3. Grain Size Distribution

Purpose
This section presents methods for characterizing streambed surface grain size distributions by collecting and analyzing sediment samples at a stream channel cross-section. It identifies the equipment needed, outlines the basic protocol, discusses the sampling frequency, and presents site-specific considerations.

Monitoring Design
As with any sampling effort, surface sediment sampling aims to characterize a larger population of bed materials for which a complete census is impractical. To do so, a sample must be random, comprise enough grains for an adequate sample size, and be drawn from a homogenous streambed area. For streams with beds dominated by sand size sediments and finer, it is relatively easy to obtain a large enough sample that can be analyzed in the lab. There, sandy sediments are dried and passed through progressively finer sieves and the weights of materials retained on sieves of particular size classes are recorded. Finer fractions must be separated by sedimentation (e.g., hydrometer or pipette), elutriation, or centrifuge separation (Kondolf et al., 2003). With the weights obtained of the various size fractions, the grain size distribution is then presented as cumulative percent finer by weight.

For gravel-bed streams, however, the requisite sample sizes are too large to be transported off-site and are impractical to sieve in the field. To address this problem, geomorphologists have developed field-sampling techniques that require no lab analyses. The most enduring protocol was developed by Wolman (1954) and is referred to as a Wolman Pebble Count. Put simply, this method prescribes randomly collecting and measuring at least 100 particles from a homogeneous area of the streambed. From these data, a grain size distribution is developed as the cumulative frequency of numbers of stones of different size classes. If the sampled stones are of the same density, which will be true if sampling one lithology, the results obtained will be comparable to a distribution by weight (Kondolf et al., 2003). [If the bed of your cross-section is composed of heterogeneous composition of bed material sizes, or facies (determined by eye), the sample can be improved by collecting 100 particles from each facies and calculating a weighted average grain size distribution with estimated proportions of the bed occupied by each facies. See Kondolf et al. (2003) for a more complete treatment of how to handle a cross-section with mixed populations of bed materials.]

Minimum Equipment
- ❑ Measuring tape in same units as rod (300 ft or 100 m)
- ❑ Ruler marked in millimeters
- ❑ Gravel template (optional)
- ❑ Field book with waterproof paper
- ❑ Pencil
- ❑ Chaining pins
- ❑ Data sheets (see Appendix E)

There are differing standards in the literature regarding the proper sample size for Wolman Pebble Counts, sources of error in conducting them, and ways to improve sampling technique to reduce those errors (see Brush, 1961; Hey and Thorne, 1983; and Fripp and Diplas, 1993 for more discussion). We do not present varying standards here but have adopted some recent modifications to the Wolman Pebble Count that are designed to address observed deficiencies. We also prescribe collecting a minimum of 100 particles, recognizing that collecting larger sample sizes—up to 300 or 400—could improve results (Olsen et al., 2005, Rice and Church, 1996). Within the context of this Monitoring Guide, we do not feel the precision gained merits the extra effort required, although we do encourage collecting a larger sample size if project resources permit.

Sampling Protocol
Because the bed sediment characteristics of a given barrier removal stream reach are not typically known beforehand, nor is the variability between cross-sections, the following protocols address sampling of beds dominated by 1) sand-size and finer sediments or 2) gravel. Note that both methods may be relevant to a given project, particularly for pre-project monitoring of proposed dam removal sites (see Site-specific Considerations below).

At a minimum, collect a bed material sample for at least one of each cross-section type representing physically distinct stream reaches in the monitoring reach and at cross-sections where important infrastructure or habitat zones are located. In all likelihood, this means you will collect bed material samples for only a subset of the cross-sections you re-survey.

At all sampled cross-sections, samples should be collected from within the normal low flow channel unless particular study objectives require characterizing the bed of the larger bankfull channel. In these situations, sample between the toe of bank on each side of the stream (some of which may be dry at sampling time).

Cross-sections Dominated by Fine Sediments (Sand Size and Finer)
At these cross-sections, each sample point should be composed of approximately one liter of surface sediments for laboratory evaluations (i.e., a bulk sample). On exposed beds or bars samples can be obtained with a trowel or shovel. A variety of bed material samplers (e.g., grab samplers) can be used for sample acquisition under water. The number and location of samples required to characterize the cross-section will depend on how heterogeneous the bed material is in that stream reach (Kondolf et al., 2003). If multiple samples are required to characterize a heterogeneous cross-section, compositing those samples for laboratory analyses may be appropriate.

Cross-sections Dominated by Gravel
1. Perform a pebble count at each selected cross-section after a cross-section survey is performed to make use of the tape already stretched across the channel.

2. Assign a sampler to collect and measure the particles and a reader to record the results. The sampler calls out the measurements to the reader. The reader repeats back each measurement as a quality control check.

3. The sampler will walk back and forth along the transect, and perhaps 2 to 4 others closely paralleling the transect, reaching down at regular intervals to pick up a particle near the tip of their boot. The intervals should be scaled to the length of the transect(s) such that 100 particles will be collected. For example, if the transect length is 10 meters and the sampler's stride is a half meter, approximately 20 samples will be collected with each bank-to-bank sampling pass, and at least 5 passes will be required to obtain a minimum of 100 samples.

4. As the sampler's finger falls to the bed to pick up the particle, the sampler should not look at the stream bottom to avoid bias toward selecting larger particles. The sampler should pick up the first particle encountered. Do not count organics such as wood fragments or other detritus. If the sampler touches fine material that is clearly less that 4 mm, the sampler should simply call out "fines" to the reader who will record the occurrence in the < 4 mm size class (see Table 3 in Analysis and Calculations below). For larger particles, the sampler measures the particle's "b-axis" in millimeters (mm) and calls out the measurement to the reader.

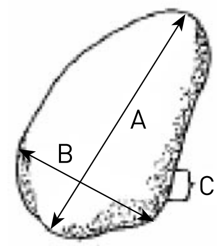

Figure 4. Particle axes (from Potyondy and Bunte, 2002).
A = Longest axis (length)
B = Intermediate axis (width)
C = Shortest axis (thickness)

The b-axis can be identified by first finding the long axis (A), then the short axis (C), and finally the intermediate axis (B) that is perpendicular to both the A and C axes (see Figure 4). The b-axis is the axis that governs whether a particle will fit through a sieve mesh of a given size, so measuring it gives results most comparable to a standard sieve test. The particle can also be measured using a particle size template or "gravelometer" (Potyondy and Bunte, 2002). Doing so can reduce observer error in measuring the b-axis. Whichever measurement method is employed, either ruler or gravel template, be sure to consistently use that method from year to year throughout the monitoring period so that results are directly comparable.

5. Repeat this procedure until at least 100 particles have been collected.

Sampling Frequency
Sampling should be conducted at the same frequency as the cross-section surveys (see Section IV.B.1) and performed during wading-depth stream conditions.

Site-specific Considerations
For dam removal sites, bed material samples should be collected from at least two cross-sections in the impoundment: one representing the upper impoundment and another representing the lower impoundment. Impounded sediments will frequently be sand-size and finer deposits that need to be collected as bulk samples from a boat with a grab sampler or other similar device (see above). As with other cross-section sampling locations, the number and location of samples at a cross-section will depend on the heterogeneity of the bed material there. If the general location of the post-removal channel is also known, this information should influence the choice of sampling locations.

For many dam removal projects, feasibility studies will include contaminant sampling of sediments in the impounded area. For efficiency purposes, the long-term bed sediment monitoring program should be coordinated with any such investigations so that some of the contaminant sampling locations are coincident with at least one long-term monitoring transect and to ensure that the samples are analyzed in the laboratory for grain size.

Analysis and Calculations

The data from a pebble count are simply counts of particles in different size classes. For example, a particle with a b-axis measuring 100 mm will be recorded in the row marked “<128” on Table 3 and a particle measuring 65 mm will be marked in the “<90” row. In the office, hash marks can be tallied and the percent frequency and cumulative percent finer can be calculated with a spreadsheet program. The cumulative percent finer can be plotted as shown in Figure 5. The results of fine sediment bulk samples sent to the lab should be reported in a similar manner.

Additional Information

Kondolf and others (2003) provide a good overview of bed sediment sampling in general. Bunte and Abt (2001) and Kondolf (1997) should be reviewed for a more thorough treatment of sampling coarse-grained bed sediments.

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Bed sediments downstream of a dam in New Hampshire.

Table 3. Example spreadsheet developed from field notes. Note that the first and second columns are the only columns needed in the field book. Note also that recording counts as hashes in the second column builds a histogram in the field.

Size Class (mm)	Count	Count	Frequency (%)	Cumulative % Finer
>=256	𝍸 ||	7	7	100
<256	𝍸 𝍸 |	11	11	93
<180	𝍸 𝍸 𝍸 |	16	16	82
<128	𝍸 𝍸 𝍸	15	15	66
<90	𝍸 𝍸	10	10	51
<64	𝍸 𝍸 |	11	11	41
<45	𝍸 |||	8	8	30
<32	𝍸 ||	7	7	22
<22.6	||	2	2	15
<16	|||	3	3	13
<11.3	||	2	2	10
<8	|	1	1	8
<5.6		0	0	7
<4	𝍸 ||	7	7	7
	Totals:	100	100	

Figure 5. Cumulative frequency curve generated from pebble counts.