Snohomish County Public Works Department

Surface Water Management Division

SNOHOMISH COUNTY WADEABLE STREAM HABITAT SURVEY PROTOCOL FOR STATUS AND TREND MONITORING

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Introduction

Snohomish County Surface Water Management (SWM) conducts salmonid habitat monitoring in streams and rivers with the goal of documenting the current status and changing trends in habitat quality and quantity. Wadeable stream habitat monitoring previously conducted by SWM directly supported salmon recovery planning by documenting stream condition status and comparing these results to regional performance standards for habitat quality (e.g., NOAA 1996, Spence et al. 1996; WFPB 1997; SRBSRTC 2002). These assessments informed the development of habitat protection and restoration strategies and projects. Following the adoption of the Puget Sound Chinook Salmon Recovery Plan by NOAA in 2007, SWM's habitat monitoring program has focused on trend detection to assess long-term changes in habitat quantity and quality; specifically, "Are habitat conditions in Snohomish County streams meeting salmon recovery and Puget Sound recovery goals and targets?

In addition to long-term trend detection, the monitoring strategy is designed to provide immediate useful and relevant information to inform conservation and restoration decision-making and adaptive management pertaining to the following questions;

1. How does land use/land cover affect instream physical habitat conditions in Snohomish County?
2. What fraction of existing habitat conditions compare favorably or unfavorably to habitat performance standards and local targets?
3. Where are good and poor habitats located and how are their abundance and distribution changing over time?
4. What and where are restoration and protection efforts needed (i.e., location or amount)?
5. Are changes to the survey methodology developed for status and trend monitoring needed to better inform adaptive management decision-making?

Snohomish County's wadeable stream monitoring approach integrates the effects of potential impacts and enhancement (from project effectiveness) at multiple scales to evaluate the cumulative effectiveness of recovery actions. Whereas project effectiveness documents the specific effectiveness and outcomes of individual projects, status and trend monitoring complements project effectiveness monitoring by assessing general habitat conditions over a larger scale in order to document the cumulative response of monitoring indicators to both upland and instream activities that affect stream habitat (i.e.; capital improvement projects, buffer protections, and land-use on the watershed scale).

Wadeable streams or rivers comprise the largest proportion of any subbasin drainage network and are considered shallow enough to safely survey during summer low flow periods without the use of a boat, approximately up to 30m wide in Puget Sound. Aquatic habitats and riparian areas reflect upstream and upland watershed processes that govern the supply, transport and storage of water, sediment, and organic material.

The distribution, composition, abundance, frequency and rate of change of habitats varies based on important controlling factors such as land cover, geology, basin geomorphology, channel network dynamics, climate and watershed disturbance history. The relationship among these landscape (independent) and habitat (dependent) factors suggests that multi-parameter linear or non-linear models can be used to interpret the effect or influence of independent variables on dependent variables. As part of future reporting, habitat monitoring results generated using this protocol will be used to parameterize and validate alternative watershed models that will help answer questions 1-3 above.

Beginning in 2000, Snohomish County identified a limited set of habitat parameters relevant to salmonid habitat limiting factors (e.g.; NMFS 1996). Then and now, we employ a relatively rapid assessment that relies on continuous and regular transect-based quantitative measurement to maximize precision and repeatability. For current trend monitoring, we chose to limit the extent of sample survey sites based on gradient, channel width, and known distribution of ESA-listed Puget Sound Chinook salmon and the majority of steelhead distribution within Snohomish County (see more below regarding sample frame criteria). To achieve strong inference, we use a random sampling approach to extrapolate our results more broadly to streams that contain important spawning and rearing areas for ESA-listed salmon populations. In this way we can broadly answer whether habitat conditions for fish are functioning, impaired or degraded across a proportion of the sample frame and assess the variability in condition by several independent factors (such as location and land use). It also allows for the detection of trends in habitat conditions to be described based on performance (e.g.; % improvement) over time.

Although the benefits of random sampling are well known, targeted sampling of wadeable stream sites established 6-14 years ago around Snohomish County also represents an alternative opportunity to detect early trends for some indicators based on repeat site monitoring. Both approaches allow comparisons of monitoring results over time to Salmon Recovery Plan-specific habitat targets where those have been described and where data are collected at appropriate locations to monitor area-specific outcomes. In our sampling scheme, we have made an effort to balance the tradeoffs of each approach and fulfill the monitoring proposals of each watershed Salmon Recovery Plan. In the Stillaguamish River, a data-rich watershed, we have prioritized returning to previously sampled sites. In the Snohomish River basin and Cedar-Sammamish watershed, we apply a random sampling approach.

Based on the analysis of all sites and conditions represented by them, the likely mechanism(s) operating to limit conditions or cause impairment (or improvement) in habitats will be investigated as will relationships between survey parameters. Descriptive and predictive models can be developed and validated in new sampling areas and can be used to hypothesize likely future habitat changes. If successful, this approach to monitoring and assessment will strongly support adaptive management decision-making. Important management and monitoring questions are included in Table 1. The objectives of this report are to describe sampling protocols for physical habitat inventory in wadeable streams and summarize key aspects of data collection, file storage and database management at Snohomish County. Exploration of the monitoring questions will be reported elsewhere.

Table 1: Monitoring indicators and associated management and monitoring questions. Not all questions are addressed in this report.

Survey Parameter	Relevance	Question	Indicator (e.g.….)
Large Woody Debris (LWD) - (includes small and large fractions >1.5 m length, >0.1 m diameter and description of woody debris jams))	Status	-What are the characteristics and functions of LWD? What condition based on performance criteria represents the baseline?	LWD frequency, loading, volume
		-What are the characteristics and functions of LWD jams? How much LWD is in jams?	Jam frequency, size, proportion of LWD
	Interactions	-Is large woody debris forming pools more frequently where LWD is abundant? Is LWD loading or frequency correlated with pool habitat quantity or quality?	% of pools formed by LWD, regression function
		-How does Jam number and frequency vary with total LWD, land use or channel size?	Jam number, frequency
		-How does LWD abundance vary with amount of streambank armoring?	LWD frequency
		-Is LWD abundance correlated with riparian cover condition or contributing area land cover?	LWD loading or volume
	Trends	-Is abundance and proportion of LWD in the low flow channel increasing?	LWD pool forming factor
		-Is large woody debris of different size fractions increasing in abundance?	LWD size fractions
		-Are LWD jams becoming more abundant and frequently spaced?	LWD jam frequency
Habitat types - (pools, riffles, glides, side channels)	Status	-What are the characteristics and functions of pools based on performance criteria? What is the composition of riffles and glide habitats?	Pool, riffle, glide frequency/area
		-What forms most pools and what quality characteristics are present?	Pool forming factor, pool spacing, pool depth
		-What are the distinguishing differences between Primary and Backwater pools?	Pool area, depth, forming factor
		-What is the total and % length and area of side channels	Side channel frequency, length, area
	Interactions	-What relationships exist between LWD and pools? Between bank conditions and pools? Between land cover and pools?	Regression function; factorial analysis
		-Is the abundance of side channel habitat correlated with bank modifications or LWD abundance? Is side channel presence explained by stream slope only?	Regression function; factorial analysis
		-Are primary or backwater pools more typically correlated with LWD abundance or spacing?	Regression function; factorial analysis
	Trends	-Is pool frequency, area, and residual depth increasing?	Slope is not = 0 or >0
		-Are there more LWD formed pools? Does this decrease pool-pool spacing?	Slope is not = 0 or >0
		-Is mainstem riffle frequency/area increasing or decreasing?	Slope is not = 0 or >0
		-As habitat improves, is unit habitat composition shifting away from glide habitat?	Slope is not = 0 or >0

		-Is relative proportion and frequency of all habitat types (pools, riffles, glides, and side channels) more diverse?	Relative standard deviation is increasing
Survey Parameter	**Relevance**	**Question**	**Indicator (e.g.…)**
Riparian Condition - (as bank and mid-channel stream site cover and as contributing land cover within riparian buffer area)	Status	-What percentage of the riparian buffer is providing adequate cover for shading?	% canopy cover
	Interactions	-What spatial scales (i.e., reach, upstream riparian buffer, land use) are good predictors of LWD recruitment and jam formation?	% Cumulative Upstream Riparian Buffer > 150 ft wide
		-Are there subasins with high development but that still have an intact riparian buffer?	Vegetative cover classification, composition, and other vegetation metrics from low- and high-resolution satellite imagery (i.e., Landsat and Quickbird, respectively)
	Trends	-Is composition of natural land cover increasing in riparian and floodplain areas?	
		-Is composition of impervious area in buffers decreasing?	
		-is composition, extent, and connectivity of mature vegetation increasing?	
		-Is number of breaks (road crossings, utilities, clearing) decreasing?	
		-Is canopy cover increasing?	
Channel condition – (Including off-, side-channels)	Status	-What do existing channel conditions indicate about watershed condition?	Channel type, width:depth ratio
	Trends	-Is cross-channel width, depth or area increasing or decreasing?	BFW, BFD, Gradient, % channel composition
		-Are channels aggrading or incising?	
		-Are side channels increasing in number, length or area?	
Substrate size –	Status	- What is the proportion of fines and sand among sites and what is the level of impairment?	% < 2mm;
	Trends	- Are average sediment particle sizes increasing? Is the proportion of fines and sands increasing or decreasing?	Cumulative distribution; Slope is not = 0 or >0
Bank conditions – modification, stability and cover	Status	-What is the degree of modification and stability of streambanks?	Percent composition of modifications and stability by reach; Regression functions;
		-Are the amounts of armoring and instability related within survey sites?	
	Interaction	-Do bank modifications limit LWD storage, enhance LWD transport, limit LWD recruitment and reduce or eliminate vegetation resulting in lower stream LWD loading or frequency?	
		-Is LWD, canopy cover, pool habitats or substrate size correlated with modified or unstable streambanks?	
		-Do modified or unstable streambanks correlate with poor LWD pool quality or quantity?	
		Do areas with more bank modification have less bank cover for fish?	
	Trends	Are bank modifications (armoring) increasing or decreasing?	Cumulative distribution

Methods

Stream Reach Delineation and Selection

A reach selection process identified stream segments that would best meet the goals of monitoring Federally-listed ESA salmon and steelhead habitat in wadeable streams. The first step in this process was to populate a sampling frame with reaches meeting criteria that reflected monitoring goals. First, stream reaches overlapped with the steelhead and Chinook salmon distribution and wadeable during summer flows. Additionally, reaches within the sampling frame were limited to those with less than 2% gradient because gradient is a strong determinant of channel morphology and habitat forming processes. Surveyed stream reaches were randomly selected from the sampling frame.

Chinook Salmon and Steelhead Distribution
In order to identify reaches within the steelhead and Chinook salmon distribution, we combined steelhead and Chinook salmon distribution data from *StreamNet (2005)* and compared it with Washington State Conservation Commission's *Salmon and Steelhead Habitat Limiting Factors Analyses* (e.g.; Haring 2002). Corresponding "known" and "presumed" steelhead distribution attributes from these data sources were transferred to the County's watercourse layer so the resulting population dataset would be spatially coincident with existing county layers. The steelhead layer was examined to ensure that it included known and presumed Chinook distribution.

Channel Gradient
The reach population that had been extracted based on steelhead and Chinook distribution was then filtered to exclude reaches with a gradient > 2%. Since Rosgen stream class data had previously been generated by the county and applied to spatially referenced stream segments, Rosgen stream type was used to select streams by channel gradient. We overlaid the steelhead distribution layer with streams that were identified as Rosgen channel types C, F and E, which corresponded to a channel gradient of 2% or less. Segments with higher gradients were excluded from the reach sample frame.

Channel Size
Reaches that remained after the gradient screen were examined for channel size with the goal of selecting streams large enough to safely survey on foot but at least five meters in BFW. We excluded the largest rivers from the population based on current knowledge of wadeability. This included reaches surveyed as part of the County's large river survey (using watercraft) as well as stream segments known to be prohibitively deep or otherwise unwadeable. We screened stream segments for minimum BFW requirements by estimating stream size as a function of the upstream contributing area. Contributing area polygons were digitized for 80 of the most upstream segments. Contributing areas were calculated for these polygons and were compared to contributing areas for

stream segments with known BFW. We established thresholds for contributing areas in west and east Snohomish County likely to yield streams smaller than five meter BFW (< 900 ha in west and <500 ha east). Segments with contributing areas less than the thresholds were removed from the population. At this point, the remaining contiguous segments were merged along stream routes.

Segment length

In order to generate a list of stream reaches with consistent lengths, we divided segments based on any existing EDT model reach breaks and major tributary inputs or, absent those, by splitting long reaches in half. This was done until all segments were less than six kilometers (ten times the length of the longest sample reach (20x30m BFW)). The final result of the stream reach selection process was a sample frame of 120 reaches, 70 in the Snohomish and 50 in the Stillaguamish. From this sampling frame, thirty primary reaches and five alternate reaches were randomly selected for survey from each basin. Using Rosgen (1996) as a guide, a standard survey reach length of 20-30 bankfull channel widths was selected. A bankfull width measured at the beginning of each unit reach is used to calculate the unit reach length.

Field Equipment

Trimble GeoExplorer (XT/XH)	Stadia rod, metric
Laser range finder	Hip chain, metric
Convex spherical densiometer	Hand level rod (metric graduated)
Hand level - pea gun	Caliper or metric ruler
Flagging tape/ indelible pen	Two way radios (optional)
Manual Tally Counter	

Training

To minimize observer / method variability and bias, training is conducted at the beginning of each survey season. Training is organized to demonstrate survey method techniques and equipment used. Measurements common to bias, errors, and high variability are identified in past repeatability analysis (Snohomish County 2002, and ongoing repeat surveys) allowing for additional emphasis on method training. Protocol is reviewed and practiced to ensure methods are understood and team members are able to demonstrate correct measurements. Practice surveys are repeated and survey data is compared to identify potential high variability.

GPS units and File Management

Survey data are entered into a data dictionary file (Appendix A) contained on a Trimble GPS field computer running the Windows™ operating system. Because wadeable stream channels (especially those with dense vegetative cover or in deep valleys) are notorious for having poor satellite coverage, this survey method does not require surveyors to collect GPS positions for each stream feature. Instead, most attributes are entered into the data dictionary without collecting discrete GPS locations. These attributes are processed in the office and exported as *.dbf tables with the ability to link to spatial data by file/reach identifier. GPS locations are recorded at the start and end of the reach and at as many transects as possible along the length of the reach. In the worst case scenario, a reach start point and end point can be digitized in the field over recent ortho-photos, stored as background files in the field computer.

"Not-in-feature" position points (GPS breadcrumbs) are also collected throughout the reach at intervals of 5 meters or whenever the unit receives sufficient satellite signals (>5 m). Each one of these points carries a time stamp that can be related to time stamps from survey data entries and their corresponding hip chain station values. This allows the approximate placement (mapping) of each feature collected along a routed stream centerline in ArcGIS.

Quality assurance and control measures are taken to ensure that data collection and management minimize bias, uncertainty, and errors (entry or transcription) and maximize accuracy and precision. During data collection, a lead surveyor is designated who coordinates the survey so that measurements are not overlooked. Data are directly entered into the field computer to avoid transcription errors with data entry from field forms. Completed reach files are transferred to an office PC after each day of survey. Data are reviewed after computer upload by the person who conducted the survey to screen for errors, and any changes to the data are documented. Any potential recording errors are noted and communicated to the data manager.

Data Management and Output for Analysis

All stream data across survey reaches are appended by feature classes and individually uploaded to a relational database. All survey and habitat tables are organized based on the survey reach identifier. For each survey, key survey information, such as total survey length is used to generate intermediate queries of channel metrics useful for estimating habitat frequencies, spacing, loading, or aerial composition.

Field Procedure

Survey Strategy

Survey teams generally consist of two or three surveyors. The lead surveyor is responsible for data entry into the field computer and survey coordination. Data recording is often a time bottleneck, and it is important for the survey lead to coordinate the survey so that measurements are not overlooked and surveyors are proceeding at a pace consistent with data entry.

At the start of each reach, surveyors tie off and zero the hip chain. They record a station number from the hip chain for each piece of information gathered in the reach. The station designation provides an organizational record for data entry into an extensive computer database. Where survey measurements are made in the main channel, MC is entered in the Channel Type field within the database. SC is entered if survey measurements are made in side channel habitat. All side channel data are organized based on only using the main channel station number where the side channel starts.

Teams begin each reach by measuring a bankfull width at an appropriate location (near survey start point, at a riffle cross-over, and without obstructions (log jams)). The result of this measurement dictates the length of the reach, the spacing of sampling transects, and the minimum pool area and depth criteria. If the initial bankfull width measurement is very close (w/in 0.1 m) to next highest bankfull width category (Table 2), the survey length is adjusted to the next higher BFW category. The survey length is not adjusted to a lower category to make a shorter reach if the opposite is true (w/in 0.1 m of the next lowest BFW category).

In an upstream direction, surveyors collect continuous physical habitat and transect data as described below. The station locations (on the hip chain) and GPS positions of log jams and side channels are recorded for later data collection. When the final transect (i.e., the survey end point) falls within a qualifying habitat feature, surveyors measure and record the information for that feature only up to the final transect. In the case of a pool, however, maximum depth is noted even if it is upstream of the final transect. In the case of a piece of upstream LWD, it is counted if a fraction crosses the final transect or station number.

After completing the upstream continuous survey, surveyors measure the gradients between flagged transects and collect log jam and side channel data in a downstream direction. Teams retrieve all hipchain and flagging, except the flag that marks transect 1 which is used as a reference in case the reach is chosen for future within-season repeat survey (to estimate residual error).

Table 2: Wadeable survey reach lengths and transect locations based on initial BFW.

Bank Full Width (m)	Reach Length (m)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 5	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11
0 - 2.4	50	0	5	10	15	20	25	30	35	40	45	50
2.5 - 4.9	100	0	10	20	30	40	50	60	70	80	90	100
5.0 - 9.9	200	0	20	40	60	80	100	120	140	160	180	200
10.0 - 14.9	300	0	30	60	90	120	150	180	210	240	270	300

15.0 - 19.9	400	0	40	80	120	160	200	240	280	320	360	400
20 - 30	600	0	60	120	180	240	300	360	420	480	540	600
>30	800	0	80	160	240	320	400	480	560	640	720	800

Protocol for Dry or Intermittent Main Channels

Channels that are dry at the time of the survey are surveyed for bankfull width and depth, wood, bank condition, and transect metrics. If these channels have standing water in pools that meet the survey criteria, the pools are recorded. In streams with intermittent flow (some surface/ some sub-surface flow), stream units with no surface flow are entered as riffles. Record the length of each unit of dry channel and record a wetted width of zero. This ensures total length is recorded and preserved and that habitat area is only estimated based on wetted units.

Bankfull Width and Depth

Purpose: Bankfull width is the primary measure of channel size and is used to determine the minimum size of functioning pools along the reach, as well as the unit reach length. Bankfull depth is also measured to calculate a width to depth ratio.

Definition: Bankfull width is the width of a stream channel at the point where over-bank flow begins during a 1.5-2 year flood event. Straight, low-gradient riffles with uniform banks, few or no obstructions (such as jams), and no side-channels are the best locations for measuring bankfull width. Bankfull width is located using any of the following indicators: the top of deposited bedload (gravel bars), stain lines, the lower limit of perennial vegetation, moss or lichen, a change in slope or particle size on the stream bank, and undercut banks (USFS 1999). Bankfull depth is defined as the vertical distance between bankfull stage and the thalweg of a riffle (Rosgen 1996).

Procedure: The BFW feature class is selected in the data dictionary. Using a laser rangefinder or stadia rod, bankfull width and wetted width is measured at the first riffle (on or near transect 1), at the riffle nearest the midpoint (on or near transect 6), and at the last riffle within the reach (on or near transect 11). Bankfull depth is measured by one surveyor at bankfull stage using a hand level (pea gun) and another surveyor holding a stadia rod vertically in the thalweg of the riffle. The known height of the hand level rod is subtracted from the reading on the stadia rod.

Data entry for bankfull width (BFW):

Required Values: Station, Bankfull Width, Wetted Width, Bankfull Depth

Transect Characterization

The spacing of transects is determined from the initial bankfull width measurement (Table 2). Beginning at transect 1 (station 0), data are collected from 11 transects and 10 half-transects (spaced in-between transects) as survey teams move upstream. A GPS location is recorded at each transect (thalweg) and transect information is recorded in the data dictionary as attributes of the transect feature class in the data dictionary. At each transect and half-transect, the dominant feature (pool, riffle, other) across a majority of the stream width is identified and recorded. Teams collect data on stream cover and substrate size as described below. Transects 1, 2, 5, 6, 10, and 11 are flagged in order to measure gradients.

Stream Cover

Purpose: To assess vegetative cover indicating the amount of shade provided for stream cooling or cover on streambanks as well as potential inputs of organic matter.

Procedure: At each transect, a total of eight cover measurements are made using a convex spherical densitometer modified as described in Lazorchak *et al*, (1998) where the number of grid points are limited from 96 to 17. While holding the densitometer level at 30 cm above the water surface, one observer counts the number of intersecting points covered by leaves, branches, etc. and records the values (0-17) in the data dictionary, where 0 corresponds to no cover (open sky) and 17 corresponds to total cover. Four readings are taken from the center of the channel facing toward the right bank, upstream, the left bank and downstream. Next, one reading at the right wetted edge and another at the right streambank are made facing perpendicular to the stream bank. The procedure is repeated at the left wetted edge and left stream bank.

Substrate Size

Purpose: To characterize size of the substrate found within the reach.

Procedure: Five sediment samples are collected across the wetted width of the stream channel at each of 11 transects and 10 half-transects, for a total of 105 samples recorded for the entire survey.

At each transect and half-transect, the wetted width is divided into four equal widths in order to sample at the wetted edge, at 25% of the wetted width, then at 50% of the wetted width, 75% of the wetted width, and at the opposite wetted edge. Beginning at the wetted edge, the first substrate particle touched in front of the surveyor’s boot toe is picked up. Using a caliper or metric ruler, the intermediate axis (the dimension by which the particle would pass through a sieve) of the particle is measured and recorded (in millimeters). The actual measurement is stored, and as part of data transformation, each particle is classified into one of the size classes listed in Table 3. Retaining the actual measurement allows for more accurate calculation of substrate size metrics (i.e., geometric mean or cumulative size distribution).

Table 3: Substrate size classes adapted from Lazorchak *et al*, (1998).

Size Class	Size Range (mm)
Fines	< 0.06
Sand	> 0.06 to 2
Gravel (fine)	> 2 to 16
Gravel (course)	> 16 to 64
Cobble	> 64 to 250
Boulder	> 250 to 4000
Hardpan	> 4000
Bedrock (rough)	> 4000
Bedrock (smooth)	> 4000

Data Entry for transect:

Required Values: Transect Number, Wetted Width, Station, Habitat Unit Type, Canopy Cover (6 values), Substrate Size (5 values).

Continuous Habitat Parameters

Stream Bank Condition

Purpose: To inventory bank modifications and assess bank stability.

Definitions:

Bank Stability: Banks are stable unless they show indications of any of the following features at or above bankfull stage (Bauer and Burton 1993):

Breakdown: Obvious blocks of bank have broken away and are lying adjacent to the bank breakage.

Slumping or False bank: The bank has obviously slipped down, but cracks may or may not be obvious.

Fracture: A crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream.

Vertical and Eroding: The bank angle is steeper than 80^{o} from the horizontal *and* the bank is mostly uncovered as defined below:

- ≤ 50% of ground cover is perennial vegetation
- ≤ 50% of the bank is covered by roots.
- ≤50% of the bank is protected by rocks of cobble size or larger.
- ≤ 50% of the bank surfaces are protected by wood ≥10-cm in diameter.

Bank Condition: Banks are categorized as being either “natural” or “modified”.

Modification Type: Types of bank modification include *Dike/levee, Berm, Revetment, Bulkhead, Grade, or N/A*. If the type of bank modification is unclear, it is classified as a revetment. Unstable, natural banks are assigned a Type value of *N/A* by default.

Modification Toe: The toe class is determined by visually examining primary bank material below bankfull stage. Toe classes include *Riprap, Rubble, Structural, and Earth*. Bank material greater than 256 mm (10 in) is considered *Riprap*. Bank material less than 256 mm is considered *Rubble* (Beamer & Henderson, 1998). Other classes such as placed wood, concrete, and gabion are lumped into *Structural* toe class. Unstable, natural banks are assigned a Toe value of *Earth* by default.

Procedure: Stream bank conditions are monitored continuously along both banks. When a portion of unstable or modified bank is encountered, the bank feature class in the data dictionary is selected, the hip chain station is recorded, and the right or left bank (facing downstream) is indicated. The length of the unstable or modified feature is measured with a rangefinder, the stadia rod or on the hip chain. If a side channel is present, the bank condition on the island separating the main channel and side channel is recorded as inner bank.

Data entry for stream bank instability:

Required Values: Station, Channel Type, Location, River Bank, Condition, Stability, Modification Type, Toe Class, Length.

Side Channel Habitat

Purpose: To quantify habitat in side channels.

Definition: Side channels are defined as channels that are separated from the main channel by a stable island and contain the smaller portion of the total flow. A stable island in a forested stream is defined by USFS (1999) as supporting woody vegetation (excluding willow) that is estimated to be at least 5 years old and covers at least 50% of the island surface at or above bankfull elevation.

Procedure: Surveyors identify whether or not a potential side channel feature is separated from the main channel by a stable island. If the feature is not separated by a stable island, include it with the main channel measurements.

Side channel conditions are recorded in the Side Channel feature class in the data dictionary. The station number of the downstream side channel outlet is recorded and a GPS point is logged. Side channels are surveyed on the way downstream after the main channel survey is completed. However, the upstream extent of the side channel should be found and flagged in order to return to that location. The side channel features are surveyed following the same method used for continuous survey of mainstem channels, identifying and recording habitat units, unstable banks, and LWD as separate feature classes. Each feature found within the side channel is recorded with same initial station number in order to identify every side channel feature with each specific side channel.

Side channel total length (wet and dry units) and mean total width are recorded in the side channel feature class. Total wetted length and mean wetted width are estimated from wetted habitat units within the side channel as part of habitat analysis. Side channels are not included as part of transect cross sections because side channels can depart far from the mainstem making the transect point difficult to locate, side channels may be marginal in their characteristics, and, very often, side channels are dry during summer low flow and are unrepresentative of low flow wetted habitat and dominant discharge processes that transects characterize.

Data Entry for side channel measurements:

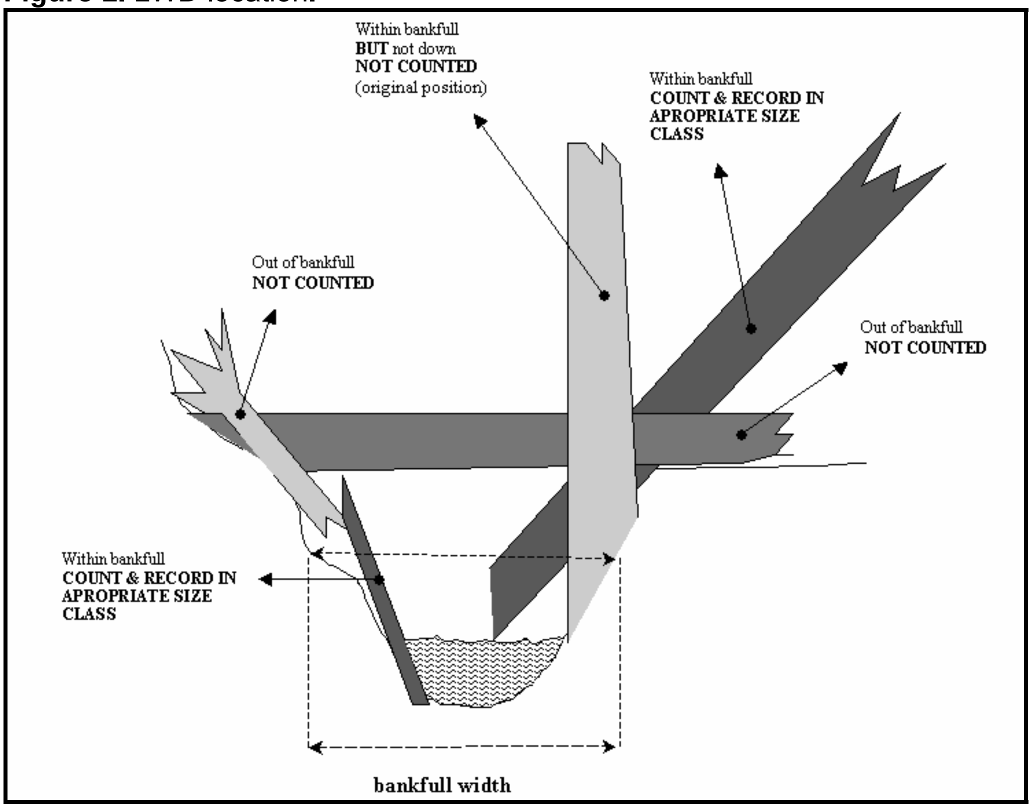
Required Values: Station, Wet Length, Total Length, Wet Width, Total Width.

Woody Debris

Purpose: To measure the characteristics and quantity of instream wood providing habitat complexity, cover and hydraulic roughness.

Definitions: The minimum size for a qualifying piece of wood is 1.5 meters long and at least 10 cm in diameter along the qualifying length of the piece (Lazorchak *et al.* 1998). For pieces that are less than 7.6 m long, the average diameter over the length of the piece is recorded. For pieces that are greater than 7.6 m long, the diameter is measured at 7.6 m from the large end. Only downed wood that intercepts the bankfull flow is counted (Figure 1). Wood above bankfull elevation is recorded only if it is part of a jam that contains wood below the bankfull level. Jams are defined as 3 or more touching pieces of wood that are >7.6 m in length and >30 cm in diameter (USFS 1999). Rootwads are defined as having an average diameter of 1 meter or greater.

Figure 1. LWD location**.**



Trees standing vertically, wholly or partially, within the bankfull area with their weight supported by attached roots are not counted. If this cannot be determined and the stump is creating a qualifying pool, then record the piece as qualifying woody debris.

Procedure: Small wood that is 10-30 cm in diameter and without a qualifying rootwad is tallied and not assigned a hipchain station. Tallies for small wood are entered for the entire reach after the survey. Hipchain stations are recorded for individual pieces of wood 10-30 cm in diameter and that have a qualifying rootwad, as well as all wood that is > 30 cm in diameter. Measure wood with a stadia rod or rangefinder, and bin into diameter and length classes (Table 3). Record whether or not each piece has a qualifying rootwad attached, if it is in contact with low flow, and if it is part of a jam.

Table 3: Woody debris size classes and recording or tally designation.

	Diameter Class			
Length Class	<30	30-60	60-90	>90
	No Rootwad			
1.5-7.6 m	Tally	R	R	R
	With Rootwad			
1.5-7.6 m	R	R	R	R
	No Rootwad			
7.6-15 m	Tally	R	R	R
	With Rootwad			
7.6-15 m	R	R	R	R
	No Rootwad			
>15 m	Tally	R	R	R
	With Rootwad			
>15 m	R	R	R	R

R – record piece in data dictionary

When a log jam is encountered, the Jam feature class in the data dictionary is utilized. The station number is entered and a GPS point is logged. Stable jams are surveyed by climbing around and on the jam to count wood as accurately as possible. Adopt a systematic approach to counting wood within large jams. Wood in jams is surveyed using the same method as single pieces. Each qualifying piece of wood in a jam is assigned the same station number. Small wood (10-30 cm in diameter and without a qualifying rootwad) found in each jam is tallied as in Table 3 and entered into the jam feature class separate from the other non-jam tallies. The amount of wood contained in jams is estimated for both inventoried and tallied pieces. Large jams can be inventoried on the way upstream or downstream.

Data Entry for wood:

Required Values: Station, Channel Type, Length Class, Diameter Class, Rootwad (Yes/No), Wet (Yes/No), Part of a Jam (Yes/No). Add final tallies for main channel and side channel wood under Reach Info.

Note: Other woody debris survey protocols or woody debris performance criteria (e.g.; WFBP 1997) are based on piece size dimensions of at least 2m length and 10cm width – slightly larger than the EMAP based measurement criteria (Lazorchak *et al.* 1998) we use. In 2006, we surveyed small woody debris (1.5m-7.6m) among 32 stream reaches. For this piece length category we noted whether the piece was also less than 2.0m length. Among 1,834 pieces, 209 (or 11.3%) were less than 2.0m length. Among the 32 reaches, we excluded the 4 highest and lowest outliers (that is, the percent composition of wood less than 2.0m). For each of these outlier reaches the total number of wood pieces encountered was always less than 15. For all other reaches, total piece count ranged from 15-332 pieces. Among these reaches, the average percent of the wood count < 2.0m length was 11.3% and the range among reaches was 2-21%. Reaches with high total piece count tended toward the total survey and among-reach mean (11.3%). In order to compare our survey results with other woody debris metrics based on the other criteria and to compare to other studies, we will reduce our total piece count in the smallest size category by 11.3% and periodically implement surveys where we not whether individual pieces meeting the minimum size criteria are also <2m length. We will use this correction to quantify LWD frequency, spacing, and loading when comparing results with other studies.

Pool Habitat

Purpose: To measure habitat area available for holding and rearing.

Definitions:

Pool – A pool is a section of stream channel where water is impounded within a closed topographical depression (Abbe and Montgomery, 1996).

Pool Type – Primary pools are located in line with the thalweg while backwater pools are separated from the main flow (Lazorchak *et al.*, 1998).

Pool Forming Feature – The feature or process that leads to the formation of a pool is described by one of the following;

- **Rip Rap or Modification** – formed by scour along a hardened bank or other instream modification; such as bridge pier or structural bulkhead
- **Bedrock** – formed by scour along bedrock material (does not include compact till)
- **Wood** – formed by scour around naturally occurring or placed wood or by being impounded by wood (a dammed pool) or plunging over wood.
- **Beaver** – formed behind beaver dam or scoured from other beaver activity
- **Free Form** – formed in ways other than above, such as from flow convergence or lateral bank resistance.

Pool Wetted and Functional Areas – Wetted area is defined as the total pool length multiplied by the average wetted width, measured from several locations. The functional area is defined by pool depths greater than or equal to 0.2 m or the pool tailout depth (which ever is greater). This definition captures the deeper areas of the pool and excludes the shallow margins as the pool tapers toward the banks or tailout.

Procedure: For a habitat unit to qualify as a pool in this survey, it must meet the minimum wetted area and depth requirements in Table 4, consistent with Pleus et al 1999.

Table 4: Minimum pool size requirements

Bank Full Width (m)	Wetted Area (m^2)	Residual Pool Depth (m)
0 – 2.49	0.5	0.10
2.5 – 4.9	1.0	0.20
5.0 – 9.9	2.0	0.25
10.0 – 14.9	3.0	0.30
15.0 – 19.9	4.0	0.35
>20	5.0	0.40

When a potential pool is encountered, the tailout depth and maximum depth are measured using a stadia rod in order to calculate the residual pool depth (maximum depth - tailout depth). If the residual depth is greater than the minimum required for the established bankfull width, the mean wetted width and wetted length of the pool are measured. If the wetted area (length * width) does not meet the requirements in Table 4, the habitat area is not recorded as a pool. In this case, the habitat unit area is lumped with an adjacent unit or recorded separately as an "other" habitat (predominantly glide- or run-like habitat).

The pool functional area is calculated using the mean functional width and functional length of the pool as defined above. In the smallest of streams (those under 2.5 meter BFW), pools may meet the minimum pool size requirements but do not have a functional area. In this case, zeros are recorded for functional length and width.

When two or more pools occur in sequence they are measured separately whenever there is a clear division (tailout) between them, when they have separate pool forming features, or when they differ in pool type. Also, when the end of the survey (transect 11) falls within a pool, the maximum depth of that pool is recorded even if that point is outside the survey reach. However, only the wetted and functional areas that lie within the survey reach are measured and recorded.

Data Entry for pools meeting minimum size criteria:

Required Values: Station, Channel Type, Pool Type, Pool Form, Tailout Depth, Maximum Depth, Wetted Width, Functional Width, Wetted Length, Functional Length.

Riffle Habitat

Purpose: To assess total wetted habitat area and composition among types .

Definitions:

> ***Riffle*** – a section of stream with shallow, turbulent, higher velocity flow. The water surface may be generally unbroken, rippled, or have small waves. Riffles are distinguished from slightly deeper, slower moving sections with a smooth surface that are considered “other” (i.e., glide). The wetted width boundary of riffles is the point at which substrate particles are no longer surrounded by free water (Lazorchak *et al.*, 1998)

Procedure: The station number of the most downstream point of the riffle is recorded. The average wetted width and wetted length are measured to determine the most accurate representation of riffle area. The riffle type is selected based on the dominant sediment size (gravel, small cobble, large cobble, boulder).

Data Entry for riffles:

Required Values: Station, Channel Type, Riffle Type, Wetted Width, Wetted Length.

Other Habitat

Purpose: To quantify other habitat areas as part of calculating total wetted area.

Definitions:

> ***Other*** – a section of stream with generally uniform cross-sectional flow, unbroken surface and mostly homogeneous depth along the thalweg. Flow may be fast but is usually slower than riffles. These are typically referred to as glides or runs and usually lack bed deforming obstructions, but may contain sizable boulders.

Procedure: The station number of the most downstream point of the habitat unit is recorded. The average wetted width and wetted length are measured to determine the most accurate representation of the area.

Data Entry for Other:

Required Values: Station, Channel Type, Wetted Width, Wetted Length.

Channel Gradient

Purpose: To calculate an average reach gradient needed to ground truth GIS derived gradients used in reach segmentation.

Procedure: Stream gradients are measured in a downstream direction after surveyors complete the transect component of the survey. Stream gradients are measured in a downstream direction between the wetted edges of transects 11 and 10, transects 6 and 5, and transects 2 and 1. To do so, one surveyor stands on the upstream transect (11, 6, and 2) and aims a hand level (pea gun) at a stadia rod held by a second surveyor on the downstream transect (10, 5, and 1). The hand level rests on a pre-fabricated pole of known height. Both rods are placed in similar water depths or at the edge of the wetted channel. The vertical elevation between transects is measured and calculated by aiming the level at the survey rod and viewing the value on the rod. The difference is calculated by subtracting the instrument height from the value read off the survey rod. The upstream and downstream transect numbers are recorded in the data dictionary, as is the absolute vertical distance. This measurement is repeated two more times at transect pairs as the team moves downstream.

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Appendix A

Snohomish County 2008 Wadeable Stream Survey Data Dictionary (Trimble Pathfinder Office Pro for Geoexplorer XH/XT)

```
"Wadeable_MAM", Dictionary
"Reach_Info", point, "", None, 1, Code
  "Reach_Ref", text, 30, normal, normal, Label2
  "Surveyor_1", menu, normal, normal
    "Andy",[AH]
    "Arden",[AT]
    "Brett",[BG]
    "Dan",[DS]
    "Frank",[FL]
    "Jeremy",[JM]
    "Josh",[JK]
    "Kevin",[KL]
    "Mike P",[MP]
    "Mike R",[MR]
    "Thomas",[TC]
    "Other",[OT]
  "Surveyor_2", menu, normal, normal
    "Andy",[AH]
    "Arden",[AT]
    "Brett",[BG]
    "Dan",[DS]
    "Frank",[FL]
    "Jeremy",[JM]
    "Josh",[JK]
    "Kevin",[KL]
    "Mike P",[MP]
    "Mike R",[MR]
    "Thomas",[TC]
    "Other",[OT]
  "Surveyor_3", menu, normal, normal
    "Andy",[AH]
    "Arden",[AT]
    "Brett",[BG]
    "Dan",[DS]
    "Frank",[FL]
    "Jeremy",[JM]
    "Josh",[JK]
    "Kevin",[KL]
    "Mike P",[MP]
    "Mike R",[MR]
    "Thomas",[TC]
```

```
    "Other",[OT]
  "Wd_Tally_MC", numeric, 0, 0, 10000, 0, normal, "Small wood tally main channel", normal
  "Wd_Tally_SC", numeric, 0, 0, 10000, 0, normal, "Small wood tally main channel", normal
  "Comment_1", text, 30, normal, normal, Label1
  "Comment_2", text, 30, normal, normal

"BFW", point, "", None, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Wet_Width", numeric, 1, 0.0, 1000.0, 0.0, normal, normal
  "BFW", numeric, 1, 0.0, 1000.0, 0.0, normal, normal
  "BFD", numeric, 2, 0.00, 10.00, 0.00, normal, normal

"Wood", point, "", None, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
  "Length_Class", menu, normal, normal, Label1
    "1.5m - 7.6m",[3]
    "7.6m - 15m",[1]
    "> 15m",[2]
  "Diam_Class", menu, normal, normal
    "< 30 cm",[4]
    "30 - 60 cm",[1]
    "60 - 90 cm",[2]
    "> 90 cm",[3]
  "Rootwad", menu, normal, normal
    "Yes",[Y]
    "No",[N]
  "Wet", menu, normal, normal
    "Yes",[Y]
    "No",[N]
  "Part_Jam", menu, normal, normal
    "Yes",[Y]
    "No",[N], default
  "Identical", numeric, 0, 1, 200, 1, normal, normal

"Pool", point, "", None, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
  "Pool_Type", menu, required, "Choose Pool Type", normal
    "Primary",[P]
```

```
    "Backwater",[B]
  "Pool_Form", menu, required, "Choose Pool Forming Factor", normal
    "Free form",[FF]
    "Rip rap",[RR]
    "Bed rock",[BR]
    "Wood",[WD]
    "Beaver",[BV]
  "Max_Depth", numeric, 2, 0.00, 10.00, 0.00, normal, normal, Label1
  "Tail_Depth", numeric, 2, 0.00, 10.00, 0.00, normal, normal, Label2
  "Wet_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Funct_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Wet_Length", numeric, 1, 0.0, 3000.0, 0.0, normal, normal
  "Funct_Length", numeric, 1, 0.0, 3000.0, 0.0, normal, normal

"Riffle", point, "", None, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
  "Riffle_Type", menu, normal, normal
    "Boulder",[BO]
    "Large_Cobble",[LC]
    "Small_Cobble",[SC]
    "Gravel",[GR]
  "Wet_Width", numeric, 1, 0.0, 1000.0, 0.0, normal, normal, Label1
  "Wet_Length", numeric, 1, 0.0, 1000.0, 0.0, normal, normal

"Other", point, "", None, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
  "Wet_Width", numeric, 1, 0.0, 1000.0, 0.0, normal, normal, Label1
  "Wet_Length", numeric, 1, 0.0, 1000.0, 0.0, normal, normal

"Bank", point, "", None, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
  "RIVER_BANK", menu, required, required
    "Right",[Right]
    "Left",[Left]
  "LOCATION", menu, normal, normal, Label2
    "Outer Bank",[O], default
    "Inner Bank",[I]
```

```
  "CONDITION", menu, normal, normal
    "Natural",[N]
    "Modified",[M]
  "STABILITY", menu, normal, normal
    "Stable",[S]
    "Unstable",[U]
  "HMOD_TYPE", menu, normal, "Enter N/A for Natural, Set Back", normal
    "Dike/Levee",[DI]
    "Berm",[BE]
    "Revetment",[RE]
    "Bulkhead",[BU]
    "Grade",[GR]
    "N/A",[NA], default
  "HMOD_TOE", menu, normal, "Describe bank material at bankfull toe", normal
    "Rip Rap (GT 256 mm) ",[RI]
    "Rubble (LT 256 mm)",[RU]
    "Structural",[ST]
    "LWD",[WD]
    "Earth/Natural",[EA], default
  "Bnk_Length", numeric, 1, 1.0, 10000.0, 1.0, normal, normal, Label1

"Side_Chan", point, "", 1, seconds, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Wet_Length", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Total_Length", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Wet_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Total_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal

"Gradient", point, "", None, 1, Code
  "UpStm_tran", numeric, 0, 0, 12, 0, normal, normal, Label2
  "DnStm_tran", numeric, 0, 0, 12, 0, normal, normal
  "Vertical Difference", numeric, 2, 0.00, 100.00, 0.00, normal, normal, Label1
  "MEASURE", numeric, 0, 0, 10, 1, normal, "Adds an identifier to each gradient",
normal, 1

"Transect", point, "", 1, seconds, 1, Code
  "Transect", numeric, 1, 1.0, 20.0, 1.0, normal, normal, Label1
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "HabUnit_Type", menu, normal, normal
    "Pool",[P]
    "Riffle",[R]
    "Other",[O]
  "Wet_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Canopy_R", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_U", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_L", numeric, 0, 0, 17, 0, normal, normal
```

```
  "Canopy_D", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_RB", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_RWE", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_LWE", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_LB", numeric, 0, 0, 17, 0, normal, normal
  "Substr1_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal, Label2
  "Substr2_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr3_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr4_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr5_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal

"Half_Transect", point, "", 1, seconds, 1, Code
  "Transect", numeric, 1, 1.0, 20.0, 1.0, normal, normal, Label1
  "HabUnit_Type", menu, normal, normal
    "Pool",[P]
    "Riffle",[R]
    "Other",[O]
  "Substr1_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr2_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr3_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr4_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr5_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal

"Jam", point, "", 1, seconds, 1, Code
  "Station", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
  "Wd_Tally_Jam", numeric, 0, 0, 10000, 0, normal, "Small wood tally per Jam",
normal
```

Appendix B

Snohomish County 2008 Wadeable Stream Survey Transect Intervals Cheat Sheet (cut and laminate).

Bank Full Width (m)	Reach Length (m)	Trans 1	Trans 1.5	Trans 2	Trans 2.5	Trans 3	Trans 3.5	Trans 4	Trans 4.5	Trans 5	Trans 5.5	Trans 6	Trans 6.5	Trans 7	Trans 7.5	Trans 8	Trans 8.5	Trans 9	Trans 9.5	Trans 10	Trans 10.5	Trans 11
0 - 2.5	50	0	2.5	5	7.5	10	13	15	18	20	23	25	28	30	33	35	38	40	43	45	48	50
2.5 - 4.9	100	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5.0 - 9.9	200	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
10.0 - 14.9	300	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
15.0 - 19.9	400	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
20 - 30	600	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600
>30	800	0	40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800

Minimum Pool Area and Depth Requirements

Bank Full Width (m)	Area (m^2)	Residual Pool Depth (m)
0 – 2.49	0.5	0.10
2.5 – 4.9	1.0	0.20
5.0 – 9.9	2.0	0.25
10.0 – 14.9	3.0	0.30
15.0 – 19.9	4.0	0.35
>20	5.0	0.40

Wood Characterization

Diameter Class	Length Class	Rootwad	Wet	Part of Jam	< 2 m
< 30 cm	1.5 -7.6 m	Y	Y	Y	Y
30 - 60 cm	7.6 -15 m	N	N	N	N
60 - 90 cm	> 15 m				
> 90 cm					

If both <30cm and no rootwad are true, then tally piece. Otherwise record using data dictionary. For some designated surveys, identify whether the piece meeting minimum size criteria is also <2m length.

Bank Condition Characterization

Stream Bank	Condition	Stability	Mod Type	Mod Toe
L	Natural	Stable	Dike/levy/berm	Rip Rap
R	Modified	Unstable	Revetment	Rubble
			Bulkhead	Structural
			Grade	Earth/Natural
			N/A	