Bonneville Power Administration-MBACI Monitoring Effectiveness of Instream Habitat Projects (Bank Stabilization Focus)

Jennifer O'Neal

Tetra Tech

Russell Scranton

Bonneville Power Administration

April, 2014

Table of Contents

Basics & Objectives **1**

Background / Rationale 1
Objectives 3
Key Assumptions 4

Study Design **5**

Spatial Design Category 5
Scale for Data Collection 5
Spatial Design Description 5
Average Site Size 5
Temporal Design Category 5
Does your intended study have a fixed duration 5
Total Number of Planned Sites 5
Temporal Design Description 5
Experimental Design Description 5
Control Reach Description 6
Replicate Strategy Description 6

Data Collection Methods **7**

Site Layout - CHaMP 7
Required Photos - CHaMP 12
Repeat Photos 13
Channel Units - CHaMP 14
Channel Segment Numbers - CHaMP 21
Ocular Substrate Composition - CHaMP 24
Fish Cover - CHaMP 25
Topographic Point Collection - CHaMP 26
Large Woody Debris 35
Quantifying Artificially Placed Instream Structures (AIS) 39
Particle Size Distribution and Particle Embeddedness - CHaMP 41
Method for Measuring Pool Tail Fines 47
Measuring Actively Eroding Streambanks 51
Site Discharge - CHaMP 53
Estimating Instream Juvenile Salmonid Abundance Using Snorkeling 55
Estimating Instream Juvenile Salmonid Abundance Using Electrofishing 59

Summary Statistics and Data Analysis Methods **62**

Sample Date 62
GPS Coordinates 62
Reach Length 62

River Bathymetry Toolkit ... 62
Bankfull Width ... 63
Reach Width (Wetted Width) ... 64
Bankfull Width to Depth Ratio Profile ... 64
Channel Units ... 64
Mean Residual Pool Vertical Profile Area ... 65
Mean Residual Pool Depth ... 65
Maximum Pool Depth Average ... 65
Pool Tail Crest Depth Average ... 66
Variation in Thalweg Profile and Channel Width ... 66
Pool/Riffle Ratio ... 67
Braid/Channel Ratio ... 67
River Complexity Index (Brown 2002) ... 67
Amount of Spawning Habitat ... 68
Log_{10} of Volume of LWD ... 68
Number of Pieces of Wood ... 68
Pool Forming Wood ... 68
Number of AIS Present ... 68
Substrate Composition ... 69
D16, D50, D84 Particle Size in Riffles ... 70
Bank Erosion ... 71
Change in Bank Stability ... 71
In-stream Fish Cover ... 72
Average Pool Tail Fines ... 72
Juvenile Salmonid Density ... 73
Fish Use by Structure Type ... 75
Fish Use of Structures by Life Stage ... 76
Fish use of Structures by Species ... 76

Metrics and Indicators ... 76

Metrics ... 76

Quality Control & Reporting ... 77

Data Handling Considerations ... 77
Quality Control Considerations ... 77
Reporting Considerations ... 78
Equipment Cleaning and Calibration ... 78

Personnel and Training ... 79

Roles and Responsibilities ... 79
Qualifications ... 79
Training Requirements ... 79
Safety Considerations ... 80

Schedule and Budget **81**
Field Schedule Notes 81
Budget Considerations 81
Literature Cited **82**
Citations 82
Appendix A – Alternative Discharge Measurement **85**

List of Tables

Table 1. Width category and site lengths according to the site average bankfull width determined during site layout. 10
Table 2. The channel classification system used by CHaMP (derived from Montgomery and Buffington, 1993). 15
Table 3. Criteria used to delineate and classify Tier I channel units. 17
Table 4. Ocular substrate size classes. Estimate b-axis diameter of particles. 24
Table 5. Types of indicators used to determine the bankfull elevation at a site. 33
Table 6. List of codes used to identify unique points and lines in the topographic survey. Note that some codes are required for all CHaMP surveys. 34

List of Figures

Figure 1. Examples of benchmark spacing. Optimally placed benchmarks are as far apart as possible while still maintaining an equilateral triangle, are inter-visible, and extend the length of the site. Poorly placed benchmarks are close in proximity and in a non-equilateral triangle (CHaMP 2013). 11
Figure 2. Example of a good site overview photo. Photo captures the stream as well as the surrounding riparian area and floodplain. 12
Figure 3. Example of a good repeat photo. Photo captures both sides of the stream as well as the woody debris in the foreground. The trees are also lined up in the exact location as the previous year's photo. 13
Figure 4. The hierarchical channel unit classification adapted from CHaMP which is a modification of the system developed by Hawkins et al. (1993) as reported in Bisson et al. (2006). 16
Figure 5. Representation of Pool A) cross-sectional (lateral) and B) longitudinal concavity from CHaMP. 16
Figure 6. An example of channel unit delineations. 17
Figure 7. Dichotomous key of criteria adapted from CHaMP used to classify Tier I (slow-water and fast water) channel units. 18
Figure 8. Dichotomous key adapted from CHaMP of criteria used to classify Tier II fast water channel units. 19

Figure 9. Dichotomous key adapted from CHaMP of criteria used to classify Tier II slow water channel units. 20
Figure 11. Representation of topographic points and descriptions used to capture the topography of the stream during surveys. 30
Figure 12. Channel cross-sectional view showing proper delineation of the bottom of site cross-section at transect 1. 30
Figure 13. Channel cross-section indicating how water surface points (*ws*) are used to represent A) the water surface elevation at overhanging banks and B) mid-channel water surface gradient changes (i.e., pitched riffles). 31
Figure 14. Channel view showing proper use of toe of bank (*to*) and top of bank (*tb*) lines. 31
Figure 15. Channel view of lines and points representing the bankfull elevation. 32
Figure 16. Longitudinal view of the stream channel showing the location of survey points that effectively capture inflection points in the thalweg profile. 32
Figure 17. Channel view of lines and points representing the thalweg. 32
Figure 18. Channel view showing channel unit perimeter points and edge of water points. 33
Figure 19. Depiction of diameter and length measurement locations for LWD with attached roots. 37
Figure 20. Cross-section view depicting LWD wet/dry scenarios. Grey pieces are considered "wet" and light grey pieces "dry". Panel A) LWD piece on left is "dry" because the portion of the main stem touching the water is < 10 cm. LWD piece on right is "wet" because a root ≥ 10 cm diameter touches the water. Panel B) Note that "dry" pieces above the bankfull elevation but within the bankfull prism are supported by other LWD pieces and are counted (see Step 2). 38
Figure 21. Example AIS inventory form. 40
Figure 22. Orientation and location of grid placement (from Heitke et al (2010)). 49
Figure 23. Non-measureable substrate at the 50% placement for pool tail fines measurements (from Heitke et al (2010)). 49
Figure 24. Pool Tail Fines Form 50
Figure 25. Bank erosion form 52
Figure 26. Cross-section of a streambed showing location of discharge measurements. Source CHaMP 2013. 54
Figure 27. Snorkeler looking for fish along a stream bank during a snorkel survey. 57
Figure 28. Sample Snorkel Survey Form 58
Figure 29. Juvenile Chinook on a measuring board. 60
Figure 30. Sample Fish Survey Form 61
Figure 33. Graph for estimations of $(1\text{-}q^k)$ from Figure 2 of Zippin (1956) 75

Basics & Objectives

Background / Rationale

Many streams in the Pacific Northwest have depleted wood volume due to past human activities such as logging in riparian areas, salvage logging of wood in streams, splash-dams, and misguided attempts to remove perceived obstructions to salmon migration. In addition, streams have been modified and simplified due to agriculture and urban development. This process has reduced channel complexity, isolated main stem habitats from side-channels and floodplains, reduced cover for aquatic species, and altered channel morphology. Instream structures can be used to create pools, increase habitat complexity, reduce sediment transport, trap gravel needed for spawning, stabilize stream channels, provide food for aquatic invertebrates, and provide stream nutrients, increasing overall stream productivity (Roni and Quinn 2001). As a result, installation of instream structures, particularly placement of large woody debris (LWD), has become one of the longest used and most common techniques for improving fish habitat and mitigating human-caused degradation (Roni and Quinn 2001; Roni et. al. 2005). Use of instream structures began as early as the 1930's in the Midwest and has been adapted to the higher gradient systems in the Pacific Northwest (Roni et al. 2005).

Though used throughout North America and Europe, the effectiveness of instream structures in enhancing habitat has been debated due to the lack of evaluation, as well as confounding results due to improper structure placement and lack of documentation of effects on factors directly limiting habitat quality (Roni et al. 2005). Calls to better evaluate habitat improvement projects began in the early 1980s (Reeves and Roelofs 1982), and continued throughout the 1990s (Reeves et al. 1991; Chapman 1996; Kauffman et al. 1997). Others have also suggested the approach to restoration should shift to protecting high-quality habitats and restoring connectivity and watershed processes before implementing instream habitat improvement projects (Roni et al. 2008; Frissell and Nawa 1992), or focusing on restoring riparian forests with trees large enough to replenish LWD naturally in the system over time (Collins and Montgomery 2002). The need for additional effectiveness monitoring and evaluation is widely apparent in the Pacific Northwest. As an example, out of 47 recent projects sampled via interviews with project managers, at least one third did not conduct sufficient monitoring to evaluate effectiveness, and more than two-thirds reported that their projects were successful, but 43 percent either had no success criteria or were unaware of any specific success criteria for their project (Rumps et al. 2007).

As the ultimate goal of most instream projects is to improve outcomes for resident and anadromous fish populations, existing studies have often focused on the response of fish to restoration projects, with mixed results. Roni and Quinn (2001) found in a study of 30 streams in western Oregon and Washington that LWD placement can lead to higher densities of juvenile coho during the summer and winter, and higher densities of age 1+ cutthroat and steelhead trout during the winter. However, the same study found that age 1+ steelhead density response to treatment during summer was negatively correlated with increases in pool area, and the response of trout fry to treatment was negatively correlated with pool area during winter (Roni and Quinn 2001). After placement of LWD in a small coastal tributary of the Chehalis River, Washington, winter populations of juvenile coho salmon increased significantly in the treated reaches, however there was no significant difference during spring and autumn (Cederholm et al. 1997). At the same site, LWD placement either did not significantly affect steelhead populations or showed a significant decline in the treated reaches compared to the reference location, depending on the season (Cederholm et al. 1997). Other studies have found that larger salmonids respond most strongly to instream structures, suggesting that the created habitat is particularly suited to adult salmonids (Whiteway et al. 2010). Improved and more widespread monitoring can help answer remaining questions about fish response to instream structures.

The extent to which instream structures remain in place and functioning after several years has also been inconsistent throughout the northwest. In a study of 161 fish habitat structures in 15 streams in southwest Oregon and southwest Washington (Frissell and Nawa 1992), the incidence of functional impairment and outright failure following a flood magnitude that recurs every 2 to 10 years varied widely among streams; the median failure rate was 18.5 percent and the median damage rate (impairment plus failure) was 60 percent. The reasons for failure were diverse and indicated no simple relationship to structure design (Frissell and Nawa 1992). Despite the risks of structural failure, very few projects in a meta-analysis of 211 stream restoration projects reported on the stability of the evaluated structures, making it difficult to draw conclusions about their effectiveness over time (Whiteway et al. 2010).

The river system type and structural design have been shown to make a key difference in the success of instream structure projects. In general, rehabilitation efforts are unlikely to achieve their intended outcomes unless they are based on an appropriate understanding of how the targeted system functions (Brierley et al. 2010). Frissell and Nawa (1992) found that commonly used structure modifications were often inappropriate and counterproductive in streams with high or elevated sediment loads, high peak flows, or highly erodible bank materials. More urban watershed systems also pose special challenges as there is little opportunity of restoring natural LWD recruitment and the ability of placed LWD to influence channel morphology is limited by channel confinement and constrictions (Larson 2000). In a recent study of ten constructed wood features in northern California (Benegar 2011), structural design significantly changed the ability of the structure to modify hydraulic and geomorphic conditions as intended. Complex structures individually designed to interact with seasonal variations in stream flow, floodplain morphology, and the dominant sediment transport regime were more effective than simple fish habitat structures (i.e. one or two logs anchored to boulders with a cable) at: 1) increasing percentage pool cover; 2) increasing scour pool habitat; 3) metering and sorting salmon spawning gravels; and 4) improving habitat heterogeneity (Benegar 2011). Larson et al. (2000) found that obstruction width and frequency of LWD pieces that met “key piece” size criteria are likely important design factors; however meeting other general design criteria was frequently not sufficient for achieving project objectives.

The variation in results reported above highlight the need for project monitoring and incorporating monitoring programs into instream structure and LWD stream enhancement actions. Monitoring single projects as well as larger scale stream and watershed level implementation provides opportunities to improve on implementation methods and placements in order to better meet the objectives of salmon recovery efforts.

This document details the monitoring design, procedures and quality assurance steps necessary to document and report the effectiveness of Instream Habitat Projects at the Project site scale. This supports the Bonneville Power Administration's Programmatic approach to project level Action Effectiveness Monitoring (AEM), as documented in "Action Effectiveness Monitoring of Tributary Habitat Improvement: a programmatic approach for the BPA Fish and Wildlife Program". This protocol is based on the Washington Salmon Recovery Funding Board (SRFB) protocol, "SRFB - Monitoring Effectiveness of Instream Habitat Projects" (ID: 35) (https://www.monitoringmethods.org/Protocol/Details/35) however variations in the design and metrics collected required modification of the protocol. This approach also draws heavily from the Scientific Protocol for Habitat Surveys within the Columbia Habitat Monitoring Program (CHaMP) (ID:806). This document details the monitoring design and procedures necessary to document and report reach scale effectiveness of projects treating:

- Channel Reconfiguration
- Installed Deflectors
- Log and Rock Control weirs
- Roughened Channels
- Woody Debris

The "Objectives" section outlines measurable goals and objectives to evaluate whether instream projects at the reach scale are effective. Common objectives for instream habitat improvement projects are to increase bank stability, pools, instream cover and complexity, spawning, and rearing areas by placing wood, boulders or artificial instream structures. The basic assumption is creating more diverse habitat (pools, riffles, and hiding cover) will result in an increase in local fish abundance and densities. Bank stability projects typically have several goals –a) reduce bank erosion rates, b) reduce instream sediment, c) improve habitat conditions, d) allow for re-vegetation along the bank, but this approach may be incorporated with other instream structure components as part of the same project effort. With that in mind, objectives below are identified for measuring different action types, but can all be achieved using this protocol.

Objectives

- **Bank Stability** (a) -Determine if bank stability changed (amount and rate) as a result of the project (Years -1, 0, 1, 3, 5, and 10)
- **Bank Stability** (b) -Determine how bank erosion rate changed as a result of bank stabilization project (Years -1, 0, 1, 3, 5, and 10)
- **Bank Stability** (c) -Determine if percent pool tail fines changed as a result of the project **(*Only if change in fines is a goal*)** (Years -1, 0, 1, 3, 5, and 10)
- **Vegetation Enhancement** – ***see Riparian Planting protocol for evaluation procedures***
- Determine if local juvenile fish density increased as a result of the project (Years -1, 0, 1, 3, 5, and 10) (seasonal focus for specific project habitat outcome)
- Determine if fish use differs by structure type (e.g. wood revetment, rock revetment, vegetated revetment), life stage, or species composition (Years -1, 0, 1, 3, 5, and 10)
- Determine the distribution of habitat types within the reach (Years -1, 0, 1, 3, 5, and 10)

- **LWD and ELJ** - Determine if pool frequency, area and depth and pool/riffle ratio changed due to the project
- **LWD and ELJ** - Determine if the volume of functional wood increased by Year 10 (Years -1, 0, 1, 3, 5, and 10)
- **LWD and ELJ -** Determine if the amount of instream cover increased as a result of the project by Year 10 (Years -1, 0, 1, 3, 5, and 10)
- **LWD and ELJ** - Determine if the complexity of the channel increased as a result of the project ***(only if increasing complexity is a stated goal of the project***)(Years -1, 0, 1, 3, 5, and 10)
- **Increase Spawning Habitat** - Determine if spawning habitat been enhanced. ***(Only if enhancing spawning habitat is a goal***) (Years -1, 0, 1, 3, 5, and 10)

Key Assumptions

Access to impact and suitable control sites is provided

Study Design

Spatial Design Category
Sites selected at project areas

Scale for Data Collection
Project Scale

Spatial Design Description
Due to the inter-annual variance in habitat and fish parameters, and based on a power analysis using pilot data from the SRFB Project Effectiveness Monitoring Program, it is anticipated that at least 30 projects will be needed to detect change for the project category as a whole for most of the parameters monitored under this protocol (Tetra Tech 2012). Each project selected for monitoring will be paired with a control reach in the same stream or river. Projects in the MBACI study will be sampled for two years of baseline data before implementation and at 1, 3, 5, and 10 years after implementation. Both the control reach and the two years of pre-project data will help address the issue of inter-annual variability. The MBACI study will employ a Multiple Before After Control Impact (MBACI) experimental design to test for changes associated with instream structures (Stewart-Oaten et al. 1986). An MBACI design samples the control and impact simultaneously at both locations at designated times before and after the restoration effort has occurred (Stewart-Oaten et al. 1986). For this type of restoration, placing instream structures for bank stabilization would be the impact, that is, the location impacted by the restoration action, and a location upstream of the bank stabilization structures would represent the control area.

Average Site Size
120-600 m

Temporal Design Category
Complete Revisit

Does your intended study have a fixed duration
12 years

Total Number of Planned Sites
30

Temporal Design Description
Sampling will be done in years -1, 0, 1, 3, 5, and 10 – two years of pre-project data and data collection events at 1, 3, 5 and 10 years post-project implementation.

Experimental Design Description
Multiple Before After Control Impact

Control Reach Description

Control reaches are selected within the same stream as the impact or project reach. To the extent possible, stream reaches that are comparable to the project reach in their bankfull width, gradient, level of confinement, riparian conditions, flow regimes, fish composition, and other physical and biological features should be selected as control reaches. For example, if the project reach is within a side channel, a comparable side channel will be selected. Alternatively, if the project is located in a mainstem channel, the control reach will be located within a mainstem channel. Control reaches should also be those that will remain stable, without human alteration, for a period of no less than ten (10) years. Additionally, access to those sites must be provided for 10 years to allow monitoring.

Project reach lengths are determined based on calculating twenty (20) times the average bankfull width of the site, or using the CHaMP reach lengths based on bankfull width, depending on the protocol to be used for sampling. Control reach lengths are established generally to match the length of the associated project reach. Suitable control reaches are generally identified upstream of the project reach so that conditions in the control reach are not influenced by work conducted as part of the project.

Replicate Strategy Description

Replicates of each project type are included in the study to develop an average response for the project category as a whole. Statistical analysis is conducted on the collection of projects within the category. A power analysis was completed using a pilot data set from the Washington Salmon Recovery Funding Board Project Scale Effectiveness Monitoring Program to determine the need for 30 projects to detect a response in most variables (Tetra Tech 2012).

Data Collection Methods

Site Layout - CHaMP

Background / Abstract

This site layout method covers locating the site, establishing benchmarks, site markers and monuments, determining bankfull elevation and site width category, laying out the site and determining channel units. This layout uses a similar strategy to the layout described in Peck et al (2003) which uses transects labeled A through K, corresponding with the odd numbered transects in the CHaMP (2013) site layout protocols described below (i.e. Transect A = Transect 1 and Transect C = Transect 5).

Step by Step Instructions

Step 1: Determine the site width category and site length.

i. Measure and record the bankfull width perpendicular to the bankfull channel at the bottom of site (BS).

ii. Measure and record 4 additional bankfull width measurements at distances upstream (as measured in a straight line from the center of the wetted channel), equal to the first bankfull width measurement.

iii. Average the 5 bankfull width measurements and consult Table 1 to determine the site width category and site length.

iv. Note: If one of the five measurements falls where there is an island (≥ bankfull elevation), exclude the portion of the island ≥ bankfull from your width measurement.

Step 2: Lay out the site.

Each new site will consist of 21 transects spaced at intervals equal to the site width category (Table 1).

i. Locate the center of the main wetted channel at the bottom of the site and establish transect 1, placing transect flags perpendicular to the channel.

ii. Stretch a tape from the center of the main wetted channel at transect 1 a distance equal to the site width category and establish transect 2. All tape measurements are straight line distances (i.e., do not measure along the thalweg or bend the tape around meander bends).

iii. Continue this process of establishing transects upstream until 21 transects have been established. Transect 21 will always be the top of site for newly established sites.

iv. In braided sections, follow the center of the main wetted channel (e.g., the channel containing the greatest amount of the total flow).

Step 3: Establish a minimum of 3 benchmarks.

Properly established benchmarks are integral to re-occupying a survey coordinate system at subsequent visits. Establish benchmarks that can be surveyed repeatedly over many years. New site surveys establish benchmark locations and the coordinate system that will be used for future surveys. Therefore, it is imperative that benchmarks be established with the following criteria: stability, geometry, and inter-visibility.

Stability refers to placing the benchmark in a location that will be unaltered by natural processes or humans. Geometry refers to placing benchmarks in a large equilateral triangle as far apart as possible.

Inter-visibility refers to the ability to see each benchmark location from the other two benchmark locations.

i. Characteristics of optimal benchmark locations include (Figure 1):

   a. Locations outside of the active channel.

   b. The ability to acquire a reasonable GPS signal (the Estimated Position Error (EPE) must be less than 15m).

   c. Locations distributed as far apart as possible while still visible to one another. Attempt to distribute benchmarks throughout the entire length of a site.

   d. Arrangement in an equilateral triangle (ideally the stream will be contained within the equilateral triangle but this may not be always possible).

   e. Locations that can be re-occupied by a tripod. For example, do not place benchmarks too close to trees, fence posts, or other structures that would preclude proper setup of a Total Station.

ii. To establish benchmarks, drive a 5/8" piece of rebar (>16" long) into the ground using a rock or a hammer, leaving approximate 6 inches of rebar above ground. Place a survey cap on it with the proper benchmark number. Place a ring of rocks surrounding the benchmark to make it visible for future surveys.

   a. At some sites such as wilderness sites or sites located on private land, alternative, less conspicuous benchmarks may be required. Alternative benchmark techniques include:

      i. Rock etching: etch an 'x' into bedrock or a large boulder. Establish the 'x' in a discrete location.

      ii. When using alternative benchmark techniques, include a detailed description (e.g., X is on the south side of the boulder, 6 cm from the ground; benchmark is located at the northeast corner of the concrete pad). All benchmarks need to be visible, stable, and easily located with detailed instructions.

Step 4: Record benchmark data.

i. Record benchmark number and type (e.g., capped rebar, chiseled boulder, chiseled rock on top of cairn, or other). If 'Other' is selected as benchmark type, be sure to include a detailed description of the benchmark in order to relocate the exact position for future surveys.

   a. Label all new benchmarks with a three digit number corresponding to the year they are established. For new benchmarks established in 2013, benchmark numbers will begin with "3" followed by two digits denoting the benchmark number (i.e., bm301, bm302, bm303, etc.)

ii. Record GPS coordinates and EPE for all three benchmarks. The GPS unit must be placed directly on top of the benchmark when capturing the coordinate.

iii. Record the bank location (left or right) for each benchmark. Left and right banks are determined by looking in the downstream direction.

iv. Record the monument number that will be used to relocate the benchmark. Take and record a bearing and distance from the monument to the benchmark. See Step 6 for monument information.

v. Record notes that may be useful when relocating each monument and benchmark.

Step 5: Establish bottom and top of site markers.

Site markers are used to relocate the top and bottom of the site.

i. Place one site marker in line with the bottom transect and one in line with the top transect in a place that will not be eroded or disturbed through time. Site markers can be rebar with attached tag or a tag nailed or tied to a tree. Make sure that markers are visible and can be relocated at a later date. Rebar site markers at the bottom and top of site can also be surveyed in and used as additional benchmarks/control points.

ii. Record GPS coordinates and EPE for bottom and top site markers as well as which bank the marker is located (right or left).

iii. Record the marker type (rebar or tree) and distance upstream or downstream to the bottom or top transect. Record a distance of 0 m upstream or downstream for markers that line up directly with transects. Also record the distance inland from the nearest bank to the site.

iv. Take a photo of each site marker and record the photo number. Good site marker photos should include flagging on the site marker and have a wide enough field of view to relocate the markers and bottom or top transects on subsequent visits.

v. Record any notes that may be useful when relocating the bottom and top site markers (e.g., "Bottom of site marker is located on a large cottonwood tree, 5 m upstream from the bottom of the site and 7 m from the bank on river right.").

Step 6: Establish site monument(s).

Monuments are used to relocate benchmark. Optimal monuments are easily identifiable, permanent features in the landscape. These features include large trees, large boulders, and artificial structures (e.g., fence posts, buildings, etc.). Because benchmarks will be spread out, it may be necessary to establish multiple monuments. Typically, a monument should not be greater than 50 m from the benchmark it is associated with. Monuments are numbered sequentially, independent upon year established (e.g., 1, 2, 3, etc.).

For each monument established:

i. Securely nail or attach a tag to the monument. Record the site number and monument number on the tag.

ii. Record the monument number.

iii. Record GPS coordinates and EPE.

    a. Coordinates should be in UTM coordinate system and include UTM zone, easting, northing and EPE.

iv. Describe the location of the monument(s).

    a. Record bank location (left or right) and the distance from the monument to the bank.

    b. Include a general description of the site monument location and any other information that would be useful for relocating the monument. If the monument is a tree, record the common name of the tree species and diameter at breast height (DBH).

v. Take a photo of the monument. Record the photo number. Include enough of the surrounding environment in the photo to locate the monument at a later date.

Equipment

- flagging
- rebar
- rebar caps
- hammer
- identification tags
- tape measurer
- GPS
- compass
- map

Photos & Figures

Table 1. Width category and site lengths according to the site average bankfull width determined during site layout.

Average Bankfull Width (m)	Width Category (m)	Site Length (m)
≤ 6	6	120
>6 and ≤ 8	8	160
>8 and ≤ 10	10	200
>10 and ≤ 12	12	240
>12 and ≤ 14	14	280
>14 and ≤ 16	16	320
>16 and ≤ 18	18	360
>18 and ≤ 20	20	400
>20 and ≤ 22	22	440
>22 and ≤ 24	24	480
>24 and ≤ 26	26	520
>26 and ≤ 28	28	560
>28	30	600

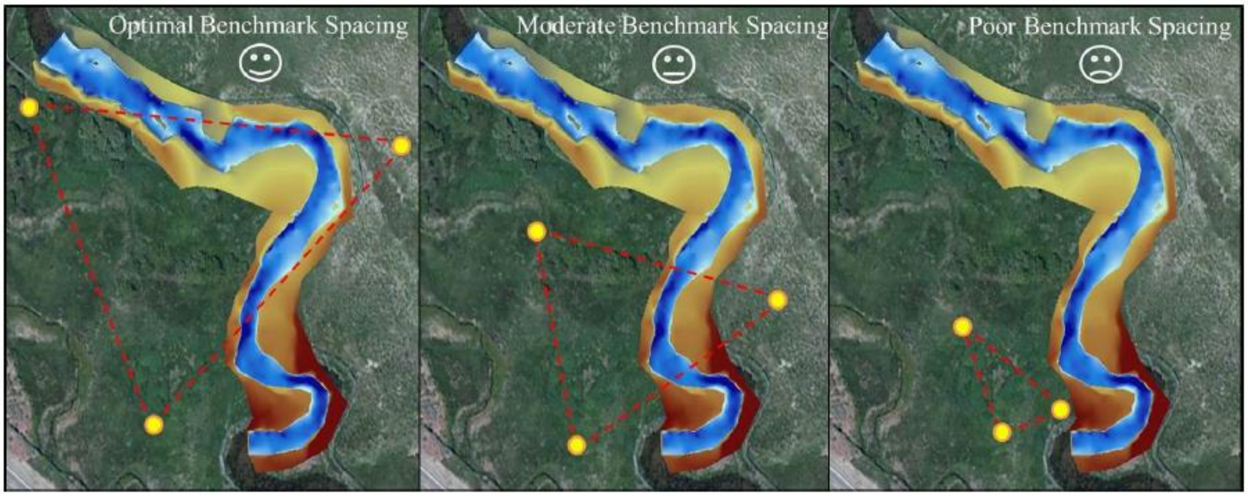

Figure 1. Examples of benchmark spacing. Optimally placed benchmarks are as far apart as possible while still maintaining an equilateral triangle, are inter-visible, and extend the length of the site. Poorly placed benchmarks are close in proximity and in a non-equilateral triangle (CHaMP 2013).

Required Photos - CHaMP

Background / Abstract

Photos are taken at repeated locations to assist with site documentation and in relocating the site in future surveys.

Step by Step Instructions

i. **Site Overview**: Taken from a point that best captures site characteristics. Attempt to gain a good view on top of a hill or other aerial vantage point (Figure 2). Take site overview photos even when the stream is not visible in the photo to capture the surrounding riparian area and floodplain. Never take an overview photo from the stream channel.

   a. Record GPS coordinates and EPE of photo location.

   b. Take a compass bearing to indicate the direction the camera was pointed for the photo.

   c. Write a descriptive note describing the photo location.

Figure 2. Example of a good site overview photo. Photo captures the stream as well as the surrounding riparian area and floodplain.

ii. **Transect**: Photos are taken from the center of the bankfull channel at transects 1, 6, 11, 16, and 21. These photos are taken at both new and revisit sites.

   a. Position the camera 1.5 m from the ground (use a depth rod as a guide). Ensure that photos are at least 0.5 m above the water surface if water is deeper than 1 m.

   b. At each transect, take a photo from the bankfull center; facing upstream (center up), facing the left bank (center left), facing downstream (center down), and facing the right bank (center right).

   c. Record all photo numbers (4-digits).

iii. **Other**: Additional required photos include monuments, bottom and top site markers, and stream temperature logger locations (where applicable). Crews are encouraged to take extra photos that may add context to a site such as large cut banks, side channels, LWD jams, or where channel migration has/may occur.

Repeat Photos

i. At revisit sites, six photos will be replicated. Replicate one photo looking upstream and one photo looking downstream at the following three transect locations; at the bottom of site (T1), at the middle of site (T11), and at the top of site (T21).

   a. Old photos will be provided from each of these three transect locations from previous site visits.

   b. Transects will not always line up exactly at revisits. Use transects as a starting point with the assistance of site markers for the bottom and top of site photos, and use the original photo to identify the exact location point from where the photo was taken. If it is not possible to line up photos with previous visits, still take photos as described above.

   c. After locating original photo point, use unique objects in the original photo frame to line up photo correctly (Figure 3).

   d. Pay particular attention to the corners of the old photo, does your photo have the same features in each corner?
   e. Does your photo look like it is too close or too far away?
   f. Is the horizon the same? For example, is the meadow behind the stream towards the top of the old photo, but near the middle of yours? If so make the necessary adjustments.
   g. Once you take the new photo, compare it to the old version. If they don't match, shoot it again.

Figure 3. Example of a good repeat photo. Photo captures both sides of the stream as well as the woody debris in the foreground. The trees are also lined up in the exact location as the previous year's photo.

Channel Units - CHaMP

Background / Abstract

The interactions among stream flow, sediment load, and channel resistance contribute to the formation of distinct areas (units) within the stream channel. These channel units, as a result, can be distinguished by their morphology (gradient, depth, shape), hydraulic properties (velocity & turbulence), and bed roughness (substrate size). Many fish habitat attributes are measured at the channel unit level.

Channel units are classified using a two-tiered hierarchical system (Figure 4). At the coarsest level, Tier I units are distinguished by gradient, relative stream velocity, and/or turbulence and include three classes: Fast Water Turbulent, Fast Water Non-Turbulent, and Slow Water/Pool. Tier I Fast Water Turbulent and Slow Water/Pool units are further subdivided into Tier II subclasses. Tier II subclasses are differentiated by hydraulic properties as well as the primary processes that form them. Below is a general definition of each Tier I class:

- **Fast Water Turbulent** channel units are topographical high points in the bed profile that feature moderate to steep gradients, coarse substrate, and tend to have consistently turbulent flow. The bedform of these units generally lacks longitudinal and/or lateral concavity (Figure 5).
- **Fast Water Non-Turbulent** channel units feature low gradients, dominantly sand to cobble substrate, and smooth laminar flow. Often, fast water non-turbulent units have a gentle slope, similar to pools, but are distinguished from pools by their general lack of lateral and longitudinal concavity. These channel units are generally deeper than riffles.
- **Slow Water/Pool** units are topographical low points in the bed profile that feature very low gradients, smooth laminar flow, and possess lateral and longitudinal concavity. Also included in this class is the subclass of off-channel units. Off-channel units include backwaters and alcove type units that are connected to the main channel but have little (< 1%) to no flow through them.

Step by Step Instructions

Step 1: Channel Class: After viewing the entire site during setup, classify the primary or most prevalent channel class according to the criteria provided in Table 2. This is based on a simplification of the classification system developed by Montgomery and Buffington (1993).

Step 2: Identify channel units and their boundaries.

Use the following criteria as a guide when identifying distinct channel units.

i. In general, ***channel units are at least as long as the wetted channel width.***
ii. Channel units are relatively homogeneous, localized areas of the stream channel characterized by four elements (Figure 6):
    a. Water surface gradient
    b. Bedform (concavity)
    c. Bed material composition
    d. Flow characteristics (e.g., velocity, turbulence)

Look for distinct changes in these components (Table 3) to determine unit boundaries.

iii. Use the descriptions found in Table 3 as well as the dichotomous keys to assist in classifying all channel units, including Tier I (Figure 7) and Tier II (Figures 8 and 9). The classification trees are read from top to bottom.

iv. Flag the unit boundaries and assign a unique number to each unit (e.g., *u1*, *u2*, etc.). Communicate the number of channel units and any details about complex unit boundaries to the crew members conducting the topographic survey so unit perimeters can be surveyed correctly.

Equipment

- flagging or flags
- Sharpie

Photos & Figures

Table 2. The channel classification system used by CHaMP (derived from Montgomery and Buffington, 1993)

	Braided	Regime	Pool-Riffle	Plane-Bed	Step-Pool	Cascade	Bedrock	Colluvial
Typical Slope (%)	< 3	< 0.1	0.1 - 3	1 - 3	3 - 8	8 - 30	Variable	> 20
Typical Bed Material	Variable	Sand	Gravel	Gravel, cobble	Cobble, boulder	Boulder	Bedrock	Variable
Typical Confinement	Unconfined	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Reach Type	Response	Response	Response	Response	Transport	Transport	Transport	Source

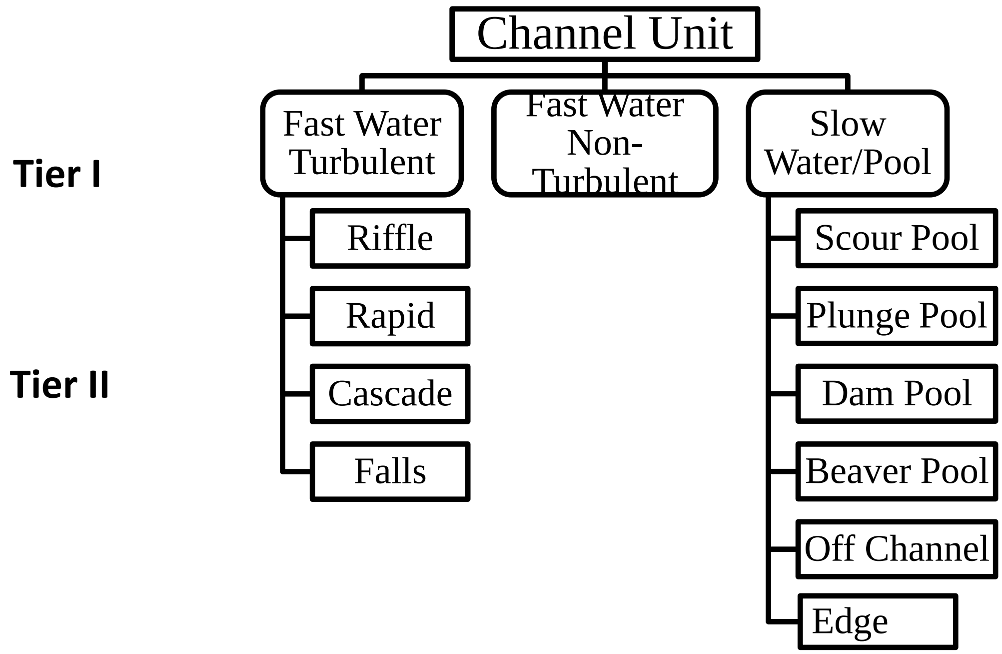

Figure 4. The hierarchical channel unit classification adapted from CHaMP which is a modification of the system developed by Hawkins et al. (1993) as reported in Bisson et al. (2006).

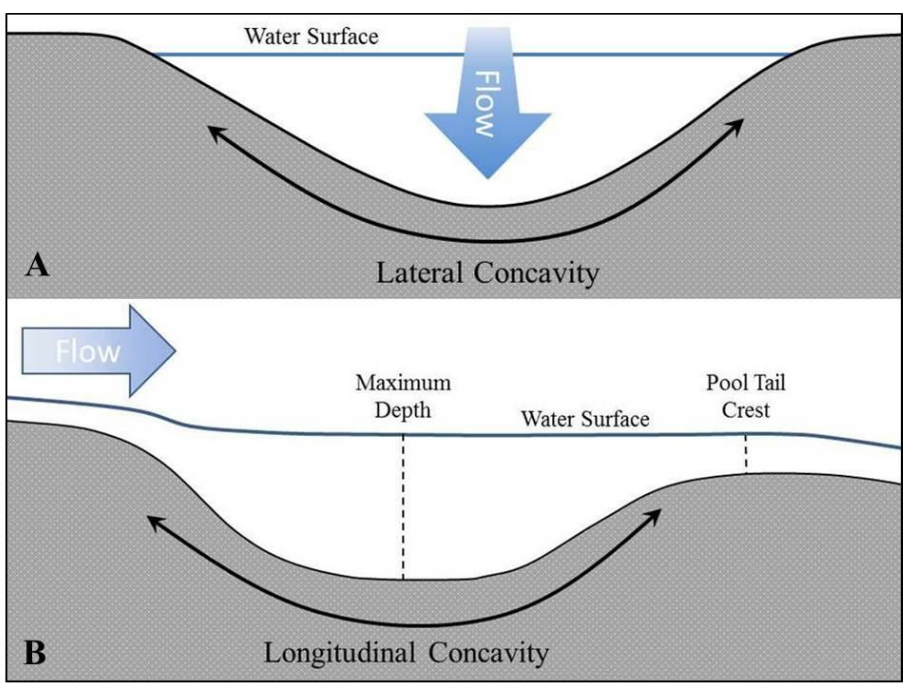

Figure 5. Representation of Pool A) cross-sectional (lateral) and B) longitudinal concavity from CHaMP.

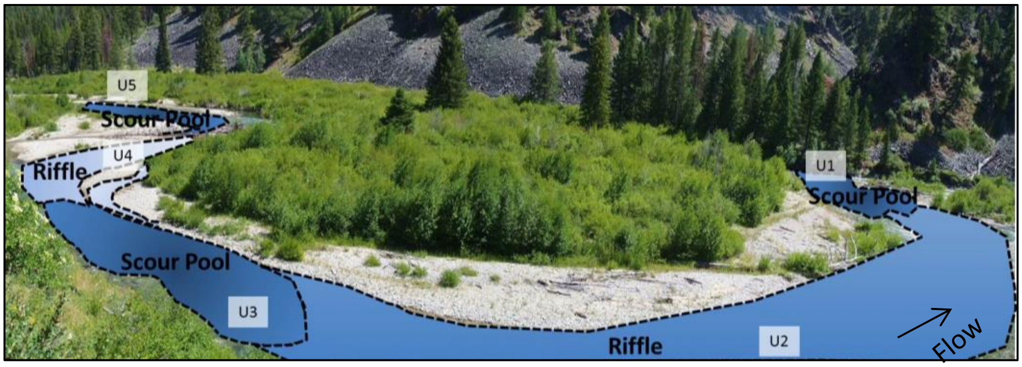

Figure 6. An example of channel unit delineations.

Table 3. Criteria used to delineate and classify Tier I channel units.

Tier I Classification	***Gradient***	***Bedform Profile***	***Substrate Composition***	***Flow Character***
Fast Water Turbulent	> 1%	Topographic high points in the bed profile	Generally have coarse substrate (cobbles and boulders)	Fast, turbulent flow
Fast Water Non-Turbulent	< 1%	Uniform depth, low complexity	Generally small cobble, gravels, and fine substrate	Smooth, even flow (laminar), minimal surface turbulence
Slow Water/Pool	0 - 1%	Pools are laterally and longitudinally concave (Figure). Off channel units have little to no flow through them	Variable, generally smaller sorted substrate	Generally laminar flow

Tier I Classification Tree

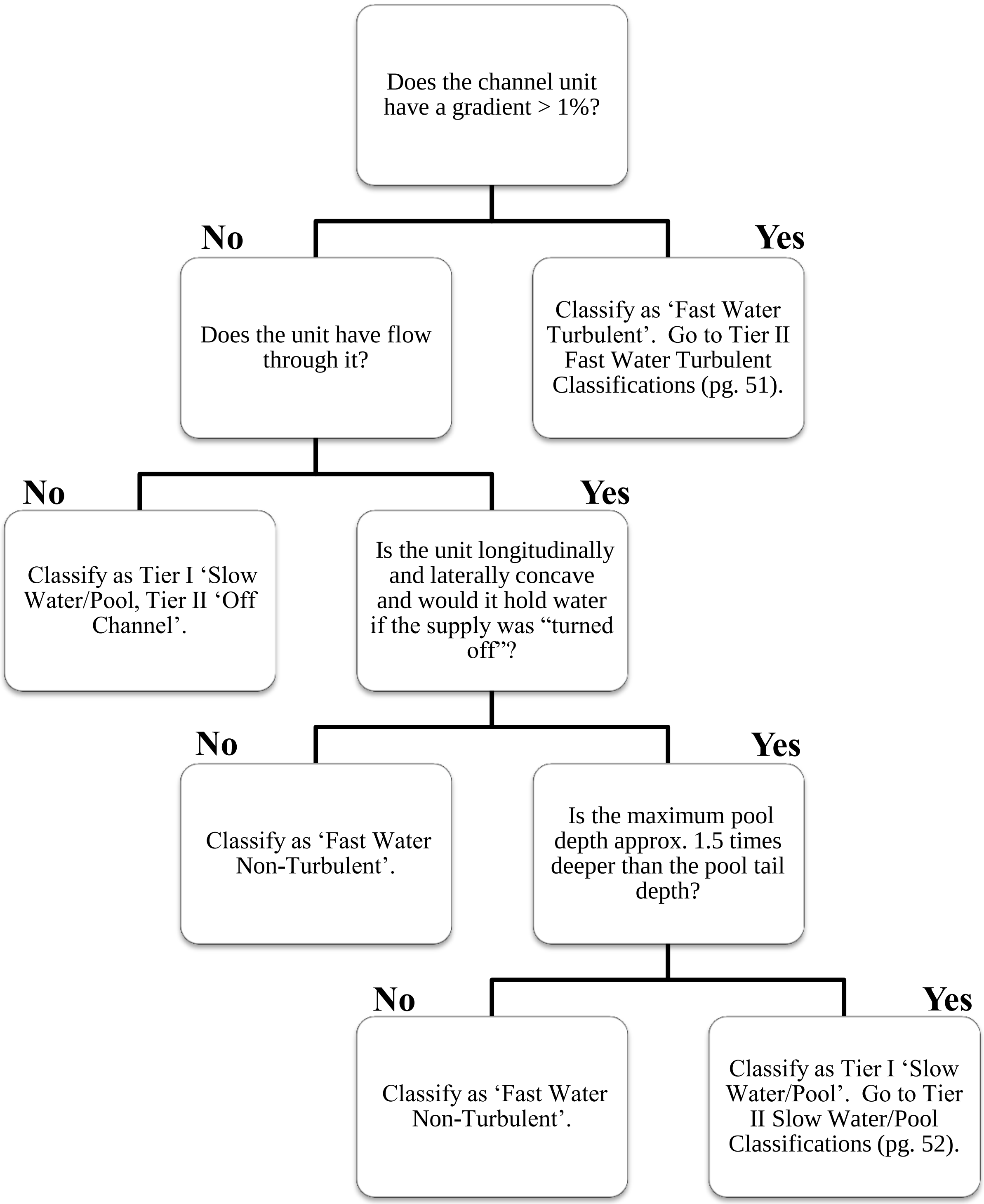

Figure 7. Dichotomous key of criteria adapted from CHaMP used to classify Tier I (slow-water and fast water) channel units.

Tier II Classification Trees

Fast Water

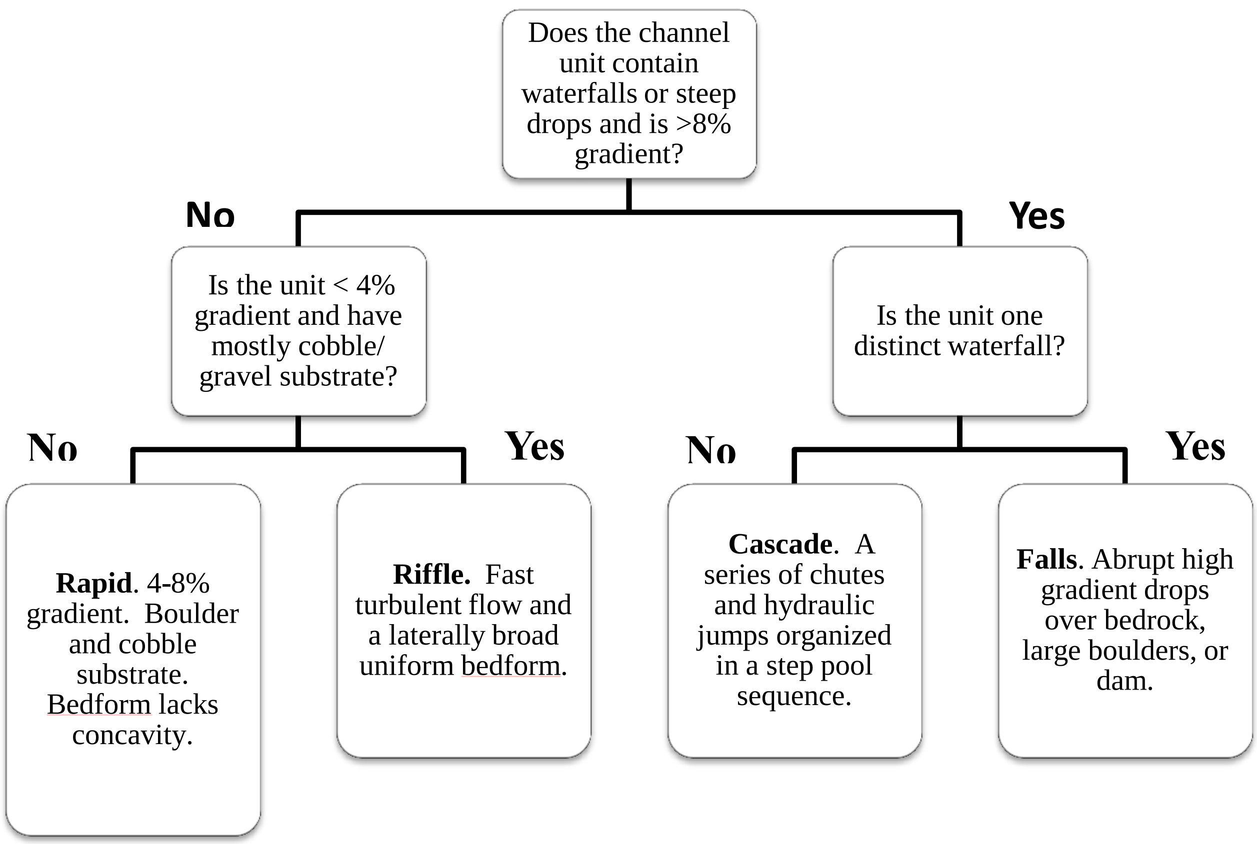

Figure 8. Dichotomous key adapted from CHaMP of criteria used to classify Tier II fast water channel units.

Slow Water/Pools

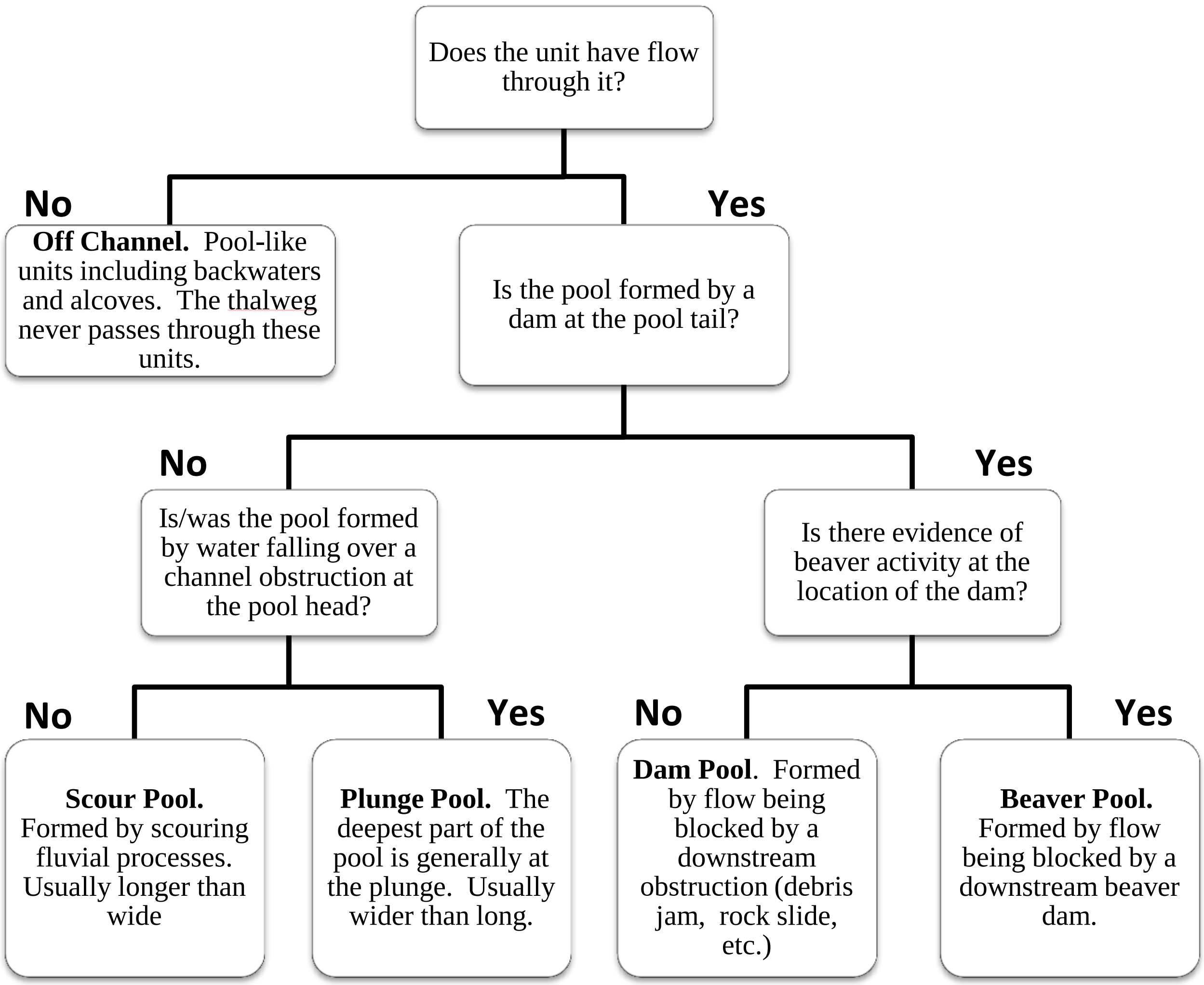

Figure 9. Dichotomous key adapted from CHaMP of criteria used to classify Tier II slow water channel units.

Channel Segment Numbers - CHaMP

Background / Abstract

Identify and label the main channel and different side channel types. Channel segment numbers are used to differentiate the main channel from side channels. Assign a unique channel segment number to the main channel and all qualifying side channels.

Step by Step Instructions

Step 1. Identify the main channel.

i. Main (primary) channel: Contains the greatest amount of stream flow at a site.

Step 2. Identify side channels.

i. Side channel: To be considered a side channel, the channel must be separated from another channel by an island that is ≥ the bankfull elevation for a length ≥ the average bankfull width. On small sites that are 120 meters in length, an island must be ≥ 6 meters to qualify.

  a. If a channel is separated from another channel by an island that is shorter than the average bankfull width (or < 6 meters at small sites), then consider the channel part of the adjacent channel.

  b. If a channel is separated from another channel by a bar (< bankfull elevation) or boulder, then consider the side channel part of the adjacent channel.

Step 3. Identify side channel type.

i. Determine if side channel is qualifying or non-qualifying.

  a. Qualifying side channel: Channel is located within the active bankfull channel and separated from another channel by an island ≥ the average bankfull width.

    i. Qualifying side channels are further divided into large and small side channels (see Step 3, ii.).

  b. Non-qualifying side channel: Channel is located outside the active bankfull channel and possesses one or more of the following characteristics:

    i. The elevation of the channel's streambed is above bankfull at any point.

    ii. Channel lacks a continuously defined streambed or developed streambanks.

    iii. Channel contains terrestrial vegetation.

ii. Determine whether qualifying side channel is large or small.

Visually estimate stream flow at both the upstream and downstream ends of the side channel as a percentage of the total flow at the site.

  a. Large side channel: Has between 16% and 49% flow at either end.

  b. Small side channel: Has <16% flow at both ends.

Step 4. Assign segment numbers to channels.

i. The main channel is assigned "Segment 1" throughout the site (Figure 21).

ii. The first large or small side channel encountered when laying out the site (moving upstream) is designated as "Segment 2". Designate additional qualifying side channels sequentially (2, 3, 4, etc.) until all large and small side channels have been uniquely numbered (Figure 21).

iii. Do not assign segment numbers to non-qualifying side channels.

Note: If a qualifying side channel continues downstream beyond the bottom of site, begin surveying the side channel in line with the bottom of site. Likewise, end surveying a side channel in line with the top of site.

Note: If a large side channel splits and each channel contains >16% of the total stream flow, assign the original segment number to the largest channel and assign a new segment number to the second channel. If a large side channel splits, and flow in either channel is <16% of the total flow, assign the original channel segment number to the largest channel, and assign a new segment number to the smaller channel (now considered a small side channel).

Step 5. Record measurements. What to measure in each channel type:

i. Main channel:

  a. Classify channel units, collect all channel unit attributes, and conduct topographic survey.

ii. Large side channels:

  a. Classify channel units, collect all channel unit attributes, and conduct topographic survey.

iii. Small side channels:

  a. Classify the entire side channel (both wet and dry portions) as a small side channel unit (Figure 10) and conduct topographic survey.

  b. Quantify Large Woody Debris (pg. 35). Do not collect any additional channel unit attributes.

  c. Categorize the side channel as continuously wet, partially wet, or dry.

  d. Estimate the total length of the side channel centerline.

  e. Estimate the average bankfull width of the side channel.

  f. Estimate the percent of the channel bed that is wet at the time of sampling.

iii. Non-qualifying side channels:

  a. Capture the area where the side channel enters/exits the adjacent channel in the topographic survey but do not conduct the topographic survey throughout the side channel.

  b. Do not classify channel units, collect any channel unit attributes, or categorize side channel.

  c. Do not estimate side channel length, width, or percent wetted.

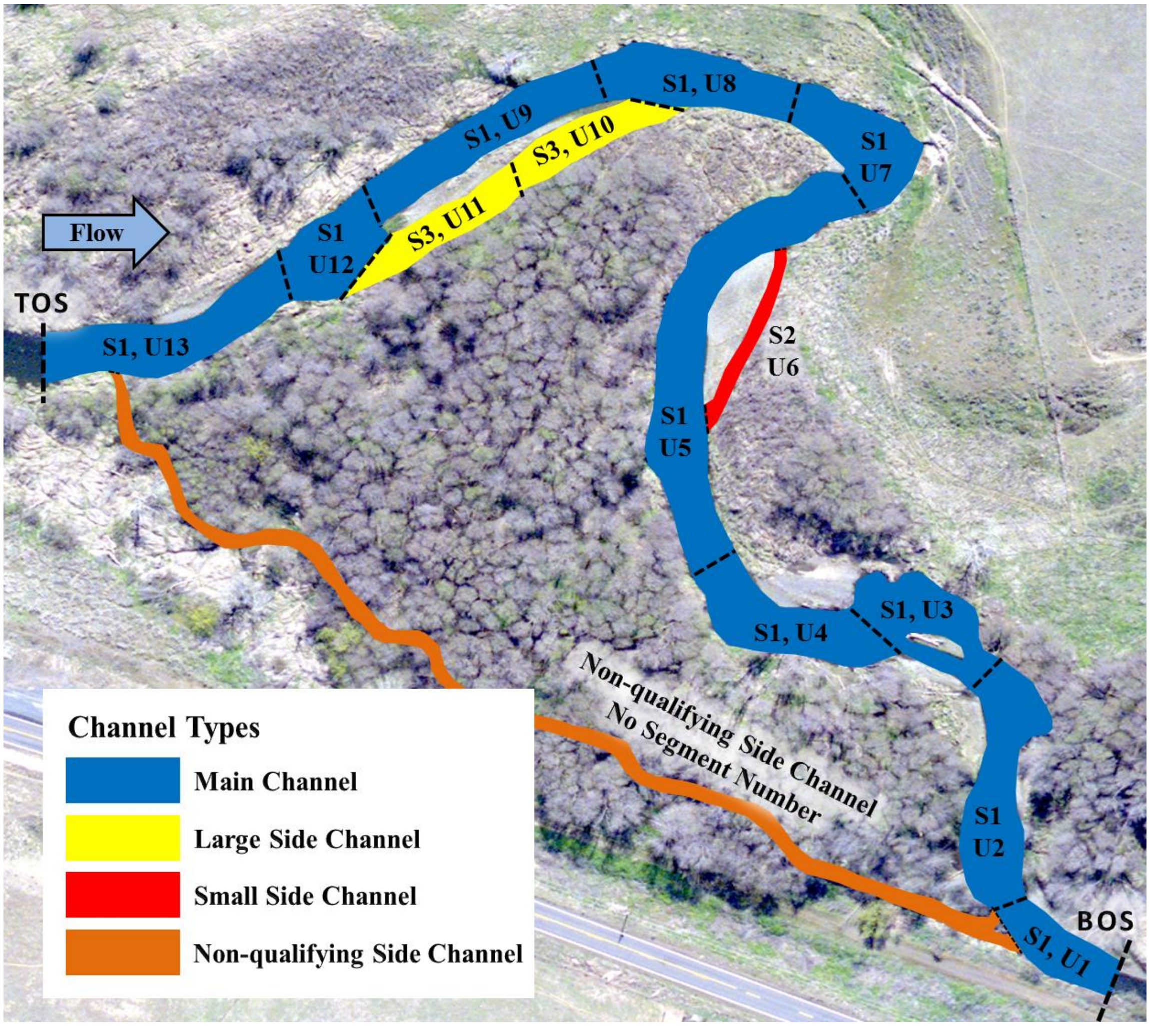

Figure 10. How to number channel segments within a site. The main channel is assigned segment 1 throughout the site. Both large and small side channels are assigned sequential segment numbers working upstream. In the figure, channel segment numbers are preceded with a "S" (S1-S3) and channel unit numbers with a "U" (U1-13).

Ocular Substrate Composition - CHaMP

Background / Abstract

The objective of this method is to visually estimate the substrate composition of each channel unit and record the percentage of each size class.

Step by Step Instructions

Step 1. Estimate the percentage of each substrate size class.

i. Visually survey the substrate composition of each channel unit and record the percentage of each substrate class (Table 4) within the wetted surface area.

ii. Round estimates to the nearest 5%.

iii. You may not be able to see the entire wetted surface area of a channel unit due to visual obstructions (aquatic vegetation, wood, or other debris). When this occurs, estimate the area you can see.

iv. The total of all classes should equal 100%.

Photos and Figures

Table 4. Ocular substrate size classes. Estimate b-axis diameter of particles.

Substrate Type	***Size class (mm)***	***Description***
Bedrock	n/a	Exposed bedrock surface
Boulders	>256	Basketball size and greater
Cobbles	64 to 256	Tennis ball to basketball size
Coarse gravel	16 to 64	Marble to tennis ball size
Fine gravel	2 to 16	Small pebble to marble size
Sand	0.06 to 2	Smaller than ladybug size, but visible as particles and gritty between fingers
Fines	< 0.06	Silt and clay that is not gritty between fingers

Fish Cover - CHaMP

Background / Abstract

The objective of this protocol is to estimate the type and total area of cover available to fish within each channel unit. Fish cover is defined as the proportion of the channel unit area that provides refuge to salmonids.

Step by Step Instructions

Step 1. Visually estimate the proportion of the wetted surface area within each channel unit that is covered by each of the fish cover elements listed in Table 4.

i. All fish cover elements must be within the wetted channel or ≤ 1 m above the water's surface.

ii. Round measurements to the nearest 5%.

iii. The sum of all fish cover elements should be at least 100%. If fish cover of different categories overlaps, count overlapping areas twice, resulting in a total percentage >100%.

Photos and Figures

Table 4. Definitions of fish cover elements evaluated at each channel unit.

Cover Element	***Cover Element Definition***
Woody debris	Wetted area of the channel unit covered by dead woody debris. There is no size requirement for woody debris to be considered fish cover. Include boards, railroad ties, wood placed for restoration purposes, etc.
Overhanging vegetation and live tree roots	Wetted area of the channel unit covered by live, terrestrial vegetation. Live tree roots suspended over the water and/or submerged. Include non-qualifying undercuts.
Aquatic vegetation and algae	Wetted area of the channel unit covered by aquatic macrophytes and filamentous algae.
Artificial structures	Wetted area of the channel unit covered by artificial structures including materials discarded in the stream (tires, old cars, concrete, etc.), or those placed in the stream for diversions, impoundments, channel stabilization, or other purposes. Rip-rap and logs placed for restoration purposes are not included in this category.
Total <u>NO</u> fish cover	Wetted area of the channel unit (i.e., open water) that does <u>NOT</u> provide fish cover by any of the above elements or boulders and undercuts.

Topographic Point Collection - CHaMP

Background / Abstract

The objective of this method is to Capture X, Y, and Z coordinates as points and lines that collectively represent a topographic surface of the stream channel and floodplain.

Many topographic surveys are time-limited, thus topographic points and lines must be collected efficiently and strategically to maximize the quality and utility of the DEM. The number of survey points collected is dependent upon the size and complexity of the site. Complex topography should be represented with a higher density of points (approx. 1,000-1,200 points) compared to more simple planar topography (500-600 points). Larger sites may have more points overall but generally have less topographic complexity.

Collect survey points at locations that represent changes in slope (inflection points). When capturing streambed topography, avoid capturing elements of bed roughness and instead, focus effort on capturing the bedform of the channel. Extend survey points far enough into the floodplain so that the areal extent of the survey encompasses all qualifying and non-qualifying side channels in areas where lateral migration may occur.

Survey points and lines are attributed with a description code that is used to further represent features in the stream channel (Figure 11). Use the topographic descriptions in Table 6 to identify and code survey points and lines throughout the site.

- *Points:* Points are used to capture changes in topography that are not captured by lines. Use points to capture non-linear features including general topographic features and channel unit boundaries.
- *Lines:* Lines are connections between two or more survey points and are used to efficiently capture visible contours or breaks in the stream channel topography. Lines are best used where there are identifiable linear features such as the edges of water, and tops and toes of banks.

Step by Step Instructions

Bottom and Top of Site Cross-Sections

Bottom and top of site cross-sections define the downstream and upstream extent of the topographic survey and provide a clean start and finish for the survey (Figure 12). The bottom of site cross-section is at transect 1 and the top of site cross-section is at transect 21.

i. The bottom of site cross-section at transect 1 must have a point indicating the outflow point at the thalweg coded *out*.
ii. The top of site cross-section at transect 21 must have a point indicating the inflow point at the thalweg coded *in*.
iii. Cross-sections must have a minimum of 9 survey points. Required point descriptions include inflow or outflow points (*in*, *out*) and left and right edge of water points (*lw*, *rw*). If bankfull, top of bank, and toe of bank (bf, tb, to) features exist at these cross-sections it is important to collect these points with the proper description.

Water Surface Features – *lw*, *rw*, *ws*, *mw, br*

Wetted surface feature codes are used to represent the planform and elevation of the water surface.

Left and right wetted edge of the channel – *lw*, *rw*

i. Left and right wetted edge features represent locations where the water surface elevation comes in contact with the stream bed or bank.

ii. Only survey *lw* and *rw* points on the outside perimeter of the main channel and qualifying side channels. Use alternative codes to describe the edge of water for islands (*mw*) and bars (*br*) on the inside perimeter of the main channel and qualifying side channels.

iii. Survey *lw* and *rw* points as either lines or points. Lines make the survey processing easier to interpret and help to create better topographic surfaces.

iv. In streams that are flat and straight, fewer points will be needed to adequately represent the wetted channel edge (approximately 50 points per edge). Add more points to the edge of water for streams that feature a complex planform and water surface elevation. Complex edge of water areas should be collected using lines.

Wetted edge of mid-channel islands – *mw*

i. Mid-wetted (*mw)* island points and lines are used to indicate water surface elevations surrounding qualifying mid-channel islands.

ii. Survey *mw* points or lines at locations representing the wetted perimeter of qualifying islands only (see Section 7.1).

Wetted edge of mid-channel bars – *br*

i. Bar (*br*) points and lines are used to indicate water surface elevations surrounding mid-channel bars.

ii. Survey enough *br* points at the wetted edge of mid-channel bars to provide a general representation of their wetted perimeters.

iii. Place topographic points (*tp)* on mid-channel bars to represent the topography above and below the water surface elevation.

Water surface – *ws*

i. Points used to represent in-channel locations where the water surface elevation is above the stream bed (Figure 13).

ii. Survey *ws* points at in-channel locations where edge of water points (*lw/rw*) cannot be surveyed such as at overhanging banks. Also survey *ws* points at locations where the lateral water surface is not uniform (i.e., pitched riffles; Figure 13).

Top and Toe of Bank Features – *tb*, *to*

Top of bank – *tb*

i. Top of bank lines are used to accurately represent convex gradient breaks that occur where steeper stream banks transition to flat floodplain-like features (Figure 14).

ii. In general, top of bank lines will run parallel to the channel but at times may run perpendicular to the channel on more complex banks.

Toe of bank – *to*

i. Toe of bank lines are used to represent the bottom of the stream bank. These concave gradient breaks occur where the stream bed transitions into a steeper stream bank. This is often times where the stream bed (typically courser substrate) and banks (typically finer substrate) meet.

Bankfull elevation - *bf*

Survey bank features that are indicative of the bankfull elevation (Table 5). Bankfull features can be surveyed using points or lines (Figure 15).

i. Use lines to survey bankfull features along consistent gradient breaks. These lines should be surveyed where stream banks transition to flat floodplain like bank features that are consistent with the bankfull elevation, and anywhere that the bankfull elevation represents a continuous linear feature in the landscape.

ii. Use points to survey bankfull features where the bankfull elevation is identifiable but does not appear as a continuous linear feature in the landscape.

A minimum of 20 bankfull points are required to be surveyed throughout the length of the site at locations that have good bankfull indicators as described in Table 5.

Main Channel Thalweg - *wg*

The thalweg is the deepest point of the wetted channel with the most continuous flow. Survey thalweg (*wg*) points and lines at inflection points that accurately represent the thalweg profile (Figure 16). Take a minimum of 20 points throughout the site.

i. Use lines to survey the thalweg profile on sections of channel when it is identifiable as a line running roughly parallel to the channel. Thalweg lines should extend the distance of the site in very small streams (usually 6 m wide or less) and contain enough points to capture inflection points in the thalweg (Figures 16 and 17).

ii. In steeper streams dominated by rapids and cascades, and in some plane-bed streams, the thalweg profile will often be discontinuous. In this situation, survey the thalweg profile using a series of points (Figure 17).

iii. Only label *wg* points and lines in the main channel. Use breaklines (*bl*) and/or topo points (*tp*) to capture the thalweg in all qualifying side channels.

Channel Unit Perimeter – *u#*

i. Channel unit perimeter points are surveyed to provide a representative outline of channel units. Channel units may be adequately represented by at least two points or up to as many as 8 points if they are larger and more complex.

ii. For each channel unit point, use a code that is consistent with the channel unit attribute data being recorded (e.g., u1, u2, etc.).

iii. In general, points describing the perimeter of channel units are surveyed at the edge of water (Figure 18). However, complex units may require additional channel unit vertices located in the wetted channel.

    a. In areas where multiple units converge in the wetted channel it may be necessary to survey additional perimeter points that represent the boundaries of each unit.

Topographic Points – *tp*

i. Survey topographic points to represent topographic features that do not follow a consistent line or fit any definition listed in Table 6.

ii. Topographic points can be sparse in areas that are topographically uniform, and should be dense in areas that are topographically complex.

iii. Always capture the deepest portion of the stream, tail crest of pools, and maximum depth of pools using topographic points (if not already captured by thalweg (*wg*) points).

Breaklines - *bl*

i. Survey breaklines to represent linear features in the landscape along any consistent gradient breaks that are not represented by other line codes.

ii. Breaklines may run parallel or perpendicular to the channel, and are often used to represent obvious breaks in the channel including tops and bottoms of steep drops (e.g., falls), and artificial structures (e.g., bridge columns).

Side Channels and Islands

i. Qualifying side channels (16% - 49% of total flow) are surveyed using the same set of procedures as the main channel.

    a. Survey channel unit perimeters in all qualifying side channels.

    b. Do not label thalweg (*wg*) points in side channels. Instead, survey side channel thalwegs using topographic points (*tp*) and/or breaklines (*bl*).

ii. Island wetted perimeters should be represented with the *mw* code. Collect bankfull, top of bank, toe of bank, and topographic points where appropriate to adequately represent the topography of the island.

iii. Extend survey points to encompass all qualifying and non-qualifying side channels in areas where lateral migration may occur.

Equipment

- total station (with tribrach and data logger)
- tripods, prism rod with topographic foot
- backsight set up
- tape measure
- notebook
- pencils
- radios (2)
- flagging
- umbrella or total station cover

Photos & Figures

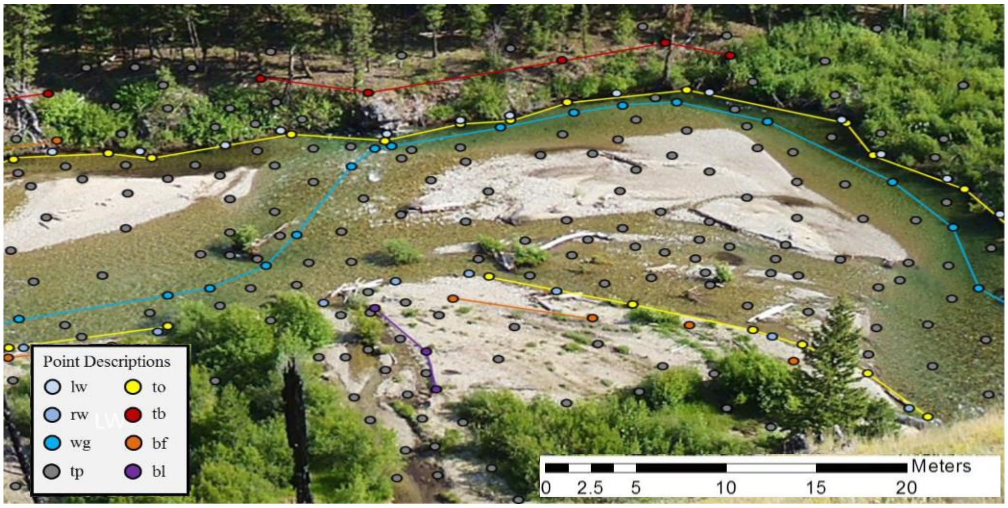

Figure 11. Representation of topographic points and descriptions used to capture the topography of the stream during surveys.

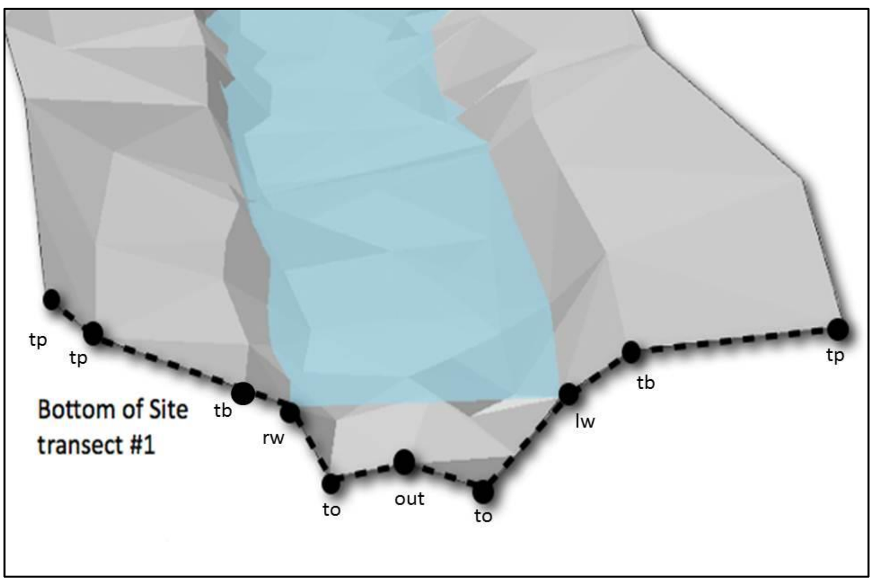

Figure 12. Channel cross-sectional view showing proper delineation of the bottom of site cross-section at transect 1.

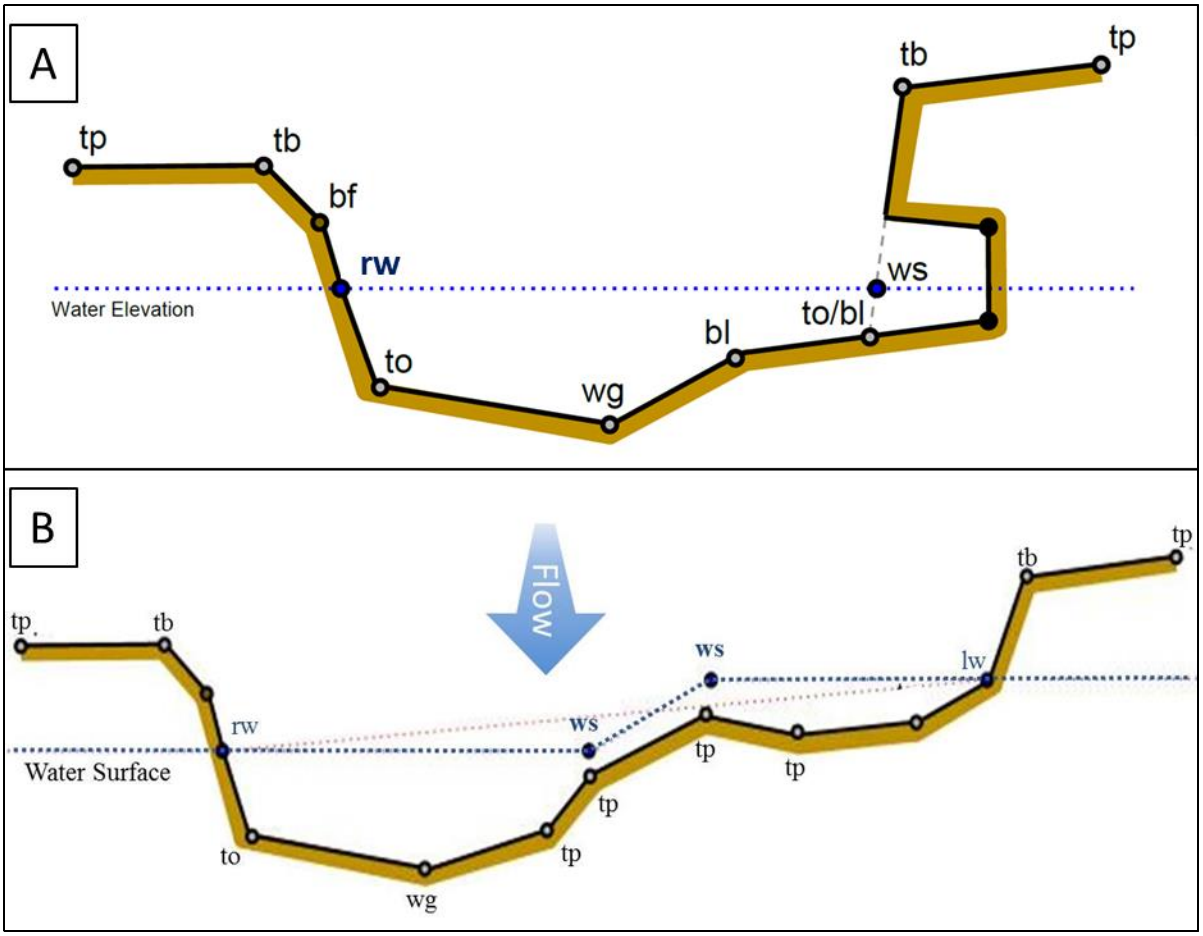

Figure 13. Channel cross-section indicating how water surface points (*ws*) are used to represent A) the water surface elevation at overhanging banks and B) mid-channel water surface gradient changes (i.e., pitched riffles).

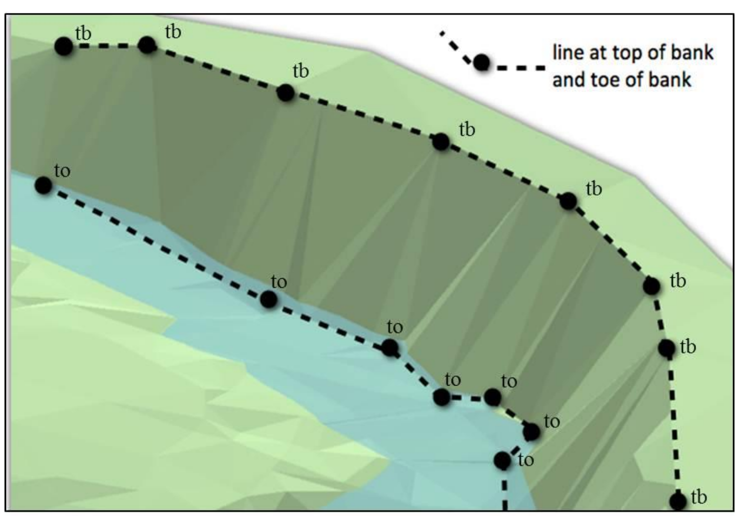

Figure 14. Channel view showing proper use of toe of bank (*to*) and top of bank (*tb*) lines.

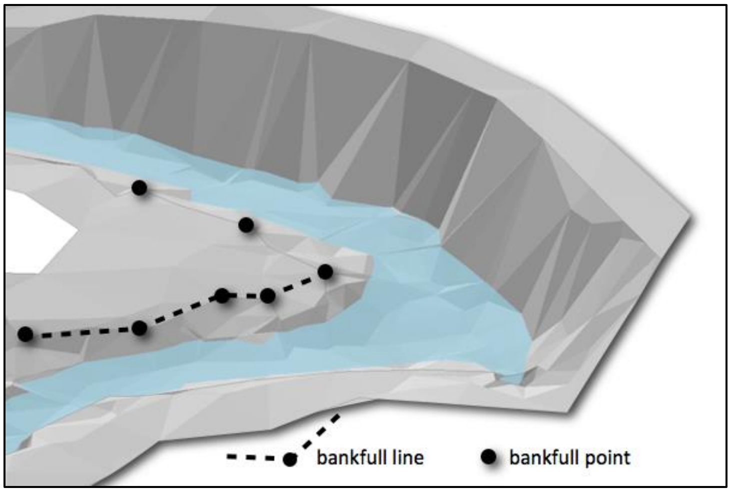

Figure 15. Channel view of lines and points representing the bankfull elevation.

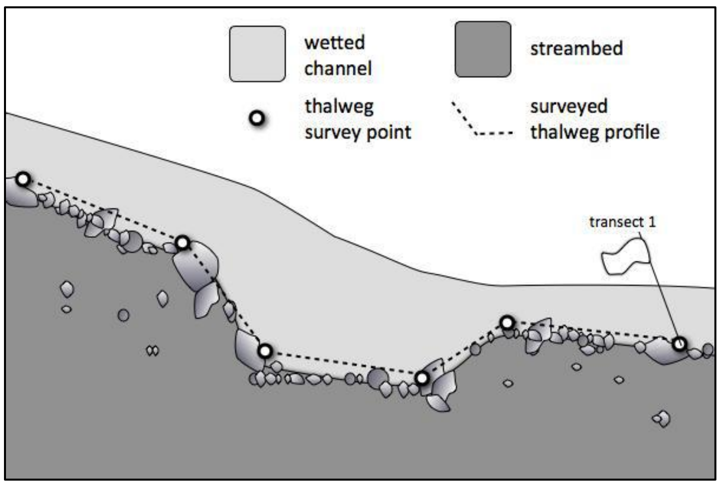

Figure 16. Longitudinal view of the stream channel showing the location of survey points that effectively capture inflection points in the thalweg profile.

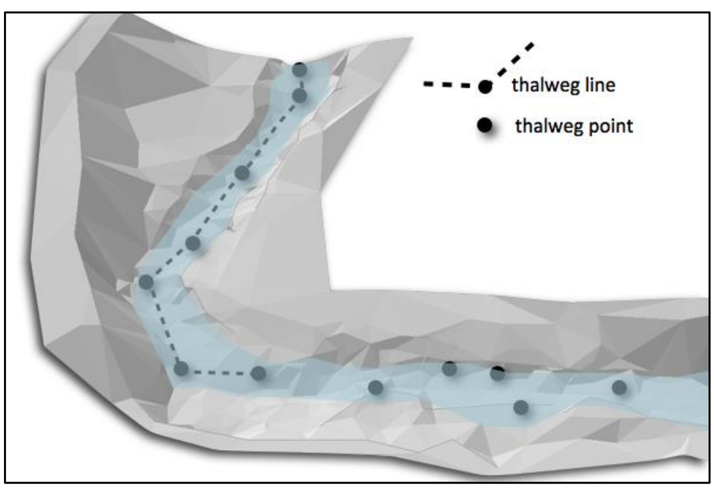

Figure 17. Channel view of lines and points representing the thalweg.

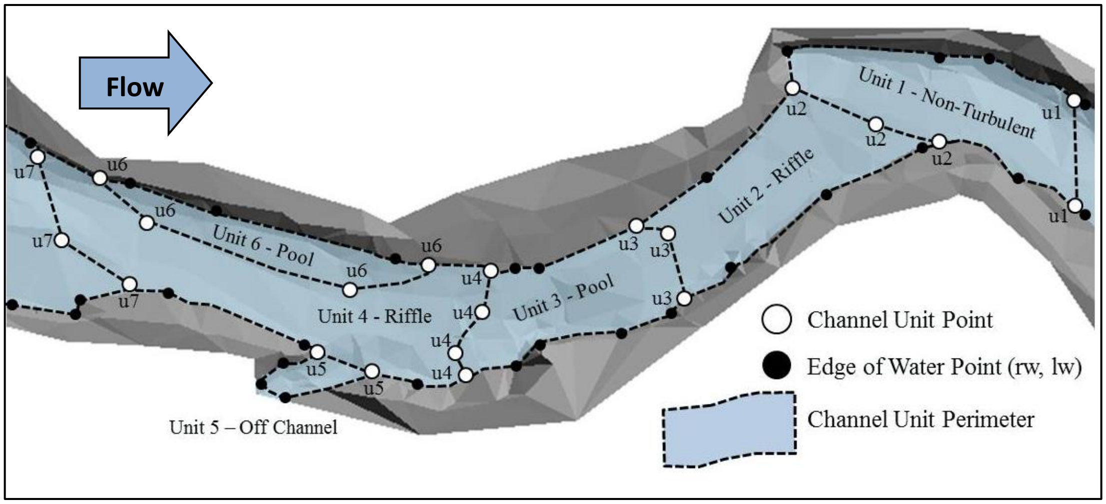

Figure 18. Channel view showing channel unit perimeter points and edge of water points.

Table 5. Types of indicators used to determine the bankfull elevation at a site.

Indicator	**Description**
Change in Slope	The change from a vertical bank to a horizontal surface is the best identifier of bankfull, especially in low-gradient meandering streams. Many banks have multiple breaks, so examine banks at several sections of the site for comparison. Slope breaks also mark the extent of stream terraces, which are old floodplains above the active bankfull. Terraces will generally have soil structure and perennial vegetation. Avoid confusing the elevation of the lower terrace with that of bankfull; they may be close in elevation.
Top of Point Bars	Point bars consist of bed material deposited on the inside of meander bends. The top elevation of point bars usually indicates the lowest possible bankfull stage. Multiple point bar elevations may be left from flows both above and below the bankfull elevation.
Changes in Vegetation	Look for the lower limit of perennial vegetation on the bank, or a sharp break in the density or type of vegetation. Often willow and alders form root lines near the bankfull elevation. The lower limit of mosses or lichens on rocks or banks, or a break from mosses to other plants may also help identify the bankfull elevation.
Change in Bank Materials	Look for changes in bank particle size, usually from coarse particles to a finer particle matrix (which is often associated with a change in slope).
Bank Undercuts	Look for bank sections where the perennial vegetation forms a dense root mat. Feel up beneath this root mat and estimate the upper extent of the undercut. This is usually slightly below bankfull stage. Bank undercuts are best used as indicators in steep channels lacking floodplains.
Stain Lines	Look for water lines on rocks that indicate where rocks are frequently inundated. Stain lines are often left by lower, more frequent flows, so stain lines should only be used to assist in identifying bankfull along with another indicator or when no other indicators exist at a site.

Table 6. List of codes used to identify unique points and lines in the topographic survey. Note that some codes are required for all CHaMP surveys.

Description Code	*Name*	*Feature Type*	*Required*	*Definition*
Water Surface Features				
lw	Left edge of water	Line or Point	Yes, Minimum of 50	Lines or points describing the elevation of the left wetted edge of the channel.
rw	Right edge of water	Line or Point	Yes, Minimum of 50	Lines or points describing the elevation of the right wetted edge of the channel.
mw	Mid-channel island	Line or Points	Yes, If island exists	Lines or points describing the wetted elevation of qualifying islands (see Section 7.1).
br	Mid-channel bar	Line or Points	No	Lines or points describing the wetted elevation of mid-channel bars.
ws	Water surface	Line or Points	No	Points describing the water surface elevation above the stream bed at overhanging banks and mid-channel locations.
Channel Features				
bf	Bankfull	Line or Point	Yes, Minimum of 20	Lines or points describing the bankfull elevation.
bl	Breakline	Line	No	Other gradient breaklines as needed.
in	Inflow point	Point	Yes	Point at the upstream (top) end of the site indicating the inflow point of the thalweg.
out	Outflow point	Point	Yes	Point at the downstream (bottom) end of the site indicating the outflow point of the thalweg.
tb	Top of bank	Line	Yes	Lines describing the top of bank elevation.
to	Toe of bank	Line	Yes	Lines describing the toe of bank, or the line separating the active stream bed from the bank. Toe locations can be in and out of the water.
tp	Topography	Point	Yes	Points describing general channel topography.
u#	Channel unit	Point	Yes	Point describing channel unit perimeter within the wetted channel (named *u1*, *u2*, etc.).
wg	Thalweg	Line or Point	Yes, Minimum of 20	Lines or points describing the longitudinal thalweg profile.
Control Network				
cp#	Control point	Point	Yes	Control points used as station or backsight setup locations (*cp301*, *cp302*, etc.).
bm#	Benchmark	Point	Yes, Minimum of 3	Established benchmarks (*bm301*, *bm302*, etc.).

Large Woody Debris

Background / Abstract

This method is used to quantify the volume and number of qualifying LWD pieces within the site and associate them with channel units. The method utilizes the CHaMP large woody debris data collection methodology, and also adds supplemental methods for assigning functional attributes to each LWD piece.

Step by Step Instructions

Step 1. Identify qualifying LWD within the bankfull channel and prism.

i. LWD and root wads must be dead with the exception of newly fallen trees that are uprooted from the bank but still have green foliage.

ii. LWD size qualifications:

  a. Must have a b-axis diameter ≥10 cm, measured at the midpoint of the piece. For LWD with attached roots, the diameter is measured at the midpoint between where the main stem joins the root mass (e.g., root collar) and the top of the piece (Figure 19).

  b. Must be ≥1 m in length. The length of LWD with attached roots is measured from the end of the main root mass to the top of the trunk.

iii. For LWD embedded in the stream bank, the exposed portion must meet the minimum length and diameter requirements to qualify. Quantify the length and diameter of the exposed portion of the piece.

iv. If a LWD piece is broken or cracked, consider it one piece if the two pieces are attached at any point along the break.

Step 2. Classify qualifying LWD as “wet” or “dry”.

i. All LWD located within the bankfull channel is classified as either “wet” or “dry” (Figure 20).

  a. Classify piece as “wet” if a portion of the main stem or root that touches the water is ≥10 cm in diameter (Figure 20).

  b. Classify piece as “dry” if a portion of the main stem or root ≥10 cm in diameter is within the bankfull channel but outside of the wetted channel (i.e. would get wet at bankfull flows).

ii. Classify pieces outside the bankfull channel but within the bankfull prism as “dry” if they meet both of the criteria below. The bankfull prism refers to the area directly above the bankfull channel elevation (Figure 20).

  a. Piece is in the bankfull prism and is suspended vertically above the bankfull channel by other pieces of LWD.

  b. Piece would fall into the bankfull channel if the supporting LWD was removed (Figure 20).

  Note: These pieces frequently occur in large wood aggregates or “jams”.

Step 3. Record the length and diameter of qualifying LWD pieces.

i. Measure and record the length and diameter of the first 10 qualifying LWD pieces encountered at the site.

ii. Estimate and record the length and diameter of the next 9 LWD pieces and measure the 10th. Repeat this process of measuring every 10th piece (#20, #30, #40, etc) until all qualifying pieces have been quantified.

iii. In addition to measuring pieces described in steps i and ii above, also measure the first 10 LWD pieces that are ≥15m long.

iv. Record length to the nearest 0.1 m, and diameter measurements to the nearest 0.01 m.

v. If a piece cannot be measured accurately, estimate the length and diameter and measure a different qualifying piece.

Step 4: Assign qualifying LWD pieces to a channel unit.

i. Assign each piece of LWD to one channel unit. If a piece of LWD is present in two or more channel units, assign it to the unit that contains the highest proportion of the piece's volume.

ii. If a piece of LWD is outside wetted portion of the channel but within the bankfull channel, assign this 'dry' piece to the nearest channel unit.

Note: Tally all qualifying LWD pieces within the entire bankfull channel including those pieces within all large and small side channels.

Step 5: Determine functional attributes for each LWD piece:

i. **Position in the channel**: left bank, right bank, or mid channel. Pieces may span across more than one position. For pieces that extend from the bank to mid channel, or span across the channel, select all the positions the piece occupies.

ii. **Pool Forming**: yes or no. More than one piece of LWD can be contributing to the formation of the same pool.

   a. Yes – piece is causing or contributing to the formation of a pool through scour or damming of water. Must be causing or contributing to a pool that has been delineated and meets CHaMP pool definitions.
   b. No – providing cover, or a racked piece of wood, but not causing scour or damming water

iii. **Part of a logjam**: yes or no.

   a. Yes – aggregation of 10 or more qualifying pieces of LWD.
   b. No – aggregation of less than 10 pieces of qualifying LWD.

iv. **Key piece**: yes or no. May have more than one key piece per logjam.

   a. Yes – Must be part of a qualifying logjam. The piece is a large tree or bole that is the primary piece or one of the primary pieces that created jam and is anchoring it in place.
   b. No – Racked members, which are wood that has piled up on key piece (or pieces), or loose members which are simply pieces of wood that fill interstitial space but don't add to integrity of jam.

Equipment

- Measuring tape and/or laser range finder

Photos & Figures

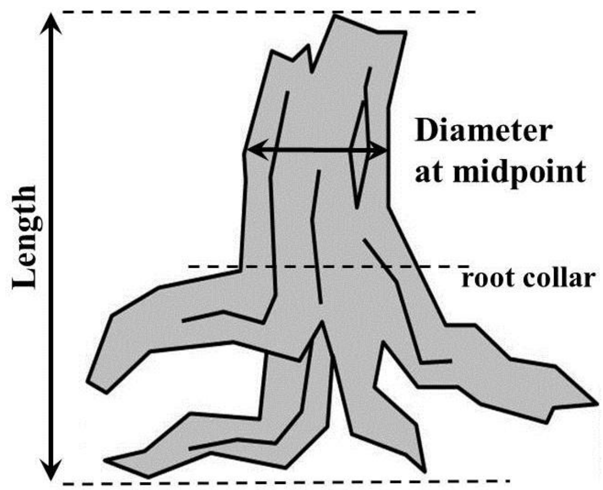

Figure 19. Depiction of diameter and length measurement locations for LWD with attached roots.

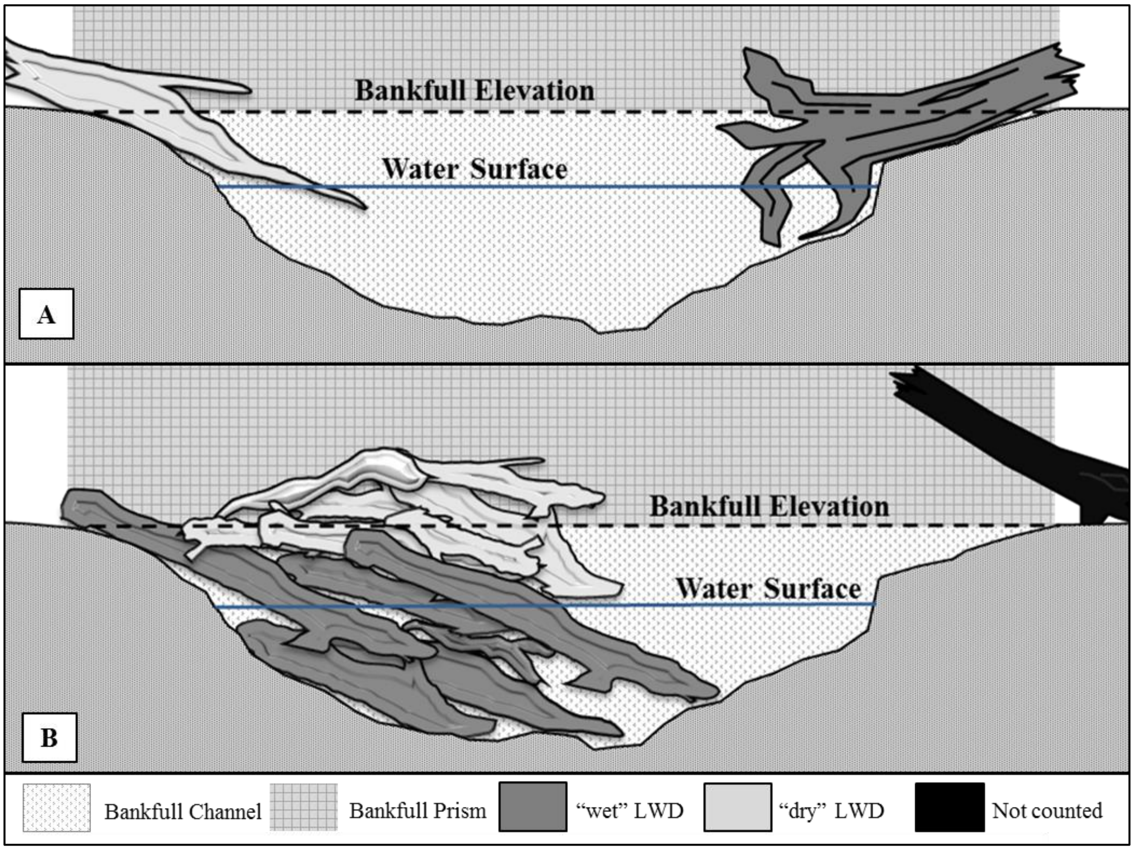

Figure 20. Cross-section view depicting LWD wet/dry scenarios. Grey pieces are considered "wet" and light grey pieces "dry". Panel A) LWD piece on left is "dry" because the portion of the main stem touching the water is < 10 cm. LWD piece on right is "wet" because a root ≥ 10 cm diameter touches the water. Panel B) Note that "dry" pieces above the bankfull elevation but within the bankfull prism are supported by other LWD pieces and are counted (see Step 2).

Quantifying Artificially Placed Instream Structures (AIS)

Background / Abstract

This method is used to tally "artificially-placed instream structures" (AIS). AIS are defined as Large Woody Debris (LWD) and rock structures. The tally includes all AIS that are in the channel. The active, or bankfull, channel is defined as the channel that is filled by moderate sized flood events that typically occur every one and a half years. AIS in the active channel is tallied over the entire length of the reach, including between the channel cross-section Transects.

Step by Step Instructions

Step 1: After all AIS have been placed into the impact reach and secured in place, inventory the number of pieces using the data collector.

Step 2: Mark each piece of AIS with a metal plate or tag that will be able to resist flooding and other kinds of abrasion over a 10-year period with a unique identifier tag and record the number for future reference. For projects where AIS are accumulated into succinct jams, tag the individual jams and inventory the volume of LWD per jam using the LWD count methodology.

Step 3: Mark the GPS location of each AIS piece using AIS form on the data collector. Record the tag number for each AIS piece and enter the number into the AIS form alongside the GPS location.

Step 4: Determine the orientation of the AIS to the direction of stream flow. Record the angle to the nearest degree (0-360°).

Step 5: Determine the type of structure the AIS is part of from this list: lateral jam, channel spanning jam, single log, mid-channel jam, sediment storage, bank protection, other (describe).

Step 6: Take photographs of each AIS, and record the photo number on the data form.

Step 7: During surveys after Year 1, scan the reach for AIS during the LWD survey, repeating steps 1 and 3-6. AIS should have already been tagged in the Year 1 survey, so additional tagging is not necessary.

TESTING FOR SIGNIFICANT CHANGES IN THE AMOUNT OF ARTIFICIALLY PLACED STRUCTURE.

The intent is that AIS remain in place unchanged during Years 1, 3, 5, and 10. In this case, 100% of AIS has remained as designed. On the other hand, some of the AIS may have moved from its original position and is either at a different location within the impact reach, or has been carried downstream to an unknown location. We can determine what proportion of the AIS remains in the impact reach in Years 1, 3, 5, and 10 and what proportion has moved and no longer remains in the sampled reach. These proportions can be compared for each of the tested years. A reduction of 50% or more of the AIS within the study reach would be considered a failure of the AIS and it would no longer be considered intact.

Equipment

- waterproof field forms
- metal tags
- hand-held GPS device
- hammer
- nails

Forms

AIS Inventory Form						
Site:	Station:		Date:		UTM zone:	Surveyor:
Transect (1-2, 2-3, etc)	AIS Tag #	Location (Northing, Easting)	Photo #	Orientation to flow (0-360°)	Structure Type	Comments
Structure types: Lateral Jam (L J), Channel Spanning Jam (CS), Single Log (SL), Mid-channel Jam (MJ), Sediment Storage (SS), Bank Protection (BP), Other (Oth) – describe in comments						

Figure 21. Example AIS inventory form.

Particle Size Distribution and Particle Embeddedness - CHaMP

Background / Abstract

This method is intended to:

1. Quantify size distribution of substrate in fast water habitats by measuring 11 particles from 10 cross-sections for a total of 110 particles per site; and
2. Estimate embeddedness of cobbles.

Step by Step Instructions

Distribution of Particle Size Measurements

Step 1: Determine where to place cross-sections.

i. Count the number of Tier II riffle channel units that occur within the main channel and qualifying side channels.
    a. If there are more than 10 riffles, place one cross-section in each of the first 10 riffles (working upstream).
    b. If there are less than 10 riffles, evenly distribute additional cross-sections into riffles according to the proportion of stream length that each unit comprises relative to the other riffles. If there is not enough space to conduct all measurements in riffles (see Step 1, ii, c), then evenly distribute remaining cross-sections into non-turbulent units (working upstream). If there is not enough space to conduct all measurements in riffles and non-turbulent units, then distribute remaining cross-sections into rapids.

ii. Cross-section location and spacing.
    a. When there is only one cross-section in a unit, place the cross-section at the midpoint of the unit.
    b. When there are multiple cross-sections in a unit, equally space the cross-sections throughout the unit (Figure 21). Cross-sections should be oriented perpendicular to the bankfull channel.
    c. Cross-sections should not be closer than 1/100th of the site length apart. Move additional cross-sections to the next largest unit if too crowded. For example, the minimum spacing between cross-sections at a 120 m long site would be 1.2 m.
    d. Cross-sections should not cross two or more laterally adjacent channel units.

Step 2: Select 11 sampling points at each cross-section.

i. At each cross-section, visually divide the cross-section into 11 equally spaced sampling points running perpendicular to the stream channel, and spanning the width of the bankfull channel. (Figure 22).

Step 3: Select and measure particles.

i. Select particles at sample points while turning your eye away and extending your finger down and picking up the first particle that you feel at the tip of your boot.

a. Use a gravelometer (Figure 23) to classify the b-axis of each particle. Record the size category (Table 8) for the largest square opening that the particle does not fit through. For example, if the particle fits through the 180 mm square but does not fit through the 128 mm square it is classified as the 128-180 mm size class.

b. Record silt and clay particles that are < 0.06 mm in the 0.0002-0.06 mm size class. Silt and clay particles are smooth when rubbed between the thumb and fingers whereas sand rolls between the fingers (is gritty).

c. Use the thin edge of the gravelometer to determine sand particles between 0.06 and 2 mm. (Note the thin edge of the gravelometer is 2 mm wide).

d. For particles >128 mm and <512 mm, measure the b-axis using the notches at the top of the gravelometer.

e. For particles > 512 mm, measure and record the length of the b-axis using the top edge of the gravelometer or a depth rod.

f. Record "bedrock" when bedrock is encountered at sample points.

g. If your finger touches a thin layer of fine sediment covering a larger particle, then measure the fine sediment, not the larger particle.

h. **Do not measure stream bank particles**.

i. For embedded particles that cannot be removed from the stream bed, use the notched edge of the gravelometer or the depth rod to measure the b-axis, and record the appropriate size class.

Cobble Embeddedness

Cobble embeddedness is a measure of the degree to which a cobble is buried by fine sediment.

Embeddedness is the percentage of a cobble's surface that is surrounded by fine sediment (< 2 mm). High cobble embeddedness results in a reduction of interstitial spaces between particles and makes the substrate more difficult to move (think of a fish's tail).

i. Estimate embeddedness for all cobble-sized particles (64 mm – 256 mm) that are selected during particle size distribution sampling. Record estimates to the nearest 5%.

ii. Embeddedness is estimated as the product of two values:

  a. The percentage of the cobble's surface that is buried below the surface of the streambed (Figure 24A), and

  b. The percentage of fine sediment < 2 mm in the substrate immediately surrounding the cobble (Figure 24B).

Step 1: Estimate percent buried.

i. Before removing a particle from the streambed for measurement, feel around the edge of the particle to determine at what point the particle is below the stream bed surface and note the boundary between the portion of the particle that was buried and the portion that was not buried (Figure 24A).

ii. Remove the particle and estimate the percent that is buried by comparing the proportion of the particle's surface that was exposed vs. buried (Figure 24A).

Note: If a cobble cannot be removed from the streambed, the particle is at least 50% buried. Measure the b-axis of the particle and confirm that it is a qualifying cobble.

Step 2: Estimate percent fines.

i. Examine the substrate within the depression immediately surrounding the cobble where the buried portion of the cobble was removed, and visually estimate the percent of the substrate that is composed of fine sediment <2 mm. If the substrate is not clearly visible due to water surface turbulence or turbidity, manually collect a small grab sample of the substrate, hold the sample above the water surface, and visually estimate percent fines for the sample.

Step 3: For each cobble, record the percent buried and percent fines.

Equipment

gravelometer

pencil

graduated cuff

data logger

depth rod

Photos & Figures

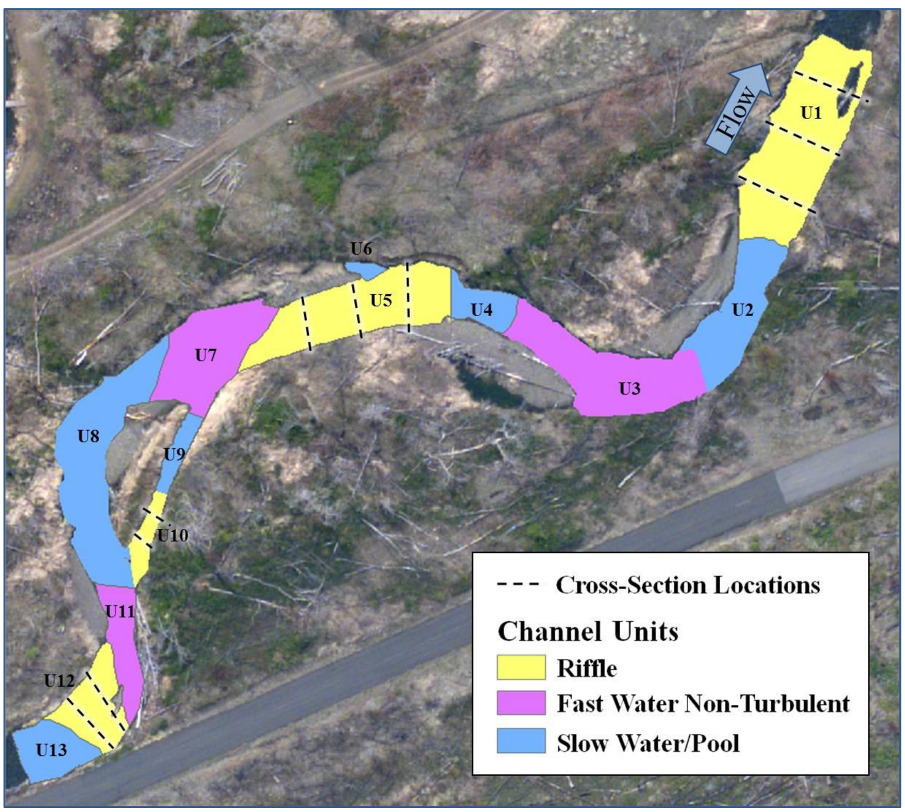

Figure 21. Example of how to distribute pebble count cross-sections at a site.

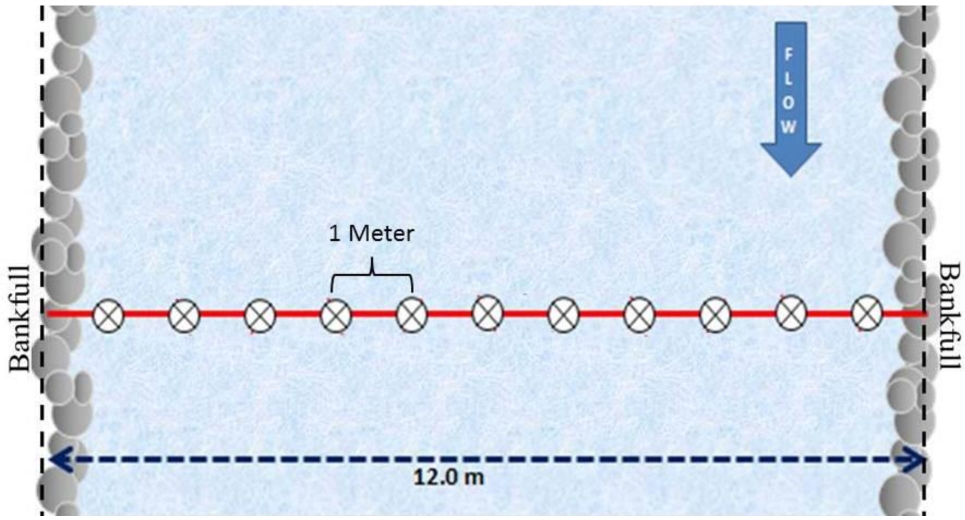

Figure 22. Example of a cross-section layout. In this example, distance between samples is 1 m, because the bankfull width is 12 m. Particle sample location is shown with a circle and crosshairs.

Figure 23. Gravelometer used to classify the b-axis of particles.

Table 8. Size categories for sediment in the range of silt and clay to bedrock. Record the size range that the particle falls within (e.g., 45-64).

Description of particle size		Size Range (mm) Lower	Upper
Bedrock		**n/a**	n/a
Boulder	mega	**>4000**	n/a
	very large	**2896**	4000
		2048	2896
	large	**1448**	2048
		1024	1448
	medium	**724**	1024
		512	724
	small	**362**	512
		256	362
Cobble	large	**180**	256
		128	180
	small	**90**	128
		64	90
Gravel	very coarse	**45**	64
		32	45
	coarse	**22.6**	32
		16	22.6
	medium	**11.3**	16
		8	11.3
	fine	**5.7**	8
		4	5.7
	very fine	**2**	4
Sand		**0.06**	2
Silt/Clay		**0.0002**	0.06

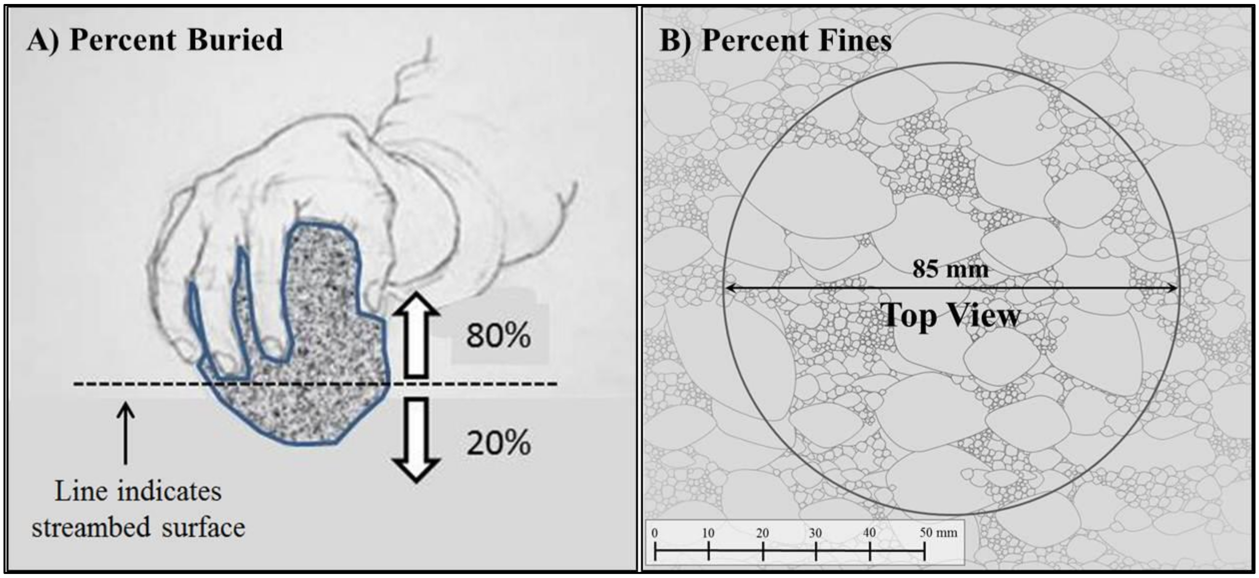

Figure 24. Illustrations depicting the two methods used to estimate embeddedness: percent buried (Panel A) and percent fines (Panel B). Panel A) The cobble is buried 20% beneath the streambed surface. Panel B) The sediment in the depression immediately surrounding the cobble or beneath the cobble (indicated by the circle) is composed of approximately 10% of fine sediment <2 mm.

Method for Measuring Pool Tail Fines

Background/Abstract

This method is designed to determine the percentage of fine sediments on the pool tail surface of plunge pools and scour pools. This method is adapted from *Heitke et al (2010), pp. 49-50.*

Step by Step Instructions

For the purposes of this method, the following criteria must be met for a feature to be considered a pool:

- Pools are depressions in the streambed that are concave in profile, laterally and longitudinally.
- Pools are bound by a 'head' crest (upstream break in streambed slope) and a 'tail' crest (downstream break in streambed slope).
- Only consider main channel pools where the thalweg runs through the pool, and not backwater pools.
- Pools span at least 50% of the wetted channel width at any location within the pool. So a pool that spans 50% of the wetted channel width at one point, but spans <50% elsewhere is a qualifying pool.
- When islands are present only consider pools in the main channel; don't measure pools in side channels.
- If a side channel is present, the pool must span at least 50% of the main channel's wetted width; disregard side channels width when making this determination.
- Maximum pool depth is at least 1.5 times the pool tail depth.

Step 1: Collect measurements in the first ten scour and plunge pools of each reach beginning at the downstream end (Transect 1). Exclude dam pools (and beaver pools). If there are fewer than 10 pools within the reach, sample all pools that meet the criteria listed above.

- Sample within the wetted area of the channel.
- Take measurements at 25, 50, and 75% of the distance across the wetted channel, following the shape of the pool tail.
- Take measurements upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less.

    For example, if the pool length is 7 meters, measurements would be taken 0.7 meters upstream of the pool tail crest, which is 10% of the pool length.

    If the pool length is 12 meters, measurements would be taken at 1 meter upstream from the pool tail crest because it is less than 10% of the pool's length, which would be 1.2 meters.

- Locations are estimated visually.

Step 2: Assess surface fines using a 14 x 14 inch grid with 49 evenly distributed intersections. Include the top right corner of the grid and there are a total of 50 intersections.

Step 3: Using the grid, take measurements in each pool by completing the following steps:

1. Place the bottom edge of the grid upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less (Figure 22).
2. Place the center of the grid at 25% of the distance across the wetted channel, making sure the grid is parallel to and following the shape of the pool tail crest.
3. If a portion of the fines grid lands on substrate 512 mm (approx. 20 inches) or larger in size (b-axis), record the intersections affected as non-measurable intersections (Figure 23).

Step 4: Record the number of intersections that are underlain with fine sediment < 2 mm in diameter at the b-axis in the Pool Tail Fines Form (Figure 23). Place a 2 mm wide piece of electrical tape on the grid and use this to assess the particle size at each intersection.

Step 5: Record the number of intersections that are underlain with fine sediment 2 - 6 mm in diameter at the b-axis in the Pool Tail Fines Form (Figure 24). Place a 6 mm wide piece of electrical tape on the grid and use this to assess the particle size at each intersection.

Step 6: Aquatic vegetation, organic debris, roots, or wood may be covering the substrate. First, attempt to identify the particle size under each intersection. If this is not possible due to debris, then record the number of non-measurable intersections. Do not attempt to move the obstructing debris

Note:

- In small streams DO NOT overlap grid placements. Only fit as many grids as possible in the wetted channel without overlapping.

Step 7: Repeat steps 2 – 6 at 50% and 75% of the distance across the wetted channel, for a total of three measurements per pool

Equipment

- grid (14"x14", with 49 evenly distributed intersections)
- measuring stick
- electrical tape
- field forms
- waders

Photos & Figures

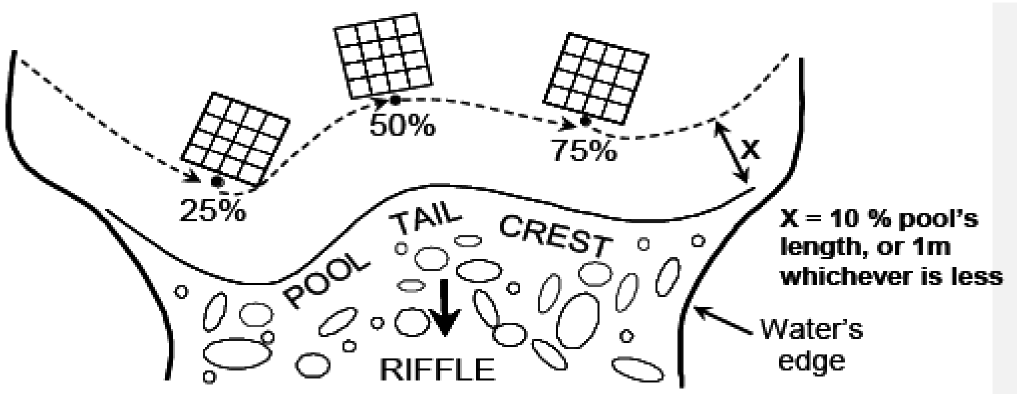

Figure 22. Orientation and location of grid placement (from Heitke et al (2010)).

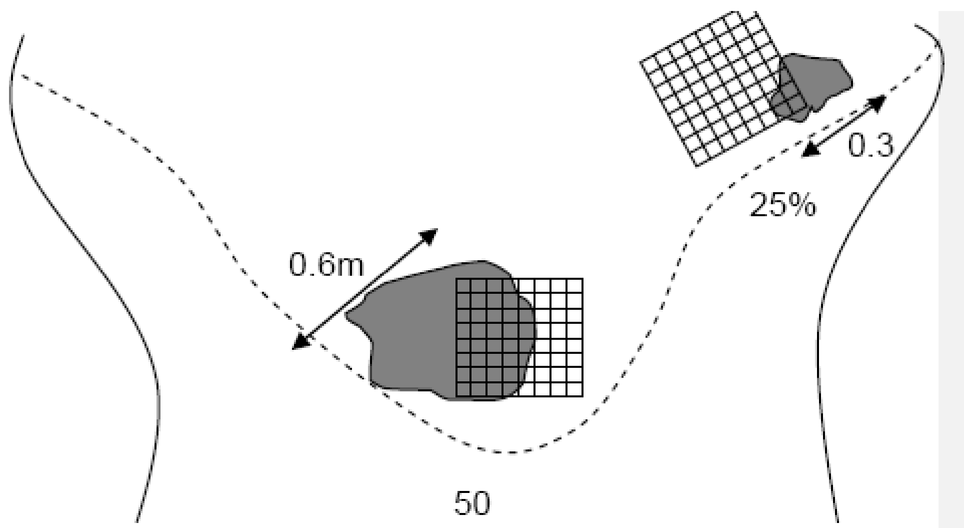

Figure 23. Non-measureable substrate at the 50% placement for pool tail fines measurements (from Heitke et al (2010)).

Forms

Pool Tail Fines Data Sheet

Site: ____________ Reach: Control Impact Surveyors: ____________

Date: ____________ Visit #: ____________

Transect (1-2, 2-3, etc.)	**Pool #** (1-10)*	**# Intersections with Fine Sediment** (out of 50 at each location)								
		25%			***50%***			***75%***		
		<2mm	***2-6mm***	***Non-measurable***	***<2mm***	***2-6mm***	***Non-measurable***	***<2mm***	***2-6mm***	***Non-measurable***

Comments:

*Pools should be numbered from 1-10 sequentially beginning at downstream end of reach.

Figure 24. Pool Tail Fines Form

Measuring Actively Eroding Streambanks

Background/Abstract

This method will allow us to determine if the stream banks within the habitat restoration area have improved and thereby reduced siltation and erosion by reducing the percentage of the streambank that is actively eroding. This method is adapted from Moore et al. (1998).

Step by Step Instructions

Step 1: Measure the lineal distance between each Transect (1 – 2, 2 – 3, etc.) that is actively eroding at the active channel height for each bank. Active erosion is defined as recently actively eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability.

Step 2: Record the measured lineal distance of erosion for each bank on the bank erosion form (Figure 25).

Equipment

- Appropriate waterproof sampling form
- Tape measure and/or range finder
- waders or hip boots

Forms

Transect	Left Bank Erosion (m)	Right Bank Erosion (m)
1-2		
2-3		
3-4		
4-5		
5-6		
6-7		
7-8		
8-9		
9-10		
10-11		
11-12		
12-13		
13-14		
14-15		
15-16		
16-17		
17-18		
18-19		
19-20		
20-21		

Figure 25. Bank erosion form

Site Discharge - CHaMP

Background / Abstract

Measure depth and velocity at increments along a cross-section in order to calculate discharge of the site at the time of sampling. Methodology from Peck et al. 2001.

Depth and velocity measurements are made at one carefully chosen channel cross-section. It is important to choose a channel cross-section that is as much like a canal as possible to get the best estimate of the amount of water flowing through the site. A glide area with a U-shaped channel cross-section that is free of obstructions provides the best conditions for measuring discharge. You may remove rocks and other obstructions to improve the cross-section before any measurements are made.

Step by Step Instructions

Step 1. Identify and flag cross-section location.

i. Locate a cross-section of the stream channel that has most of the following qualities:
   a. Segment of stream above and below the selected cross-section is straight.
   b. Depths are mostly greater than 15 cm, and velocities are mostly greater than 0.15 m/s. Do not measure discharge in a pool.
   c. "U" shaped channel with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
   d. Flow is relatively uniform with no eddies, backwaters, or excessive turbulence.

ii. If an appropriate cross-section location cannot be identified within a site, extend the search upstream or downstream of the site boundary, avoiding locations that would differ in flow from that of the site such as entry areas of tributaries and side channels within the site extent.

iii. Avoid locating cross-sections where 100% of the flow is not in the channel (side channels are present). If this situation is unavoidable, such as a braided channel, take separate cross-section measurements, one in the main channel and one in the side channel(s).

Note: At smaller streams during low flows, velocity with a flow meter may be impossible to measure. On occasions where the average depth of the stream along a cross-section is <10 cm and velocities average <0.05 m/s, use the alternative discharge measurement procedures outlined in Appendix A.

Step 2. Set up cross-section and identify measurement locations.

i. Stretch and secure a meter tape across the stream perpendicular to the flow with the “zero” end on the left bank.

ii. Divide the total wetted stream width into 15 to 20 equally spaced intervals (Figure 36).
   a. To determine interval width, divide the width by 20 and round up to a convenient number.
   b. Intervals should not be spaced less than 10 cm apart, even if this results in less than 15 intervals.

iii. Take the first depth and velocity measurement at the left edge of water. If depth is 0, record velocity as 0. Conduct the second measurement one interval out from the left bank and continue measurements at each interval. The last depth and velocity measurement will be at the right edge of water.

Step 3. Measure depth and velocity.

i. Stand downstream of the velocity meter when taking measurements.

ii. If the depth is 0 record the velocity as 0. If velocity is negative (-), record the measured velocity.

iii. Place the topset rod in the stream at the interval point and record the water depth. Set the topset rod to the correct height. This will raise or lower the velocity probe to 60% of the water depth at that interval. Position the velocity probe directly perpendicular to the stream channel and hold the topset rod vertically level. Wait for the progress on the velocity meter to go through a full 10 second cycle (i.e., fully through 0% to 100%). Record the velocity. Move to the next interval point and repeat the same procedure until depth and velocity measurements have been recorded for all intervals.

iv. Take the last depth and velocity measure at the right edge of water. Verify that the tape distance of your final measurement recorded in the data logger is equal to the tape distance at the right wetted edge.

Equipment

- Top set wading rod
- Flow meter
- Measuring tape

Photos & Figures

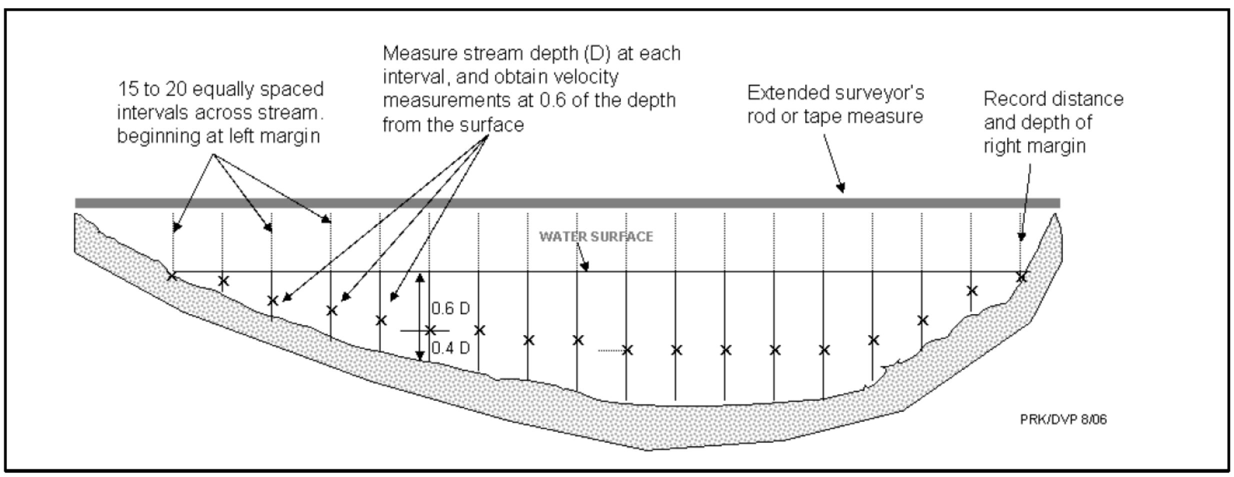

Figure 28. Cross-section of a streambed showing location of discharge measurements. Source CHaMP 2013.

Estimating Instream Juvenile Salmonid Abundance Using Snorkeling

Background / Abstract

Estimating the density of juvenile salmonids at the project allows the investigator to obtain a sample over time of the change in abundance of rearing juvenile salmonids produced in the stream reach examined. Methodology is adapted from O'Neal (2007).

Step by Step Instructions

The sample reaches are those laid out according to the CHaMP Site Layout method. Be sure that all necessary collectors' permits and ESA clearances have been obtained before proceeding with snorkeling.

Sampling for juvenile abundance should occur during the low flow period in late summer. It should be done in one or two days within the same week to avoid changes in conditions, rainfall events, etc.

Step 1: Measure the water temperature and record the temperature in the Snorkel Survey Form (Figure 28).

Step 2: Begin at the downstream boundary of the reach (Transect 1) and proceed upstream through each Transect, ending at Transect 21. In wadeable stream reaches, one crew member should snorkel each pool-riffle area while the other crew member records the counts as they are given by the snorkeler. In non-wadeable areas, crew members should snorkel side by side and sum their individual counts. Each snorkeler counts the fish to the immediate front and to the sides opposite the other snorkeler or as designated by the team leader to avoid duplication of counts. In all wadeable and most non-wadeable stream reaches, snorkeling should involve only a single pass through each Transect.

Note: In many smaller streams the riffle areas will be too shallow to snorkel and will contain mostly smaller young of the year trout species. A two person snorkeling crew can conduct snorkel surveys in wadeable stream control and impact study reaches. In areas where the stream is not wadeable, up to four snorkelers may be needed.

Step 3: Counts of the number of juvenile salmonids should be recorded from one Transect to the next (juvenile salmonids from Transect 1 to 2, Transect 2 to 3, etc.) in the Snorkel Survey Form. Continue proceeding upstream counting the number of juvenile salmonids until the survey is completed at Transect 21. Salmonid fork lengths should be estimated to the nearest 10 mm.

Document the channel unit and fill out the channel unit field for each observation record on the Snorkel Survey Form.

Document use of instream wood, boulders, or off channel area by juvenile salmonids, especially structures placed as part of restoration, and fill out the appropriate structure use type on the Snorkel Survey Form.

Step 4: After snorkeling, the underwater visibility of each study reach is ranked on a scale of 0 to 3, 0 being not snorkelable due to extremely high amounts of hiding cover and zero visibility, and 3 being little hiding cover and good water clarity. Visibility is recorded on the Snorkel Survey Form.

Note: Only reaches with a visibility rank of two or three should be used in data analysis. Where possible, the proportion of trout estimated by sample electrofishing that were cutthroat and steelhead should be used to reclassify unknown trout as underwater determination of species is often impossible.

Equipment

- waterproof field forms or electronic forms for recording fish counts
- thermometer to measure water temperature
- dry suits or wet suits, masks, snorkels, and rubber or felt soled boots
- additional equipment such as hand counters, underwater white boards, and dive lights may be needed for enumerating fish

Photos & Figures

Figure 27. Snorkeler looking for fish along a stream bank during a snorkel survey.

Forms

Snorkel Survey Form													
Site:	**Species -** Note in Comments specifics for CY,SU and Other						**Structure**		Site Comments:
Station:	Chinook	CH	Sockeye	SK	Lamprey	LP	Natural wood	NW	
Date:	Coho	CO	Steelhead	ST	Sculpin	SC	Placed wood	PW	
H_2O temp:	Chum	CM	Bulltrout	BT	Stickleback	SB	Natural boulder	NB	
Team:	Cutthroat	CT	Brooktrout	BK	Sucker	SU	Placed boulder	PB	
Visit:	Pink	PK	Mtn White Fish	MWF		Other	Natural off-channel	NoF	
Visibility:	Rainbow	RB	Cyprinids	CY			Created off-channel	CoF	

Transect	Channel Unit #	Snorkeler	Number	Species	Size	Structure Type	Comments

Figure 28. Sample Snorkel Survey Form

Estimating Instream Juvenile Salmonid Abundance Using Electrofishing

Background / Abstract

Estimating the density of juvenile salmonids at the project allows the investigator to obtain a sample over time of the change in abundance of rearing juvenile salmonids produced in the stream reach examined.

Step by Step Instructions

The removal method is based upon the theory that a segment of stream can be fished two or more times to attempt to remove all of the fish and obtain a total count. Because some fish are successful in avoiding capture, a total count cannot normally be obtained. However, a regression equation can be developed that will estimate, with known accuracy and precision, the total number of fish in the sampled reach.

Step 1: Measure temperature and conductivity at location within sample reach that is representative of the reach overall. Record these values on Elecrofishing Survey Form (Figure 30).

Note: In general, electrofishing should not be conducted when any of the following conditions exist:

- Visibility is less than 0.5 meters,
- Conductivity exceeds 350 µS/cm, or
- Water temperatures exceeds 18°C (64°F) or is below 4°C (39°F), or is expected to exceed these limits prior to concluding the electrofishing survey (WSDOT 2012).

Step 2: Place blocking nets at the upstream and downstream end of the sample reach in order to reduce escapement of fish from the sample area.

Step 3: Record the Start Time of the pass.

Step 4: Using an electrofisher adjusted for maximum efficiency, fish the sample reach thoroughly, one channel unit at a time. Capture all fish discovered in capture nets and placed them in buckets with cool water for later enumeration.

Step 5: After a channel unit is sampled, enumerate all fish by species and size and record this information on the Electrofishing Survey Form for each channel unit (Figure 30).

Step 6: Document the channel unit number and transect where fish are captured. When applicable document the structure type where fish are captured. Fill out appropriate fields on the Electrofishing Survey Form.

Step 7: Sample the remaining channel units, working in an upstream direction. When the first pass is complete, and all channel units are sampled, record the end time, number of seconds logged (pass time) in the electrofisher, and the voltage and amperage settings for the electrofisher used for the pass on the Electrofishing Survey Form.

Step 8: Repeat steps 2-7 two more times, for a total of three passes, to improve accuracy of the sampling.

Equipment

Use a backpack electrofisher consisting of an anode and cathode pole and capable of producing adjustable pulsed D.C. voltage up to 300 volts and an amp meter allowing adjustable amperage up to 1.5 amps. Determine that all team members are wearing waders and gloves, polarized sunglasses, and capture nets. The electrofisher should have automatic current switches in case the operator falls. The electrofisher should be equipped with an audio indicator when the unit is turned on and warning devices when voltage or current exceeds 300 volts or 1.5 amps. Appropriate capture nets and buckets should be available to capture and hold fish.

Photos & Figures

Figure 29. Juvenile Chinook on a measuring board.

Forms

Electrofishing Survey Form

Site:	Conductivity:
Station:	Pass:
Date:	Voltage:
Team:	Amperage:
Visit:	Start Time:
Visibility:	End Time:
H2O temp:	Pass time (sec):

Species - Note in Comments specifics for CY,SU and Other					
Chinook	CH	Sockeye	SK	Lamprey	LP
Coho	CO	Steelhead	ST	Sculpin	SC
Chum	CM	Bulltrout	BT	Stickleback	SB
Cutthroat	CT	Brooktrout	BK	Sucker	SU
Pink	PK	Mtn White Fish	MWF		Other
Rainbow	RB	Cyprinids	CY		

Structure	
Natural wood	NW
Placed wood	PW
Natural boulder	NB
Placed boulder	PB
Natural off-channel	NoF
Created off-channel	CoF

Transect	Channel Unit #	Number	Species	Size	Structure Type	Comments

Figure 30. Sample Fish Survey Form

Summary Statistics and Data Analysis Methods

Data analysis for this protocol involves calculations that are processed through automated software as well as other calculations and assessments that are made from the data outside of the automated process. This approach includes processes developed as part of the CHaMP, but also includes data collection and analysis that are not included in the CHaMP study, as appropriate to evaluate the function of bank stabilization projects. This section includes descriptions of calculations within the CHaMP process that are automated using software toolkits, and those that are independent of that process.

Sample Date

This is the date that the reach was surveyed, which is entered into the stream verification form on-site for each reach, treatment and control.

GPS Coordinates

The GPS coordinates are taken at Transect 1 and Transect 21 in each reach, treatment and control. These response variables are the GPS coordinates in UTMs, which are entered into the data logger. Coordinates are also taken at each benchmark and recorded in the data logger.

Reach Length

Reach length is calculated as twenty times the average bankfull width of the stream. The reach length is determined for both the impact and control reaches, and laid out according to the site layout guidelines. In general, the treatment reach length is scaled to the reach width and the control reach length is set to match the impact reach length unless that is not feasible. The Reach Length variable is simply reported as this measurement or calculated distance in meters.

River Bathymetry Toolkit

The River Bathymetry Toolkit (RBT) is a suite of GIS tools for processing high resolution Digital Elevation Models (DEMs) of stream reaches. The RBT is being actively developed by ESSA Technologies and is available free of charge. The goal is to characterize in-stream and floodplain geomorphology to support aquatic habitat analyses and numerical models of flow and sediment transport.

Tools were created for ArcGIS to conduct several types of analyses associated with DEMs, including geomorphic change detection, uncertainty analyses, user-defined density of cross-sections and longitudinal profiles. These tools can extract hydrologic parameters such as wetted area, bankfull width, water depths, hydraulic radius, gradient, sinuosity (McKean et al. 2009), erosion and depositional patterns and budgets, and uncertainty in the DEM (Wheaton et al. 2010). Using an automated de-trending algorithm, we are able to remove the overall valley slope.

Tools are being created that use the de-trended raster to investigate flooding outside a main channel at any prescribed discharge or flow stage. The RBT will also allow users to recreate other survey protocols that use cross-sectional and longitudinal profile approaches. The CHaMP - Topographic Point Collection Method provides background on collection of the X, Y, Z point measurement data used to generate the DEM that is analyzed for this calculation. See http://www.monitoringmethods.org/Method/Details/836. Topographic data are processed using a suite of tools in GIS created for CHaMP. The CHaMP topographic processing tools generate the necessary input files for the RBT, including DEMs, ensuring data requirements for the RBT are met.

Bankfull Width

Background / Abstract

Bankfull width measurements are used to provide context to the size of a river or stream and help to establish the correct sample reach length. As part of this study, bankfull width is measured in the field to establish the sample reach length, but is also generated from the RBT to compare with the field measurements.

Using the RBT, cross sections are cut into a DEM at a user specified distance along the centerline of the bankfull or wetted polygons. Each profile metric comprises several output values:

- Mean for all profile values
- Standard deviation across all profile values
- Coefficient of variation across all profile values
- Filtered mean of selected profile values
- Filtered standard deviation across selected profile values
- Filtered coefficient of variation across all profile values
- All profile values along with their cumulative interval distance downstream from the top of the site.

The filtered metrics report the same statistics but for a subset of the profile intervals. Filtering removes any values from the population that are more than a set number of standard deviations from the population mean. For CHaMP 2013 this filtering threshold is set at 4 standard deviations. This is intended to exclude outliers from the metrics.

The methodology for this calculation follows RBT – Bankfull Width Profile Calculation v1.0. https://www.monitoringmethods.org/Method/Details/1273

Step by Step Instructions

Data should be processed according to the CHaMP protocols for processing DEMS using the CHaMP Toolkit in GIS. As part of this process, the bankfull width is calculated by the RBT. The RBT will move down the centerline at 50 cm intervals creating cross-sections perpendicular to the centerline to create a bankfull width profile, and report the width at which these cross-sections intersect the bankfull polygon. Width values will be averaged and reported at the site-level.

Reach Width (Wetted Width)

Reach width (wetted width) is calculated using the wetted width profile created by the RBT. The process mirrors the bankfull width calculation, but uses the wetted polygon instead of the bankfull polygon. The methodology for this calculation follows RBT – Wetted Width Profile Calculation v1.0. https://www.monitoringmethods.org/Method/Details/1276

Bankfull Width to Depth Ratio Profile

Background / Abstract

Bankfull Width to Depth Ratio Profile utilizes profiles created by the RBT. See the bankfull width metric background for description of how RBT profiles are created.

The CHaMP - Point Collection Methods provides background on collection of the measurement data that are analyzed for this calculation. http://www.monitoringmethods.org/Method/Details/836

The Bankfull Width to Depth Ratio Profile metric calculation follows the steps outlined in RBT – Bankfull Width to Depth Ratio Profile Calculation v1.0. https://www.monitoringmethods.org/Method/Details/1275

Step by Step Instructions

The bankfull width to depth ratio for each cross-section is calculated as the length of each cross-section across the bankfull polygon, divided by the average depth of each station along the cross-section. Stations are positioned across each cross-section at a customizable distance.

Channel Units

Background / Abstract

Channel Unit metrics are calculated using the RBT from the DEM, wetted polygon, and channel unit delineations from the topographic survey. These calculations follow the methodology from RBT – Channel Unit Calculation v1.0 (https://www.monitoringmethods.org/Method/Details/1258)

Step by Step Instructions

The channel unit polygons are first clipped to the site wetted polygon and all metrics are reported for this clipped area. Channel unit metrics are reported for each individual channel unit identified by the field crew and include:

- number assigned to each unit by the field crews.
- tier 1 tag assigned by the field crews and recorded in the associated data file.
- tier 2 tag assigned by the field crews and recorded in the associated data file.
- area of the clipped channel unit polygon in meters squared. Area by channel unit type, for both Tier 1 and Teir 2 channel units types are also calculated by summing the individual areas by channel unit type.
- volume of the clipped channel unit in meters squared. Volumes by channel unit type are calculated in a similar fashion as area. See the site volume metric for how the RBT calculates volumes.
- frequency: the sum of the area of the particular type of channel units divided by the wetted site length.
- percent: the sum of the area of the particular channel units divided by the wetted site area.

Mean Residual Pool Vertical Profile Area

The mean residual pool vertical profile area is the calculation of an accumulation of areas over the course of the reach. The input data includes the thalweg depths of the channel, the slope of the reach, and the increment which is the reach length divided by 100. At each increment we calculate a residual pool profile area, and we accumulate those areas to determine Mean Residual Pool Vertical Profile Area in meters squared per reach. The calculations used to determine Mean Residual Pool Vertical Profile Area are derived from the EPA EMAP program and additional information may be obtained from Phil Kauffman of the EPA.

Mean Residual Pool Depth

Mean Residual Pool Depth is derived directly from the Mean Residual Pool Vertical Profile Area calculation performed above. It is simply the Mean Residual Pool Vertical Profile Area divided by the total length in meters of the reach, and then multiplied by 100 to get a residual depth in centimeters.

Maximum Pool Depth Average

Background / Abstract

The Maximum Pool Depth Average is an average of the maximum pool depths (measured in cm) obtained from the DEM. Using the maximum pool depths for all pools within the reach, calculate the average by summing the maximum pool depths and dividing by the number of pools within the reach. This will be calculated for the treatment and control reaches.

Step by Step Instructions

Step 1: A pool is identified as a point or series of points along the Thalweg with a residual depth greater than zero that is bounded by points along the thalweg with a residual depth(s) equaling zero.

Step 2: The maximum depth of each pool is determined by examining all points within a pool and selecting the point with the highest value.

Step 3: The maximum depth value for each pool is summed and then divided by the total number of pools to produce the value for max average depth.

Pool Tail Crest Depth Average

Background / Abstract

The Pool Tail Crest Depth Average is an average of the pool tail crest depths (measured in cm) obtained from the DEM. This calculation is automated by the RBT.

Step by Step Instructions

Step 1: A pool tail crest is located by looping over the list of Thalweg depths and identifying points where the residual depth is greater than zero and the previous depth along the thalweg equals 0 (i.e. not a pool).

Step 2: The depth at each of the identified pool tail crests is summed and then divided by the total number of pools to produce the value of the average pool tail crest depth.

Variation in Thalweg Profile and Channel Width

Background / Abstract

This metric involves the calculation of a variation index for residual pools from thalweg profile data and also creates a histogram of channel widths. This variation index for residual pools has been found to have a strong correlation with habitat complexity and fish use (Mossop and Bradford 2006).

Step by Step Instructions

Step 1: After collecting thalweg profile data for your site via the topographic survey, determine the residual pools that are within the thalweg profile. Use the automated output from the RBT (Console version) to determine the population of residual pool depths and channel widths.

Step 2: Calculate the standard deviation of the population of residual pool depths within the sample reach. This serves as the variation index.

Step 3: For channel widths, using a minimum of 21 channel widths evenly distributed along the sample reach, create a histogram of channel widths to determine the variation. Channel widths can be determined from the water surface polygon associated with the site DEM.

Pool/Riffle Ratio

Background / Abstract

Determine changes in fish habitat by assessing the pool to riffle ratio in each reach. This ratio can be calculated using the channel unit output from the RBT.

Step by Step Instructions

Step 1: Determine the area of the sample reach that is pool habitat by summing the area of each channel unit identified as a pool.

Step 2: Determine the area of the sample reach that is riffle habitat by summing the area of each channel unit identified as a riffle.

Step 3: Divide the area of the reach in pools by the area of the reach in riffles to determine the pool/riffle ratio.

Braid/Channel Ratio

Background / Abstract

From Pess et al. 2005, this metric is the calculation of the ratio of side channel length to main channel length.

Step by Step Instructions

Step 1: Measure total length of qualifying side channels within the study reach.

Step 2: Measure the total length of the mainstem channel in the study reach.

Step 3: Divide length of side channel by length of main channel to determine ratio.

River Complexity Index (Brown 2002)

Background / Abstract

Based on Brown (2002), this method outlines the calculation for the River Complexity Index (RCI).

Step by Step Instructions

Determine the total channel length (of main channel and side channels) in the sample reach from the digital elevation model (DEM). Multiple channels within the main channel are counted individually. Determine the total reach length (thalweg distance from bottom of site to top of site). Count the number of junctions (where side channels meet main channel, or where main channel splits). Calculate RCI using the following equation:

$$RCI = S\,(1+J)$$

where: S = sinuosity= total channel length/reach length

J = no of junctions in the reach

Amount of Spawning Habitat

Total area of spawning habitat for target salmonid species. The area of spawning habitat is calculated using predetermined spawning habitat preference curves and velocity and depth outputs from a hydraulic model. The hydraulic model is set to flow at the time of the survey, and the resulting data is mapped areas suitable for spawning habitat.

Log_{10} of Volume of LWD

Background / Abstract

This is a measure of the volume of large woody debris (LWD) of all sizes within the study reach. LWD are counted and grouped within various size classes (diameter and length). The volume of each piece of LWD is estimated by the standard formula for volume of a cylinder, which is the area of the base (pi times the radius squared) times the length. The LWD volumes are summed to calculate site LWD volume. The site LWD volume calculations follow the methodology for CHaMP Large Wood Volume Calculation, monitoringmethods.org #872. The site LWD volume is then multiplied by the log base 10 (log_{10}) to report the site metric Log_{10} of Volume of LWD.

Step by Step Instructions

Step 1: Calculate total site volume of LWD using CHaMP Large Wood Volume Calculation.

Step 2: Multiply site volume by 100

Step 3: Transform to Log_{10}

Number of Pieces of Wood

Count of the total number of LWD pieces at a site. The total number of pieces of LWD helps provide additional context to site LWD volume.

Pool Forming Wood

Count of the total number of LWD pieces identified as a pool forming piece.

Number of AIS Present

In-stream habitat projects involve the placement of artificial in-stream structures (AIS). In years following project implementation, the number of AIS remaining in the impact reach is tallied. This value is only reported for the treated reach, as artificial structures are not placed within the control reach. The location of each of the placed structures is marked using a GPS unit. In subsequent monitoring events, these locations will be used to determine if structures have moved.

Substrate Composition

Background / Abstract

Visual estimate of the percent of different substrate types (boulder, cobble, coarse gravel, fine gravel, sand or fines) within the wetted site area.

Estimated for each channel unit in the site or tier, then weighted by channel unit area to arrive at site or tier level estimate. Estimates are rounded to the nearest 5% for a total of 100%; 1% denotes minimal presence.

Metrics are calculated at the site level for:

- Percent Boulders and Cobbles
- Percent Boulders
- Percent Cobbles
- Percent Coarse and Fine Gravel
- Percent Sand and Fines

The CHaMP - Ocular Channel Unit Substrate Composition Method provides background on identification of the channel units that are analyzed for this calculation. See - http://www.monitoringmethods.org/Method/Details/839

Step by Step Instructions

Step 1: For each channel unit, divide the wetted area of the unit by the wetted area of the site to determine the percent area of each channel unit; where channel unit area is derived by RBT.

Step 2: Multiply the percent of wetted channel area by the percent cover of each substrate class for each channel unit.

Step 3: Sum the percent wetted channel area for each substrate class and report at the tier1 channel type (slow-water, riffle, or glide) and the site-level. Criteria: Channel Unit Sum of Substrate Cover is >=90 And <=110

- Equations:
- SumOfArea = Sum(Area)
- BoulderPlusCobblesNormalized = ([Boulders]*[Area])+([Cobbles]*[Area])
- SumOfBoulderPlusCobblesNormalized = Sum(BoulderPlusCobblesNormalized)
- BoulderAndCobbleBySite = [SumOfBoulderPlusCobblesNormalized]/[SumOfArea]

- CoarsePlusFineGravelNormalized = ([CoarseGravel]*[Area])+([FineGravel]*[Area])
- SumOfCoarsePlusFineGravelNormalized = Sum(CoarsePlusFineGravelNormalized)
- CoarseAndFineGravelBySite = [SumOfCoarsePlusFineGravelNormalized]/[SumOfArea]
- SandPlusFinesNormalized = ([Sand]*[Area])+([Fines]*[Area])
- SumOfSandPlusFinesNormalized = Sum(.SandPlusFinesNormalized)
- SandAndFinesBySite1 = [SumOfSandPlusFinesNormalized]/[SumOfArea]

D16, D50, D84 Particle Size in Riffles

Background / Abstract

D16, D50, and D84 are the diameters of the 16th, 50th, and 84th percentile streambed particles from fast water channel units.

Within a site, 210 particles are measured at 10 transects in fast-water turbulent and non-turbulent channel units. Measurements are made with a gravelometer and recorded in size classes. Bedrock measurements are excluded and bank particles are not measured.

Percentiles are calculated using a logarithmic interpolation.

Description and steps for this calculation are taken from:
https://www.monitoringmethods.org/Method/Details/1730

Step by Step Instructions

Step 1: Filter to exclude pebble records where the cross-section is associated with channel units of Tier1Type = “Slow/Pool”

Step 2: Count the total number of pebbles for the visit (after removing pebbles observed in “Slow/Pool” units)

Step 3: Count the number of pebbles by size class (after removing pebbles observed in “Slow/Pool” units) (b-axis diamter is recorded using the following size classes: 0.002≥0.06mm, 0.06≥2mm, 2≥5.7mm, 5.7≥8mm, 8≥11.3mm, 11.3≥16mm, 16≥22.6mm, 22.6≥32mm, 32≥45mm, 45≥64mm, 64≥90mm, 90≥128mm, 128≥180mm, 180≥256mm, 256≥362mm, 362≥512mm, 512≥724mm, 724≥1024mm, 1024≥1448mm, 1448≥2048mm, 2048≥2896mm, 2896≥4000mm, >4000mm.)

Step 4: Calculate the percentage of pebbles in each size class

Step 5: Create a vector to union the MaxDiameter of the size class and the SubstrateMeasurement value into a new single attribute

Step 6: MaxDiameter for the size class should be stored as a look up table.

Step 7: When size class = ">512" select SubstrateMeasurement instead of MaxDiameter

Step 8: Calculate the Log of MaxDiameter as a new attribute in the above vector

Step 9: Sort the data by MaxDiameter

Step 10: Calculate the cumulative percentage

Step 11: Add PercentageOfPebble for size class 1 to size class 2, then add size class 3, then add size class 4, etc

Step 12: Search CumulativePercentage for

- the largest values less than 16
- the smallest value greater than 16

Step 13: Grab the log transformed MaxDiameter for those two size classes

Step 14: Interpolate a log transformed MaxDiameter between those two MaxDiameters

Step 15: Inverse the log transformation and report the interpolated MaxDiameter in millimeters

Bank Erosion

Background / Abstract

Bank erosion is a measure of the proportion of the reach containing actively eroding stream banks. At each transect we measure the lineal extent of erosion in meters along the left and right banks.

Step by Step Instructions

Step 1: Calculate the percentage of erosion along each bank at every transect using the equation:

Percent Erosion (%) = (lineal extent of erosion / transect length) * 100

Step 2: Calculate the mean percent erosion for the site by averaging each of the 42 individual measurements.

Change in Bank Stability

Using the information from the locations of channel migration – change in bank location- the proportion of the channel length where active bank migration is taking place is calculated. The units for this metric are a percent with the length of active bank migration divided by the total reach length. This value is compared to the bank erosion proportion that is visually estimated in the field.

In-stream Fish Cover

Background / Abstract

Percent of wetted area that has cover for fish. Cover is estimated for each channel unit, then a weighted average (based on channel unit area) is calculated for either the entire site or for each tier within a site.

Percent fish cover is calculated for each type of cover: Large Woody Debris, Vegetation, Aquatic Vegetation, or Artificial. The total percent cover, as well as the area with no cover, are also calculated.

The CHaMP - Fish Cover Elements Method provides background on collection of the measurement data that are analyzed for this calculation. See - http://www.monitoringmethods.org/Method/Details/838

Metric calculation follows the methodology follows Percent Fish Cover Calculation v1.0. https://www.monitoringmethods.org/Method/Details/873

Step by Step Instructions

Step 1: For each channel unit, divide the wetted area of the unit by the wetted area of the site to determine the percent area of each channel unit; where channel unit area is derived by RBT.

Step 2: Multiply the percent of wetted channel area by the percent cover of each fish cover class for each channel unit.

Step 3: Sum the percent wetted channel area for each fish cover class and report at the tier1 channel type (slow-water, turbulent, or non-turbulent) and the site-level.

Average Pool Tail Fines

Background / Abstract

This is an average percentage of pool tail substrates comprised of fine sediements < 2 mm and < 6 mm. A fines grid with 50 intersections is placed at three locations at the tail of Slow Water/Pool and Non-Turbulent channel units. For each grid, the number of intersections <2mm, and between 2mm and 6mm is recorded for each grid. The percent of fines <2mm for each grid is calculated by dividing the total number of <2mm intersections by 50 (intersections) minus the number of nonmeasureable intersections. The percent of fines <6mm for each grid is calculated by adding together the number of <2mm intersections and 2-6mm intersections and then dividing by 50 minus the number of nonmeasureable intersections. The percent of fines <2mm and <6mm are averaged across a site.

Metric calculation methodology follows Pool Tail Fines: Particles < 2 mm and < 6 mm v1.0. https://www.monitoringmethods.org/Method/Details/868

Step by Step Instructions

Particles <2mm:

Step 1: Calculate the percentage of 50 substrate observations that we less than 2mm for each of three grids at the pool tail of each channel unit.

Step 2: Average across the entire site.

Equations: PercentLessThan2mm = [Grid1Lessthan2mm]/(50-[Grid1NonMeasureable]) PercentLessThan2mm = [Grid2Lessthan2mm]/(50-[Grid2NonMeasureable]) PercentLessThan2mm = [Grid3Lessthan2mm]/(50-[Grid3NonMeasureable]) PercentOfObservationLessThan2mm = Avg(PercentLessThan2mm)

Particles <6mm:

Step 1: Calculate the percentage of 50 substrate observations that we less than 6mm for each of three grids at the pool tail of each channel unit.

Step 2: Average across the entire site.

Equations: PercentLessThan6mm = [Grid1Lessthan6mm]/(50-[Grid1NonMeasureable]) PercentLessThan6mm = [Grid2Lessthan6mm]/(50-[Grid2NonMeasureable]) PercentLessThan6mm = [Grid3Lessthan6mm]/(50-[Grid3NonMeasureable]) PercentOfObservationLessThan6mm = Avg(PercentLessThan6mm)

Juvenile Salmonid Density

Background / Abstract

The response variables for juvenile fish are calculated in the same way for Chinook, coho, and steelhead par. The metric used is number of fish per square meter within each reach. The number of fish is found by querying the snorkel survey results for fish of each species that are less than 250 mm in length. Water surface area is reported from the RBT as the area of the wetted polygon. Calculation methodologies are different for Electrofishing versus snorkeling and are described below.

Step by Step Instructions using snorkel surveys

Calculations for fish density from snorkeling are derived from Thurow (1994) and O'Neal (2007).

Step 1: Sum the number juvenile fish by species.

Step 2: Divide the number of fish for each species by water surface area to calculate the fish density by species (number of fish/m^2)

Step by Step Instructions using backpack electrofishing surveys

Total salmonid abundance for the sampled reach is estimated using the method described by Zippin (1956) or using an established calculation program such as MicroFish 3.0 (Van Deventer 2005). Once abundance for a unit area is determined, divide by the unit area to get the density estimate. The Zippin (1956) calculation methodology is summarized below:

i. Calculate to total catch

   T= Total catch = $\Sigma y_i = y_1 + y_2 + y_3$

   where y_i is the number of fish captured on the ith pass.

ii. Calculate the probability of catchability ratio, R.

   $R = (q/p) - (kq^k)/(1-q^k) = [\Sigma (i-1)y_i = (1-1)y_1 + (2-1)y_2 + (3-1)y_3] / T = (y_2 + 2y_2)/(y_1 + y_2 + y_3)$

iii. Calculate the estimated population using the equation $N = T/(1-q^k)$
   1. Find the estimate of $(1-q^k)$corresponding to the calculated R using Zippin's first graph in Figure 2 of Zippin (1956) (See Figure 33) for three passes or formula presented below.
   2. Divide the total catch, T, by the graphical result for $(1-q^k)$

Where:

R = Probability of catchability ratio

q = probability of escaping capture during a single pass (1 – p)

p = probability of capture (1 – q)

k = the number of passes (so in a 3-pass depletion survey, k=3)

T = total catch estimate

N = total population = total catch/estimated proportion of population captured = $T/(1 - q^k)$

Notes: If using more than three passes, use the appropriate graph from Figure 33; A = 3 passes, B = four passes, C = 5 passes, and D = 7 passes. Refer to Zippin 1956 for further explanations of equation derivations and calculations of error and coefficients of variation: http://www.jstor.org/stable/i353441

Photos & Figures

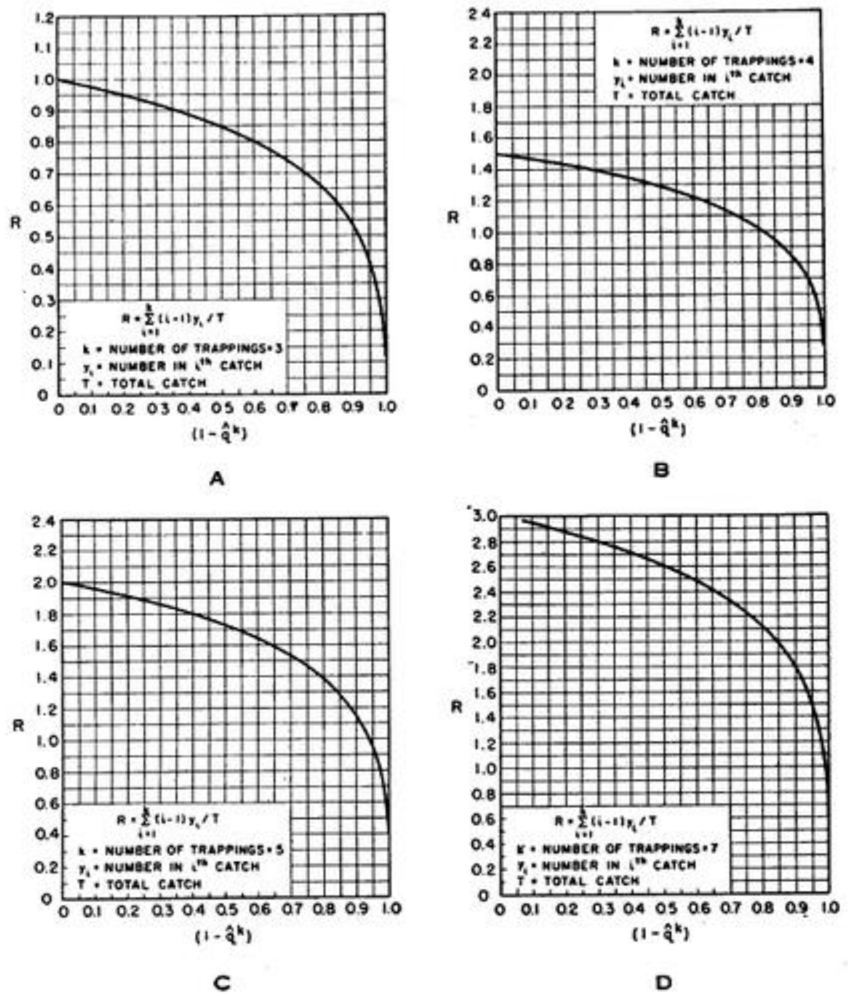

FIG. 2 GRAPH FOR ESTIMATION OF $(1-q^k)$ FROM THE RATIO R

Figure 33. Graph for estimations of $(1\text{-}q^k)$ from Figure 2 of Zippin (1956)

Fish Use by Structure Type

Background / Abstract

Fish utilizing structures within the stream are documented during fish sampling. The number fish observed using each structure type are summed, and reported as (number of fish / structure type). The total number of fish using each type of structure provides information on the preference of different structures by fish. The use of structures installed as part of restoration can help report fish utilization of restoration. Structure types include: natural wood, placed wood, natural bolder, placed bolder, natural off-channel, created off-channel

Step by Step Instructions:

Step 1: Sum the total number of fish associated with natural wood structure.

Step 2: Repeat for placed wood, natural bolder, placed boulder, natural off-channel, and created off-channel.

Fish Use of Structures by Life Stage

Fish use of all structure types by life stage. All observations of fish at structures are lumped together, regardless of structure type. A length frequency histogram is created to show the distribution of lengths of fish using structures. Local length-age relationships can be applied to histograms to determine number of fish by life stage.

Fish use of Structures by Species

Fish use of all structure types by species. All observations of fish at structures are lumped together, regardless of structure type. The total number of each species observed using any structure are determined and reported as the total number of each species using structures.

Metrics and Indicators

Metrics

- "Sample Date" - Time - Date -
- "Reach Length" - Landscape Form & Geomorphology - Length/Width/Area - Habitat Type: Rivers & Streams
- "GPS Coordinates" - Other - Location -
- "Reach Width" - Landscape Form & Geomorphology - Length/Width/Area - Habitat Type: Rivers & Streams
- "Bankfull Width" - Landscape Form & Geomorphology - Length/Width/Area - Habitat Type: Rivers & Streams
- "Bankfull Width to Depth Ratio" - Landscape Form & Geomorphology - Length/Width/Area - Habitat Type: Rivers & Streams
- "Channel Unit Area"
- "Channel Unit Volume"
- "Channel Unit Frequency"
- "Channel Unit Percent"
- "Mean Residual Pool Vertical Profile Area" - Landscape Form & Geomorphology - Length/Width/Area - Habitat Type: Rivers & Streams
- "Mean Residual Pool Area" - Landscape Form & Geomorphology - Length/Width/Area - Habitat Type: Rivers & Streams

- “Average Maximum Pool Depth” - Landscape Form & Geomorphology - Depth: Pool -
- “Average Pool Tail Crest Depth” - Landscape Form & Geomorphology - Depth: Pool –
- “Variation in Thalweg Profile and Channel Width”
- “Pool/Riffle Ratio”
- “Juvenile Fish Density” - Fish - Density of Fish Species - Fish Life Stage: Juvenile Fish
- “Fish Use by Structure Type”
- “Fish use of structures by life stage”
- “Fish use of structures by species”
- “Log10 of Volume of LWD” - Landscape Form & Geomorphology - Size: Wood Structure -
- “Number of AIS” - Disturbance/Restoration - Abundance of Disturbance or Restoration -
- “Number of pieces of wood”
- “Pool Forming Wood”
- “Bank Erosion”
- “Pool Tail Fines < 2 mm”
- “Pool Tail Fines < 6 mm”
- “In-stream Cover”
- “River Complexity Index”
- “Braid/Channel Ratio”
- “Amount of Spawning Habitat”
- “Variation in Thalweg Profile and Channel Width”
- “Substrate Composition”
- “D15, D50, D84”
- “Stream Dischrage”

Quality Control & Reporting

Data Handling Considerations

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the BPA at the end of the project. Summarized data from the project will be entered into the online database after each sampling season.

Quality Control Considerations

All data collected in the field is uploaded into a replication of the database on a laptop computer and run through a series of QA/QC checks prior to leaving the site. In addition to the automated QA/QC process, this allows field staff to visually review the data for errors. Should errors or omissions be found, field staff can correct items that may be recorded improperly or collect additional data that may be missing from the data forms while still onsite.

Reporting Considerations

A progress report will be prepared in writing by the monitoring entity after the sampling season for Years 1, 3, and 5, including preliminary results. A final report will be prepared in writing by the monitoring entity after the sampling season for Year 10. It shall include:

- Estimates of precision and variance
- Confidence limits for data
- Summarized data required for PRISM database
- Determination whether project met decision criteria for effectiveness
- Analysis of completeness of data, sources of bias

Equipment Cleaning and Calibration

Field equipment (i.e., waders, wading socks, boots, dry suits, snorkel equipment or any other field gear) should be maintained to prevent the spread of disease or invasive species. This can be accomplished by thoroughly cleaning equipment prior to leaving a site or at the office prior to using that equipment at another location.

Electronic equipment should be maintained in good working condition to ensure that measurements are collected and recorded accurately. This includes ensuring that equipment is fully charged or has sufficient battery power to operate correctly, as well as any calibration that may be required or recommended by manufacturers.

Personnel and Training

Roles and Responsibilities

Field Manager (FM): The Field Manager is responsible for and has the authority to direct all operations related to the field work necessary to complete this project. The Field Manager oversees all field crews and is directly responsible for insuring that all safety procedures are followed. The Field Manager shall be directly responsible for the safety of all field crews when in the field and for strictly following a daily field plan. He/She shall implement an established emergency plan at the field level should an emergency situation arise. The Field Manager will know the location of crews and their itineraries at all times and shall keep the field team leaders advised of significant project developments on a daily basis by providing and following a daily field plan or itinerary.

Field Team Leader (FTL): Each Field Team Leader shall be directly responsible for the safety of his or her field crew when in the field and for strictly following the daily field plan. Each FTL shall implement the emergency plan at the field level during emergency situations. Each FTL in the field shall know the location of his or her field crew and their itineraries at all times and shall keep the other FTLs advised of significant project developments on a daily basis by providing and following a daily field plan or itinerary.

Field Investigators: Each field investigator shall be responsible for following the Health and Safety Plan. He or she shall maintain scheduled communications with the FTL and shall assure that during emergency situations appropriate procedures are followed. In the event the FTL is incapacitated or unavailable, the most senior field investigator shall assume the duties of the FTL.

Qualifications

Field Manager: The FM must have experience with the type of work that is being conducted and must be familiar with all field operations related to the field work. The FM must also be familiar with safety and emergency procedures and be capable of overseeing and/or carrying out any necessary tasks associated with those procedures.

Field Team Leader: The most experienced member of every field team will be designated as the FTL. The FTL must also be familiar with safety and emergency procedures and be capable of carrying out any necessary tasks associated with those procedures.

Field Investigator: The field investigators must be trained in the type of work that is being conducted or have sufficient experience/education to be capable of conducting the necessary tasks and adhering to safety policies.

Training Requirements

An interdisciplinary training session and site-specific orientation shall be given to all field personnel by personnel who have used the protocols for at least three years prior to beginning site work. This training may be internal, or contracted using personnel who have already implemented these protocols to ensure consistency across organizations. The training shall cover materials related to health and safety procedures as well as technical aspects of the work to be performed. This training shall also be provided to any new employees arriving after the start of the field season before they begin field work.

The Field Manager will conduct field safety meetings and prior to the start of any new activities. These meetings will provide the chance for field personnel to present questions or address any safety issues that may have arisen

Safety Considerations

At least two team members of each field team will be current with their first aid/CPR training. First aid/CPR training is recommended for any subcontractors. A copy of the Health and Safety Plan shall accompany each field team into the field. Field staff must always work in teams of 2 or more and may never work alone. At the end of each work day, the FTL will check in with the Field Manager to confirm that all team members are accounted for and have left the site safely. Check in can be done by leaving a phone message for the Field Manager.

Schedule and Budget

Field Schedule Notes

Surveys are scheduled to coincide with summer low flow conditions whenever possible. Monitoring of the treatment and control reaches should be conducted consecutively to capture similar flow and environmental conditions at each reach. Monitoring of a site should be conducted during each monitoring year on a schedule similar to that of the previous years so that seasonal fluctuations in stream conditions and fish use are not an issue.

Budget Considerations

For each project, a team of 3-4 field staff surveying for two 10-hour days (1 day control, 1 day treatment) is budgeted. The number of field staff required is dependent on the size of the site and the level of effort that will be required to collect all data at both reaches within the two-day period. In order to reduce costs associated with travel and mobilization, monitoring of sites within the same geographic region may be grouped such that multiple sites can be surveyed during a given trip.

Literature Cited

Citations

Benegar, J.R. (2011) Evaluation of constructed wood jams in a forest, gravelbed stream. A thesis presented to the faculty of Humboldt State University in partial fulfillment of the requirements for the degree of Masters of Science in Natural Resources: Watershed Management. Natural Resources graduate project number: 11-WM-748-06/08. June 2011.

Cederholm, C. J., Bilby, R. E., Bisson, P.A., Bumstead, T.W., Fransen, B. R., Scarlett, W. J., and Ward, J. W. 1997. Response of juvenile salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management. 17: 947-963.

Bisson, P. A., D. R. Montgomery, and J. M. Buffington. 2006. Valley segments, stream reaches, and channel units. Pages 23-49 in Methods in Stream Ecology, 2nd edition. Elsevier.

Brierley, G., Reid, H., Fryirs, K., and Trahan, N. 2010. What are we monitoring and why? Using geomorphic principles to frame eco-hydrological assessments of river condition. Science of the Total Environment. 408: 2025-2033

Chapman, D.W. (1996) Efficacy of structural manipulations of instream habitat in the Columbia River Basin. Northwest Science. 5(4):279-293.

Collins, B.D., and Montgomery, D.R. (2002) Forest development, wood jams, and restoration of floodplain rivers in the Puget lowland, Washington. Restoration Ecology. 10(2): 237-247.

Frissell, C.A., and Nawa, R.K. (1992) Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management. 12: 182-197.

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

Hawkins, C. P., J. L. Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory. D. A. McCullough, C. K. Overton, G. H. Reeves, R. J. Steedman and M. K. Young. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.

Heitke, Jeremiah D.; Archer, Eric K.; and Roper, Brett B. 2010. Effectiveness monitoring for streams and riparian areas: sampling protocol for stream channel attributes. Unpublished paper on file at: http://www.fs.fed.us/biology/fishecology/emp.

Kauffman, J., Beschta, R.L., Otting, N ., and L ytjen, D . (1997). An ecological perspective of riparian and stream restoration in the western United States. Fisheries (Bethesda). 22: 12-24.

Larson, M.G., Booth, D.B., and Morely, S.A. (2000) Effectiveness of large woody debris in stream rehabilitation projects in urban basins. Ecological Engineering. 18: 211-226.

Montgomery, D. R., and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition: Olympia, Rep. TFW-SH10-93-002, 84 p., Wash. State Dep. of Nat. Resour., Olympia, 1993.

Moore, K., K. Jones and J. Dambacher (1998). Methods for stream habitat surveys aquatic inventory project. Oregon Department of Fish and Wildlife. Corvallis, OR. 36pp.

O'Neal, J.S. 2007. Snorkel Surveys. Pages 325-340 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neill, and T. N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft (2003). Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Peck, D.V., A.T. Herlihy, B.H. Hill, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchak, F.H. McCormick, S.A. Peterson, P.L. Ringold, T. Magee, and M.R. Cappaert. (2001) Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Wadeable Streams. EPA/620/R-06/003, U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Reeves, G. H., and T. D. Roelofs. (1982) Rehabilitating and enhancing stream habitat: field applications. U.S. Forest Service General Technical Report PNW- 140.

Reeves, G.H., Hall, J.D., Roelofs, T.D., Hickman, T.L., and C.O. Baker. (1991) Rehabilitating and modifying stream habitats. Pages 519-557 in W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society, Special Publication 19, Bethesda, Maryland.

Roni, P. and Quinn, T.P. (2001) Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences. 58: 282-292

Roni, P., Hanson, K., and Beechie, T. (2008) Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management. 28: 856-890.

Rumps, J.M., Katz, S.L., Barnas, K., Morehead, M.D., Jenkinson, R., Clayton, C.R., and Goodwin, P. (2007) Stream restoration in the Pacific Northwest: Analysis of interviews with project managers. Restoration Ecology 15(3): 506-515.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker (1986). Ecology. Vol. 67(4) pp. 929-940. Temple, G. M. and T. N. Pearsons. 2007. Electrofishing: Backpack and drift boat. Pages 95-132 in D. H.

Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neill, and T. N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Tetra Tech. 2012. An inventory and assessment of distribution of monitoring projects targeting Chinook and steelhead tributary habitat in the Columbia River Basin. Prepared for the Bonneville Power Administration, 43pp.

Thurow, R.F. (1994). Underwater methods for study of salmonids in the Intermountain West. U.S. Forest Service. Gen Tech Rept. INT-GTR-307. 29 pp.

Washington Department of Transportation (WSDOT). 2012. WSDOT Fish Exclusion Protocols and Standards. http://www.wsdot.wa.gov/NR/rdonlyres/70E7E285-ECC6-41BA-A2DF-87FD0D68128D/0/BA_FishHandling.pdf. August 20, 2012.

Whiteway, S.L., P.M. Biron, A. Zimmermann, O. Venter, and J.W.A. Grant. 2010. Do in-stream restoration structures enhance salmonid abundance? A meta-analysis. Canadian Journal of Fisheries and Aquatic Sciences 67:831-841.

Zippin, C. (1956). The removal method of population estimation. Journal of Wildlife Management 22:82-90.

Appendix A – Alternative Discharge Measurement

Background / Abstract

The purpose this method is to measure discharge of the site at the time of sampling. An alternative method for discharge measurement will be used at sites with water depths that are too shallow to use the flow meter. A channel cross-section that is free of obstructions provides the best conditions for measuring discharge. You may remove rocks and other obstructions to improve the cross-section before any measurements are made. Methods are derived from Gordon et al. 2004.

Step by Step Instructions

Step 1. Identify and flag the cross-section location.

i. Locate a cross-section of the stream channel that has most of the following qualities:
    a. Segment of stream above and below the selected cross-section is straight.
    b. Depths will be less than 15 cm, and velocities will probably be less than 0.15 m/s. Do not measure discharge in a pool.
    c. "U" shaped channel with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
    d. Flow is relatively uniform with no eddies, backwaters, or excessive turbulence.

ii. If an appropriate cross-section location cannot be identified within a site, extend the search upstream or downstream of the site boundary, avoiding locations that would differ in flow from that of the site, such as entry areas of tributaries and side channels that are included within the site extent.

iii. Avoid locating cross-sections where 100% of the flow is not in the channel (side channels are present). If this situation is unavoidable, such as a braided channel, take separate cross-section measurements, one in the main channel and one in the side channel(s).

Step 2. Set up cross-section and measure water depth.

i. Stretch and secure a meter tape across the stream perpendicular to the flow with the “zero” end on the left bank.

ii. Divide the total wetted stream width into 15 to 20 equally spaced intervals.

iii. To determine interval width, divide the width by 20 and round up to a convenient number.

iv. Intervals should not be spaced less than 10 cm apart, even if this results in less than 15 intervals.

v. Take the first depth measurements at the left edge of water. Conduct the second depth measurement one interval out from the left bank. Move to the next interval. Continue until depth measurements have been recorded for all intervals.

Step 3. Calculating travel time of a neutrally buoyant object.

i. Measure a five meter length of stream channel upstream from the cross section location and mark the location with flags (Figure 2).

ii. Place a neutrally buoyant object (e.g., half-filled water bottle or orange) in the middle of the wetted channel a short distance upstream of the flagged location to allow the floating object to reach the speed of the water before passing the first mark. Start the stop watch when the floating object passes the first mark.

iii. Stop the watch when the object passes the cross-section and record the time.

iv. Repeat the process 2 additional times.

v. Disregard any float trials if the object gets hung up in the stream (by cobbles, roots, debris, etc.).

Equipment

- tape measure
- depth rod
- neutrally buoyant object
- stop watch