B. MONITORING METHODS

1. Monumented Cross-sections

Purpose

This section describes how to establish and survey permanent (i.e., monumented) stream cross-sections for long-term monitoring. It identifies the equipment needed, describes the basic protocol, discusses the frequency with which the cross-sections should be re-surveyed, and presents some site-specific considerations. This section does not provide detailed instruction on basic surveying techniques, such as conducting a level survey. For a more complete treatment of stream surveying techniques, see Harrelson et al. (1994).

Monitoring Design

Sampling Protocol

1. Define the monitoring reach.

Defining the length of the stream monitoring reach is the first step in conducting cross-section surveys. Upstream of the barrier, the monitoring reach should, at a minimum, include the length of the impoundment and a representative portion of undisturbed reach upstream of the barrier (e.g., a reach length of approximately 10 channel widths). The downstream monitoring reach is less easily defined because the length of reach physically impacted by the barrier, and/or its removal, is not generally known precisely beforehand.

Minimum Equipment

- ❑ Automatic level (surveyor's level) or laser level
- ❑ Leveling rod in English (to tenths and hundredths) or metric units, preferably 25-foot length
- ❑ Measuring tape in same units (300 ft or 100 m)
- ❑ Field book with waterproof paper
- ❑ Data sheets (see Appendix E)
- ❑ Pencil
- ❑ Permanent marker
- ❑ Two-way radios
- ❑ Topographic maps and/or aerial photographs
- ❑ Chaining pins
- ❑ Flagging tape
- ❑ Machete
- ❑ Wood survey stakes
- ❑ 4 ft (1.2 m) steel rebar stakes
- ❑ Hacksaw
- ❑ Small sledge or mallet
- ❑ Spring clamps
- ❑ GPS
- ❑ Compass

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Installing a monument.

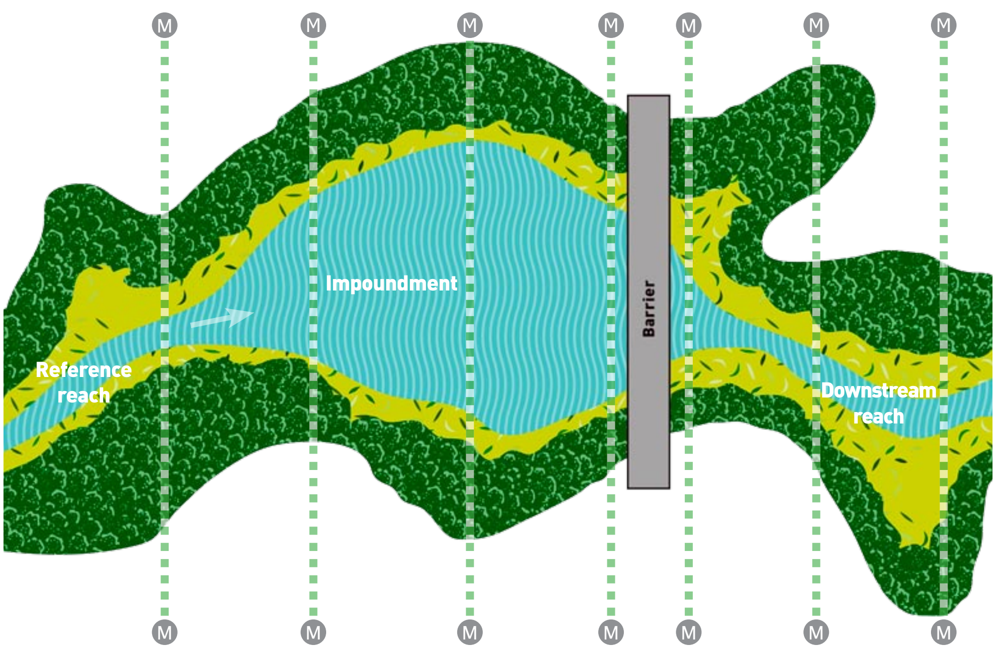

Figure 1.
At minimum, monumented cross-sections should be established immediately upstream and downstream of a stream barrier, at bridges, in the impoundment, and upstream and out of the influence of the impoundment. The number and location of cross sections will depend on site-specific conditions. Figure not to scale.

This length can be estimated, or the downstream limits can be identified based on other project considerations such as downstream habitats of concern, infrastructure, or locations of hydraulic or geomorphic controls such as bridges, outcrops, or knickpoints.

2. Determine number and location of cross-sections.
Once the length of the monitoring reach has been identified, the monitoring team must determine the number of cross-sections needed to adequately represent that reach. The most easily identifiable locations are those areas where infrastructure in the floodplain is likely to be impacted by the project. For example, cross-sections should be established immediately upstream and downstream of the barrier and at bridges within the identified project reach. There also should be cross-sections representing the impoundment (see Site Specific Considerations below), at least one in the undisturbed reach upstream of the impoundment, and at any locations judged to be sensitive to disturbance or of high habitat value. The engineering and geomorphic analyses used to plan the barrier removal should be consulted to identify critical locations. If present in the monitoring reach, cross-sections should be established at existing, monumented cross-sections and/or stream gage locations (Figure 1).

The choice of other cross-section locations should be based on the number of physically homogeneous stream reaches within the monitoring reach—those with similar slopes, bed and bank material, floodplain/terrace sequences, riparian vegetation, and channel-forming processes (Simon and Castro, 2003). For example, the number of cross-sections representing pools, riffles, meander bends, straight reaches, and flow divergence should closely approximate their proportion in the entire monitoring reach. Identification of these sub-reaches or cross-section types should begin with a pre-field inspection of available topographic maps, aerial photographs, surficial/bedrock geology maps, soil surveys, and other relevant information. In addition to subsequent field inspection, you may want to perform and plot a longitudinal profile to use in selecting cross-section locations (see section IV.B.2). Reviewing these data will be valuable for identifying reaches with similar physical characteristics and dominant processes.

3. Locate and establish the cross-section monuments.
At each cross section, establish the permanent markers for both endpoints by driving a ½-inch-diameter, 4-foot rebar stake either flush with the ground or ½ inch above the surface. You may want to cover the tops of the stakes with colored plastic caps available from survey suppliers and use different colors to distinguish different cross-sections (Harrelson et al., 1994). Be sure to note the color associations in the field book. The cross-sections should be straight and perpendicular to the bankfull flow direction, and they should extend across the floodplain/riparian zone to the first terrace or as far as practicable.

To facilitate locating each cross-section for future surveys, establish the horizontal position of the monuments via GPS and one other method. You can fix the position of monuments by taking a bearing and measured distance to the benchmark (see step 4 below), or by triangulating between the monument, benchmark, and another permanent feature on site (e.g., large, healthy tree or bedrock outcrop) (Harrelson et al., 1994; Miller and Leopold, 1961). If the benchmark is not visible from a given cross-section, triangulate with two permanent features. The GPS coordinates of each monument will facilitate mapping the cross-section locations in GIS. Once located, depict the cross-sections on a scaled map or aerial photograph of the project area.

4. Locate or establish the benchmark.
Once the cross-sections have been established, you must either locate, or establish, a local benchmark for the site. This is a permanent marker of known, or assumed, elevation that functions as survey control and the survey starting point. The U.S. Geological Survey (USGS) and other entities historically involved in developing geodetic control networks have benchmarks throughout the country. If one is available at your site, use it. They are typically found on stable site features such as bedrock outcrops; the tops of large, embedded boulders; and bridges.

In the event that a USGS or other geodetic control benchmark is not present in reasonable proximity to the project area, you will need to create a local, or project, benchmark. This offers the opportunity to establish it in a location that is advantageous for the survey; that is, locate it at a point relatively high on the site and visible from most, or at least many, of the permanent cross-sections. You can do so by driving a rebar stake 3 or 4 feet into the ground, chiseling a mark in an outcrop feature or stable boulder, or other means described by Harrelson et al. (1994). Be sure to describe its location in the field book and establish its coordinates with GPS. Always record the horizontal datum employed by the GPS (e.g., NAD 83). If you establish a benchmark, it is conventional to assign it an arbitrary elevation of 100 feet. Alternatively, the benchmark can be tied into an established vertical datum (e.g., NAVD

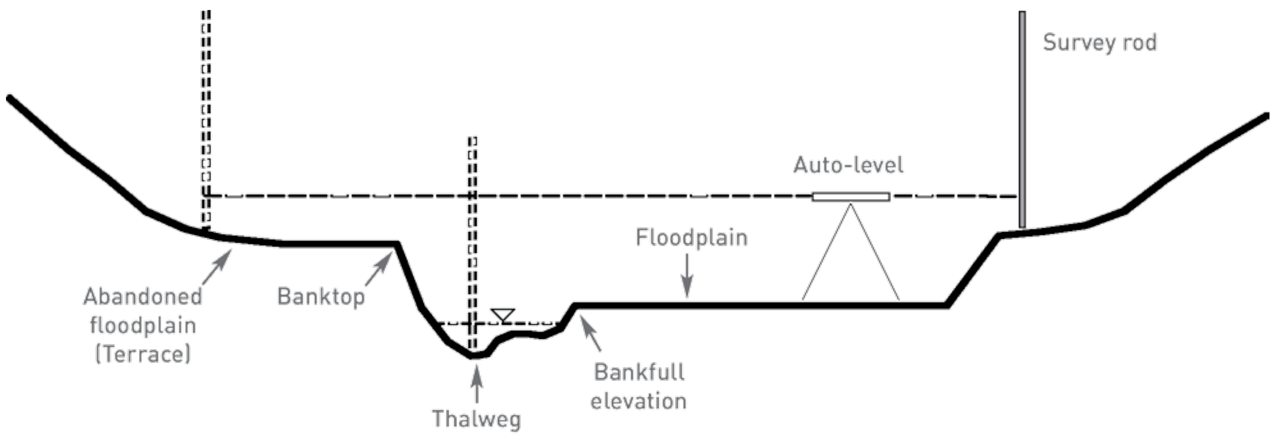

Figure 2. Basic channel and valley features of an unimpacted (reference) stream reach. Note that some features, such as the bankfull elevation, will not be identifiable in the impacted project reach or in all reference reaches.

88) or referenced to mean sea level for projects in areas subject to tidal influence. The horizontal and vertical datums used for the cross-sections should be used also for the longitudinal profile.

5. Set-up the survey instrument and tape.
If possible, set up the survey level in a location from which the local benchmark and all points of one or more cross-sections are visible. Though one or more cross-sections might be shot from one instrument station, to complete all cross-sections for your site you may need to set up two or more instrument stations. From each new instrument station you will need to take backsights on the benchmark (see below), if it is visible, or from turning points if it is not (Harrelson et al., 1994). A machete can be useful to trim low-hanging branches or other vegetation and decrease the number of times you need to move the instrument, but you should avoid cutting large amounts of vegetation for this purpose to minimize property and habitat impacts. At each cross-section, stretch a tape as taut as possible between the monuments. It can be attached to the monument itself with spring clamps, to a shorter rebar stake driven next to the monument with 6 inches exposed for easier attachment, or with chaining pins (Harrelson et al., 1994).

If you are using an optical surveyor's level (auto-level), the person operating the level will make and record the rod readings while the rod person will choose the survey points and call out the lateral distances to the level operator. Lateral distances are referenced to the left bank monument, which is the cross-section zero (left bank is referenced as the left bank looking in the downstream direction). A third person dedicated to recording all readings and descriptions in the field book is recommended and will be necessary for surveying the impoundment with a boat (see Site Specific Considerations below). One advantage of using a laser level is that one person can execute the cross-section survey (or two for impoundment surveys).

6. Survey the cross-section.
Begin with a rod reading on the benchmark. This "backsight" will be added to the elevation of the benchmark to establish the "height of instrument" (HI). All "foresights" on cross-section locations will be subtracted from the HI to obtain the elevation of those points (Harrelson et al., 1994). The first foresight will be taken at the left bank monument. From there, take readings at all breaks in slope and especially at significant geomorphic features as you make your way across the valley (e.g., bankfull, bank top, bank toe, bar tops, edge of water, thalweg), describing each feature in the notes for the respective reading (Figure 2). Capture features such as woody debris and bank-failure deposits, and record in the notes important changes in substrate type.

Also make notes about the nature of the vegetation, especially its structure (e.g., trees, shrub, herbaceous; see Section II.B.7 for the riparian plant community structure method), and be sure to record the locations where discrete changes occur. Adequately characterizing the complexity of the cross-section will typically require a minimum of 30 to 40 rod readings. Larger floodplains and more complex geometry can require many more. Record the horizontal distances to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Cross-section elevations are also recorded to hundredths of feet.

Bear in mind that identifying a bankfull channel will be most applicable to the cross-section(s) upstream of the hydraulic influence of the impoundment that represent the un-impacted channel reach. The bankfull channel is adjusted to an approximately 1.5- to 2-year recurrence interval discharge and the prevailing sediment transport conditions (Leopold et al., 1964). Because water flow and sediment discharge conditions will, in most cases, be changing at a barrier removal site, a persistent bankfull channel likely will not be identifiable in the monitoring reach. This may also be true of the reference reach, especially in watersheds with changing land use. See Harrelson et al. (1994) for a good discussion about field identification of the bankfull channel. The USDA Forest Service Stream Systems Technology Center (2003) also produces a video specifically geared towards field identification of the bankfull channel in the eastern United States (www.stream.fs.fed.us/publications/videos.html).

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Monument at a cross-section.

Sampling Frequency

Pre-removal surveys are essential for comparison with post-removal data to assess channel and floodplain response. Pre-removal surveys may be most easily accomplished if the impoundment can be drawn down before removal (see Site Specific Considerations below), such as during project feasibility studies. In any case, for efficiency purposes, selection of the long-term monitoring cross-sections and pre-removal data collection should be integrated with any planned feasibility work. As a general guideline, post-removal re-surveys should occur annually, or every other year, for at least 5 years. However, sampling frequency and duration should reflect project objectives and site conditions. For example, sites with great amounts of loose sediment may require more frequent sampling over a longer period than sites with bedrock channels or beds dominated by coarse materials. At a minimum, the frequency should conform to any regulatory requirements. The monuments should be recoverable for much longer so that longer-term studies of channel evolution are possible.

Site-specific Considerations

Some of the pre-removal cross-sections will need to traverse the impoundment. The determination of whether cross-section data in an impoundment can be acquired by wading or using watercraft must consider the depth of the impoundment and suitability of sediment for wading. Impounded sediments may be unconsolidated, fine-grained material with saturated interstitial spaces, making them very soft and incapable of supporting a wader. In such conditions, it will be necessary to obtain the data from a boat. Depending on the nature and depth of the impoundment, surveying cross-sections within it can be accomplished either by employing the methods described in the previous section and taking rod readings at fixed intervals from a small boat, or by using a fathometer from a boat navigated along the transect and integrating the readings with the rod readings on shore via GPS positioning. If you are taking rod readings from a small boat, you will need to take care in positioning the rod and try to make sure the rod rests on top of the sediments and does not sink into soft substrate. At least two people are needed for boat work—one to work the survey rod and the other to station the boat.

Analysis and Calculations

The data from a cross-section survey are elevations and distances. Horizontal distances are recorded to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Cross-section elevations are recorded to hundredths of feet. These data should be recorded in standard level-survey notation (see Cross-Section Survey Data Sheet in Appendix E). Harrelson et al. (1994) also provide a nice graphic example of proper field book notation for level surveys. The horizontal and vertical datums of the survey must always be recorded (see Site Information Data Sheet in Appendix E). The distances and elevations can be plotted manually on graph paper as 'x' and 'y' coordinates, respectively, or brought into a spreadsheet program for plotting and analyses.

Additional Information

Harrelson et al. (1994) provide an excellent reference for basic survey techniques and for specific information on conducting cross-section and longitudinal profile re-surveys. We strongly recommend that readers with minimal experience consult this reference. It also is a useful review for those with more experience.