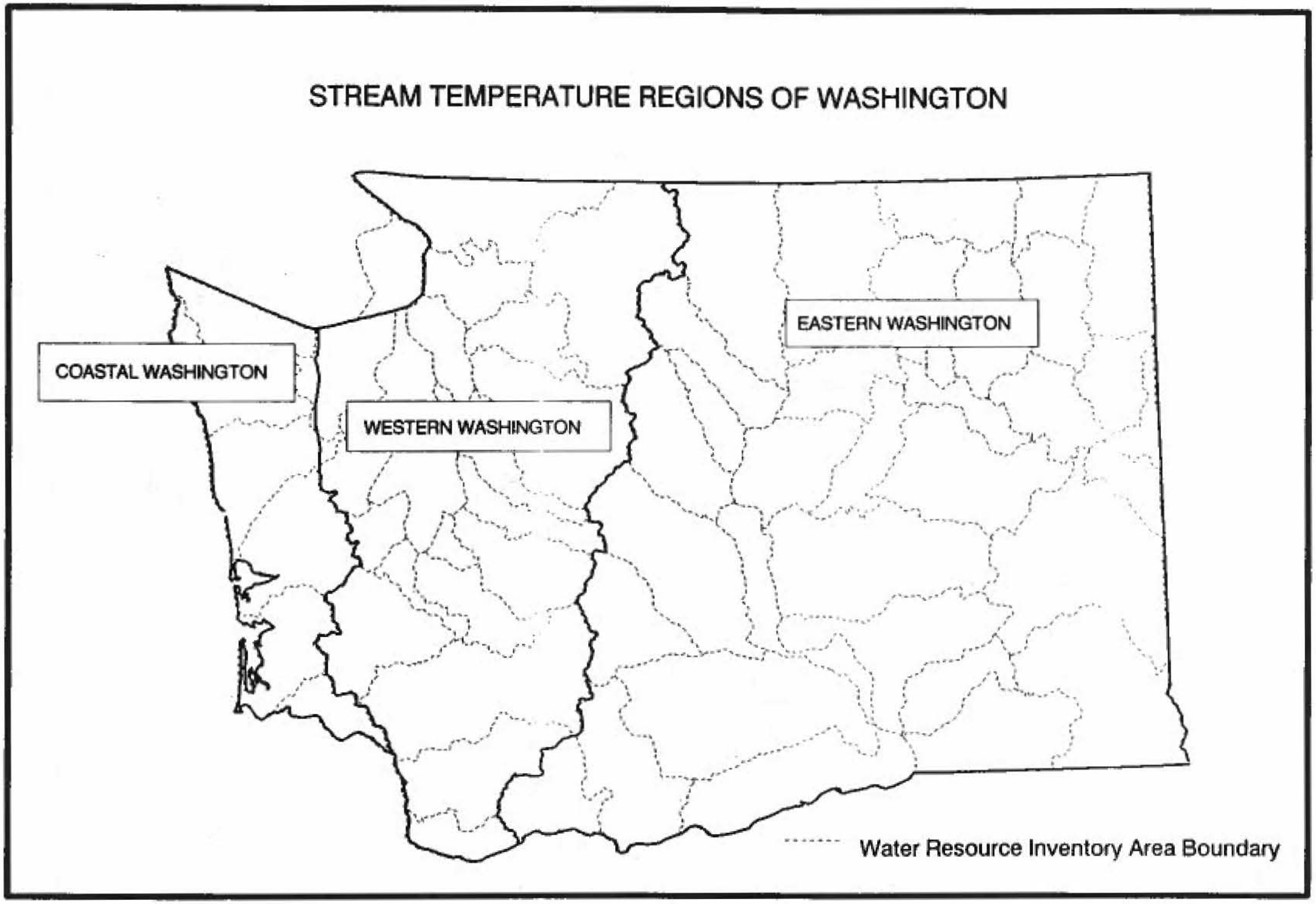
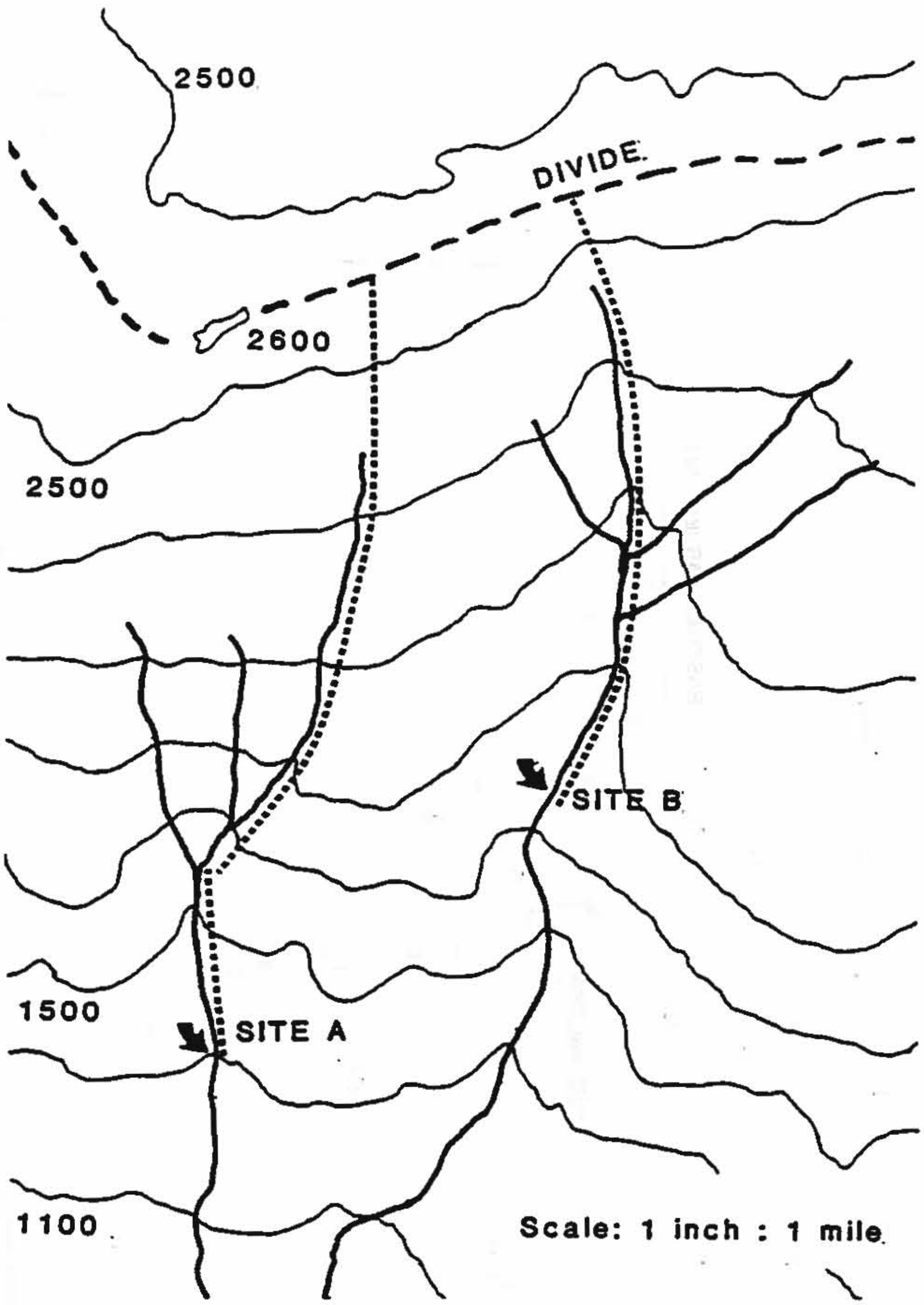


Figure 1: Temperature Regions for Applying TFW Temperature Screens and TFWTEMP Model



Use a 7' or 15' USGS topographic map, or a Water Type map. Pinpoint the site(s). Determine the divide, by freehand-drawing a line between the next-to-highest contour lines (2500 ft. in this example), making sure you intersect with the highest contour line as well (2600 ft.). Using a ruler or a map wheel, measure from the site up to the hand-drawn divide line, moving up the stream channel. (Use the contour lines to approximate the channel if the channel is not on the map.) TFWTEMP requires the distyance-from-divide value in miles or kilometers.

In this example, distance from divide from Site A is 4.5 miles, and 3.4 miles from Site B.

Fig. 2. Distance from divide determination.

4. Measure stream depth and width.

Measure water depth and bankfull depth at cross-sections spaced at 50 meter intervals through the thermal reach. Also measure wetted and bankfull width. These should be measured during the same flow regime as the monitoring period (i.e. summer baseflow).

5. Document other parameters.

These are optional depending on your objectives and the level of evaluation you wish to conduct:

Groundwater inflow rate. This is difficult to determine, but can be approximated. Careful discharge measurements made at the upstream and downstream ends of the thermal reach on the same day and time of day can be compared to yield an approximation of the flow gain or loss within the reach. This can be converted to groundwater inflow rate (volume per unit length). Whether or not the rate is measured, make notes of obvious groundwater features such as significant springs or seeps or places where the stream appears to lose flow to the subsurface.

Riparian Management Zone Width. Determine the average RMZ width on each side of the stream by measuring from the ordinary high water mark to the edge of the RMZ (determined by tree markings and/or harvest boundary) at each transect established for stream depth/width or canopy closure (preferably 50 meter intervals).

Other RMZ Characteristics. At each RMZ width transect, make a visual estimate of other important characteristics including the ratio of hardwoods to conifer at that location, seral stage of the riparian forest, extent of blowdown, and other pertinent observations. Document with photographs wherever possible. For more objective data on these characteristics, plots can be installed for sampling the hardwood/conifer ratio, etc. See Washington Department of Wildlife (1990) for methods.

Stream Gradient. Using a clinometer, take gradient between 50 meter sampling points, or more often if necessary.

Channel Morphology. Describe the predominant channel morphology within the reach; note whether there is substantial modification by aggradation, debris flows, beaver activity or other influences. The classification scheme given in Montgomery and Buffington (1993) may be used to describe channel morphology.

Study Design Considerations

If the monitoring objective is to test the effects of a land management activity (e.g. timber harvest) on the temperature regime of a stream reach, there are various alternatives for designing the monitoring program. The main difference between characterizing the conditions of a stream reach and evaluating a management activity is the need to establish a reference point of comparison to assess effects of the activity. Either an upstream/downstream design or a before/after design may be used, or the two approaches can be combined. There are advantages and disadvantages to each approach.

The before/after design requires a minimum of two summers. The pretreatment summer provides the control against which the effects of changes caused by management are compared. If both the before and after monitoring periods are representative of maximum equilibrium temperature conditions (i.e. monitored between July 15 and August 15), then the comparison is valid and incremental temperature change can be assessed. This sample design requires the assumption that minor year to year climatic variability is inconsequential to stream temperature conditions, since the maximum equilibrium stream temperature is independent of minor fluctuations in regional air temperature maximums. Rather, the maximum equilibrium temperature of a given stream reach is dependent primarily on riparian conditions as they affect local air temperature, solar radiation, and relative humidity. Major variation in regional summer weather and air temperature would invalidate the assumption of year to year comparability. This can be checked by reviewing regional NOAA weather station records.

The upstream/downstream design can be conducted in a single summer. It requires monitoring at the upstream end of the thermal reach affected by management to establish incoming stream temperature (i.e. the conditions resulting from the thermal reach above the treatment). If the riparian vegetation and stream channel of the upstream reach are similar to that of the downstream reach before management (i.e. similar stand age, similar stream morphology, etc.), then an assessment of the incremental temperature change attributable to the management can be made by comparing upstream and downstream values. Any major differences between the upstream and the pre-management downstream reach would invalidate an assessment of incremental change, but one could still assess the effects of management on stream temperature as water flowed through the affected reach.

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APPENDIXES

Appendix A.

Water Quality Classification List

APPENDIX A

WAC 173-201A-120 General classifications. General classifications applying to various surface water bodies not specifically classified under WAC 173-201A-130 or 173-201A-140 are as follows:

(1) All surface waters lying within national parks, national forests, and/or wilderness areas are classified Class AA or Lake Class.

(2) All lakes and their feeder streams within the state are classified Lake Class and Class AA respectively, except for those feeder streams specifically classified otherwise.

(3) All reservoirs with a mean detention time of greater than 15 days are classified Lake Class.

(4) All reservoirs with a mean detention time of 15 days or less are classified the same as the river section in which they are located.

(5) All reservoirs established on preexisting lakes are classified as Lake Class.

(6) All unclassified surface waters that are tributaries to Class AA waters are classified Class AA. All other unclassified surface waters within the state are hereby classified Class A.

[Statutory Authority: Chapter 90.48 RCW. 92-24-037 (Order 92-29), § 173-201A-120, filed 11/25/92, effective 12/26/92.]

WAC 173-201A-130 Specific classifications—Freshwater. Specific fresh surface waters of the state of Washington are classified as follows:

(1)	American River.	Class AA
(2)	Big Quilcene River and tributaries.	Class AA
(3)	Bumping River.	Class AA
(4)	Burnt Bridge Creek.	Class A
(5)	Cedar River from Lake Washington to the Maplewood Bridge (river mile 4.1).	Class A
(6)	Cedar River and tributaries from the Maplewood Bridge (river mile 4.1) to Landsburg Dam (river mile 21.6).	Class AA
(7)	Cedar River and tributaries from Landsburg Dam (river mile 21.6) to headwaters. Special condition - no waste discharge will be permitted.	Class AA
(8)	Chehalis River from upper boundary of Grays Harbor at Cosmopolis (river mile 3.1, longitude 123°45'45" W) to Scammon Creek (river mile 65.8).	Class A
(9)	Chehalis River from Scammon Creek (river mile 65.8) to Newaukum River (river mile 75.2). Special condition - dissolved oxygen shall exceed 5.0 mg/L from June 1 to September 15. For the remainder of the year, the dissolved oxygen shall meet Class A criteria.	Class A
(10)	Chehalis River from Newaukum River (river mile 75.2) to Rock Creek (river mile 106.7).	Class A
(11)	Chehalis River, from Rock Creek (river mile 106.7) to headwaters.	Class AA
(12)	Chehalis River, south fork.	Class A
(13)	Chewuch River.	Class AA
(14)	Chiwawa River.	Class AA
(15)	Cispus River.	Class AA
(16)	Clearwater River.	Class A
(17)	Cle Elum River.	Class AA
(18)	Cloquallum Creek.	Class A
(19)	Clover Creek from outlet of Lake Spanaway to inlet of Lake Steilacoom.	Class A
(20)	Columbia River from mouth to the Washington-Oregon border (river mile 309.3). Special conditions - temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed 0.3°C due to any single source or 1.1°C due to all such activities combined. Dissolved oxygen shall exceed 90 percent of saturation.	Class A

(21) Columbia River from Washington-Oregon border (river mile 309.3) to Grand Coulee Dam (river mile 596.6). Special condition from Washington-Oregon border (river mile 309.3) to Priest Rapids Dam (river mile 397.1). Temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9). Class A
(22) Columbia River from Grand Coulee Dam (river mile 596.6) to Canadian border (river mile 745.0). Class AA
(23) Colville River. Class A
(24) Coweeman River from mouth to Mulholland Creek (river mile 18.4). Class A
(25) Coweeman River from Mulholland Creek (river mile 18.4) to headwaters. Class AA
(26) Cowlitz River from mouth to base of Riffe Lake Dam (river mile 52.0). Class A
(27) Cowlitz River from base of Riffe Lake Dam (river mile 52.0) to headwaters. Class AA
(28) Crab Creek and tributaries. Class B
(29) Decker Creek. Class AA
(30) Deschutes River from mouth to boundary of Snoqualmie National Forest (river mile 48.2). Class A
(31) Deschutes River from boundary of Snoqualmie National Forest (river mile 48.2) to headwaters. Class AA
(32) Dickey River. Class A
(33) Dosewallips River and tributaries. Class AA
(34) Duckabush River and tributaries. Class AA
(35) Dungeness River from mouth to Canyon Creek (river mile 10.8). Class A
(36) Dungeness River and tributaries from Canyon Creek (river mile 10.8) to headwaters. Class AA
(37) Duwamish River from mouth south of a line bearing 254° true from the NW corner of berth 3, terminal No. 37 to the Black River (river mile 11.0) (Duwamish River continues as the Green River above the Black River). Class B
(38) Elochoman River. Class A
(39) Elwha River and tributaries. Class AA
(40) Entiat River from Wenatchee National Forest boundary (river mile 20.5) to headwaters. Class AA
(41) Grande Ronde River from mouth to Oregon border (river mile 37). Special condition - temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9). Class A
(42) Grays River from Grays River Falls (river mile 15.8) to headwaters. Class AA
(43) Green River (Cowlitz County). Class AA
(44) Green River (King County) from Black River (river mile 11.0 and point where Duwamish River continues as the Green River) to west boundary of Sec. 27-T21N-R6E (west boundary of Flaming Geyser State Park at river mile 42.3). Class A
(45) Green River (King County) from west boundary of Sec. 27-T21N-R6E (west boundary of Flaming Geyser State Park, river mile 42.3) to west boundary of Sec. 13-T21N-R7E (river mile 59.1). Class AA
(46) Green River and tributaries (King County) from west boundary of Sec. 13-T21N-R7E (river mile 59.1) to headwaters. Special condition - no waste discharge will be permitted. Class AA
(47) Hamma Hamma River and tributaries. Class AA
(48) Hanaford Creek from mouth to east boundary of Sec. 25-T15N-R2W (river mile 4.1). Special condition - dissolved oxygen shall exceed 6.5 mg/L. Class A
(49) Hanaford Creek from east boundary of Sec. 25-T15N-R2W (river mile 4.1) to headwaters. Class A
(50) Hoh River and tributaries. Class AA
(51) Hoquiam River (continues as west fork above east fork) from mouth to river mile 9.3 (Dekay Road Bridge) (upper limit of tidal influence). Class B
(52) Humptulips River and tributaries from mouth to Olympic National Forest boundary on east fork (river mile 12.8) and west fork (river mile 40.4) (main stem continues as west fork). Class A
(53) Humptulips River, east fork from Olympic National Forest boundary (river mile 12.8) to headwaters. Class AA
(54) Humptulips River, west fork from Olympic National Forest boundary (river mile 40.4) to headwaters. Class AA
(55) Issaquah Creek. Class A
(56) Kalama River from lower Kalama River Falls (river mile 10.4) to headwaters. Class AA
(57) Klickitat River from Little Klickitat River (river mile 19.8) to boundary of Yakima Indian Reservation. Class AA
(58) Lake Washington Ship Canal from Government Locks (river mile 1.0) to Lake Washington (river mile 8.6). Special condition - salinity shall not exceed one part per thousand (1.0 ppt) at any point or depth along a line that transects the ship canal at the University Bridge (river mile 6.1). Lake Class
(59) Lewis River, east fork, from Multon Falls (river mile 24.6) to headwaters. Class AA
(60) Little Wenatchee River. Class AA
(61) Methow River from mouth to Chewuch River (river mile 50.1). Class A
(62) Methow River from Chewuch River (river mile 50.1) to headwaters. Class AA
(63) Mill Creek from mouth to 13th Street Bridge in Walla Walla (river mile 6.4). Special condition - dissolved oxygen concentration shall exceed 5.0 mg/L. Class B
(64) Mill Creek from 13th Street Bridge in Walla Walla (river mile 6.4) to Walla Walla Waterworks Dam (river mile 25.2). Class A
(65) Mill Creek and tributaries from city of Walla Walla Waterworks Dam (river mile 25.2) to headwaters. Special condition - no waste discharge will be permitted. Class AA
(66) Naches River from Snoqualmie National Forest boundary (river mile 35.7) to headwaters. Class AA
(67) Naselle River from Naselle "Falls" (cascade at river mile 18.6) to headwaters. Class AA
(68) Newaukum River. Class A
(69) Nisqually River from mouth to Alder Dam (river mile 44.2). Class A
(70) Nisqually River from Alder Dam (river mile 44.2) to headwaters. Class AA
(71) Nooksack River from mouth to Maple Creek (river mile 49.7). Class A
(72) Nooksack River from Maple Creek (river mile 49.7) to headwaters. Class AA
(73) Nooksack River, south fork, from mouth to Skookum Creek (river mile 14.3). Class A
(74) Nooksack River, south fork, from Skookum Creek (river mile 14.3) to headwaters. Class AA
(75) Nooksack River, middle fork. Class AA
(76) Okanogan River. Class A
(77) Palouse River from mouth to south fork (Colfax, river mile 89.6). Class B
(78) Palouse River from south fork (Colfax, river mile 89.6) to Idaho border (river mile 123.4). Special condition - temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9). Class A

(79) Pend Oreille River from Canadian border (river mile 16.0) to Idaho border (river mile 87.7). Special condition - temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9). Class A
(80) Pilchuck River from city of Snohomish Waterworks Dam (river mile 26.8) to headwaters. Class AA
(81) Puyallup River from mouth to river mile 1.0. Class B
(82) Puyallup River from river mile 1.0 to Kings Creek (river mile 31.6). Class A
(83) Puyallup River from Kings Creek (river mile 31.6) to headwaters. Class AA
(84) Queets River and tributaries. Class AA
(85) Quillayute River. Class AA
(86) Quinault River and tributaries. Class AA
(87) Salmon Creek (Clark County). Class A
(88) Satsop River from mouth to west fork (river mile 6.4). Class A
(89) Satsop River, east fork. Class AA
(90) Satsop River, middle fork. Class AA
(91) Satsop River, west fork. Class AA
(92) Skagit River from mouth to Skiyou Slough-lower end (river mile 25.6). Class A
(93) Skagit River and tributaries (includes Baker, Suak, Suiattle, and Cascade rivers) from Skiyou Slough-lower end, (river mile 25.6) to Canadian border (river mile 127.0). Special condition - Skagit River (Gorge by-pass reach) from Gorge Dam (river mile 96.6) to Gorge Powerhouse (river mile 94.2). Temperature shall not exceed 21°C due to human activities. When natural conditions exceed 21°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C, nor shall such temperature increases, at any time, exceed t=34/(T+9). Class AA
(94) Skokomish River and tributaries. Class AA
(95) Skookumchuck River from Bloody Run Creek (river mile 21.4) to headwaters. Class AA
(96) Skykomish River from mouth to May Creek (above Gold Bar at river mile 41.2). Class A
(97) Skykomish River from May Creek (above Gold Bar at river mile 41.2) to headwaters. Class AA
(98) Snake River from mouth to Washington-Idaho-Oregon border (river mile 176.1). Special condition:
(a) Below Clearwater River (river mile 139.3). Temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9).
(b) Above Clearwater River (river mile 139.3). Temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed 0.3°C due to any single source or 1.1°C due to all such activities combined. Class A
(99) Snohomish River from mouth and east of longitude 122°13'40"W upstream to latitude 47°56'30"N (southern tip of Ebey Island at river mile 8.1). Special condition - fecal coliform organism levels shall both not exceed a geometric mean value of 200 colonies/100 mL and not have more than 10 percent of the samples obtained for calculating the mean value exceeding 400 colonies/100 mL. Class A
(100) Snohomish River upstream from latitude 47°56'30"N (southern tip of Ebey Island river mile 8.1) to confluence with Skykomish and Snoqualmie River (river mile 20.5). Class A
(101) Snoqualmie River and tributaries from mouth to west boundary of Twin Falls State Park on south fork (river mile 9.1). Class A
(102) Snoqualmie River, middle fork. Class AA
(103) Snoqualmie River, north fork. Class AA
(104) Snoqualmie River, south fork, from west boundary of Twin Falls State Park (river mile 9.1) to headwaters. Class AA
(105) Soleduck River and tributaries. Class AA
(106) Spokane River from mouth to Long Lake Dam (river mile 33.9). Special condition - temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9). Class A
(107) Spokane River from Long Lake Dam (river mile 33.9) to Nine Mile Bridge (river mile 58.0). Special conditions:
(a) The average euphotic zone concentration of total phosphorus (as P) shall not exceed 25µg/L during the period of June 1 to October 31.
(b) Temperature shall not exceed 20.0°C, due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time exceed t=34/(T+9). Lake Class
(108) Spokane River from Nine Mile Bridge (river mile 58.0) to the Idaho border (river mile 96.5). Temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time exceed t=34/(T+9). Class A
(109) Stehekin River. Class AA
(110) Stillaguamish River from mouth to north and south forks (river mile 17.8). Class A
(111) Stillaguamish River, north fork, from mouth to Squire Creek (river mile 31.2). Class A
(112) Stillaguamish River, north fork, from Squire Creek (river mile 31.2) to headwaters. Class AA
(113) Stillaguamish River, south fork, from mouth to Canyon Creek (river mile 33.7). Class A
(114) Stillaguamish River, south fork, from Canyon Creek (river mile 33.7) to headwaters. Class AA
(115) Sulphur Creek. Class B
(116) Sultan River from mouth to Chaplain Creek (river mile 5.9). Class A
(117) Sultan River and tributaries from Chaplain Creek (river mile 5.9) to headwaters. Special condition - no waste discharge will be permitted above city of Everett Diversion Dam (river mile 9.4). Class AA
(118) Sumas River from Canadian border (river mile 12) to headwaters (river mile 23). Class A
(119) Tieton River. Class AA
(120) Tolt River, south fork and tributaries from mouth to west boundary of Sec. 31-T26N-R9E (river mile 6.9). Class AA
(121) Tolt River, south fork from west boundary of Sec. 31-T26N-R9E (river mile 6.9) to headwaters. Special condition - no waste discharge will be permitted. Class AA
(122) Touchet River, north fork from Dayton water intake structure (river mile 3.0) to headwaters. Class AA
(123) Toutle River, north fork, from Green River to headwaters. Class AA
(124) Toutle River, south fork. Class AA
(125) Tucannon River from Umatilla National Forest boundary (river mile 38.1) to headwaters. Class AA
(126) Twisp River. Class AA
(127) Union River and tributaries from Bremerton Waterworks Dam (river mile 6.9) to headwaters. Special condition - no waste discharge will be permitted. Class AA

(128)	Walla Walla River from mouth to Lowden (Dry Creek at river mile 27.2).	Class B
(129)	Walla Walla River from Lowden (Dry Creek at river mile 27.2) to Oregon border (river mile 40). Special condition - temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9).	Class A
(130)	Wenatchee River from Wenatchee National Forest boundary (river mile 27.1) to headwaters.	Class AA
(131)	White River (Pierce-King counties) from Mud Mountain Dam (river mile 27.1) to headwaters.	Class AA
(132)	White River (Chelan County).	Class AA
(133)	Wildcat Creek.	Class A
(134)	Willapa River upstream of a line bearing 70° true through Mailboat Slough light (river mile 1.8).	Class A
(135)	Wishkah River from mouth to river mile 6 (SW 1/4 SW 1/4 NE 1/4 Sec. 21-T18N-R9W).	Class B
(136)	Wishkah River from river mile 6 (SW 1/4 SW 1/4 NE 1/4 Sec. 21-T18N-R9W) to west fork (river mile 17.7).	Class A
(137)	Wishkah River from west fork of Wishkah River (river mile 17.7) to south boundary of Sec. 33-T21N-R8W (river mile 32.0).	Class AA
(138)	Wishkah River and tributaries from south boundary of Sec. 33-T21N-R8W (river mile 32.0) to headwaters. Special condition - no waste discharge will be permitted.	Class AA
(139)	Wynoochee River from mouth to Olympic National Forest boundary (river mile 45.9).	Class A
(140)	Wynoochee River from Olympic National Forest boundary (river mile 45.9) to headwaters.	Class AA
(141)	Yakima River from mouth to Cle Elum River (river mile 185.6). Special condition - temperature shall not exceed 21.0°C due to human activities. When natural conditions exceed 21.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9).	Class A
(142)	Yakima River from Cle Elum River (river mile 185.6) to headwaters.	Class AA

[Statutory Authority: Chapter 90.48 RCW. 92-24-037 (Order 92-29), § 173-201A-130, filed 11/25/92, effective 12/26/92.]