

**U.S. Geological Survey
Techniques of Water-Resources Investigations**

**Book 9
Handbooks for Water-Resources Investigations**

National Field Manual for the Collection of Water-Quality Data



Chapter A4. COLLECTION OF WATER SAMPLES

Revised 2006



U.S. DEPARTMENT OF THE INTERIOR
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Foreword

The mission of the Water Resources Discipline of the U.S. Geological Survey (USGS) is to provide the information and understanding needed for wise management of the Nation's water resources. Inherent in this mission is the responsibility to collect data that accurately describe the physical, chemical, and biological attributes of water systems. These data are used for environmental and resource assessments by the USGS, other government agencies and scientific organizations, and the general public. Reliable and quality-assured data are essential to the credibility and impartiality of the water-resources appraisals carried out by the USGS.

The development and use of a *National Field Manual* is necessary to achieve consistency in the scientific methods and procedures used, to document those methods and procedures, and to maintain technical expertise. USGS field personnel use this manual to ensure that the data collected are of the quality required to fulfill our mission.

Robert M. Hirsch
Associate Director for Water

To field rinse the cone splitter:

1. Put on gloves.
2. Uncover the splitter reservoir and pour or pump 2 to 4 L of rinse water into the cone-splitter reservoir, one liter at a time.
3. Lightly tap the splitter to dislodge adhering water drops. Discard rinse water.
4. Cover the splitter.

Isokinetic, Depth-Integrated Sampling 4.1.3.A

Methods at Flowing-Water Sites

Collection of isokinetic, depth-integrated samples involves using either an equal-width-increment (EWI) or equal-discharge-increment (EDI) sampling method. The EWI or EDI methods usually result in a composite sample that represents the discharge-weighted concentrations of the stream cross section being sampled.

The EWI and EDI methods are used to divide a selected cross section of a stream into increments having a specified width. The term vertical refers to that location within the increment at which the sampler is lowered and raised through the water column.

- ▶ EWI verticals are located at the midpoint of each width increment.
- ▶ EDI verticals are located at the centroid, a point within each increment at which stream discharge is equal on either side of the vertical.

If properly implemented, EDI and EWI methods should yield identical results. The uses and advantages of each method are summarized below and in table 4-5. Isokinetic samplers usually are used to obtain a discharge-weighted sample along the stream cross section. **When using an isokinetic sampler there should be no change in velocity (speed and direction) as the sample enters the intake (fig. 4-3).**

Table 4-5. Uses and advantages of equal-width-increment (EWI) and equal-discharge-increment (EDI) sampling methods

EWI method	Advantages of the EWI method
EWI is used when information required to determine locations of sampling verticals for the EDI method is not available, and (or) the stream cross section has relatively uniform depth and velocity. Use EWI whenever: • The location of EDI sampling verticals changes at the same discharge from one sampling time to another. This situation occurs frequently in streams with sand channels.	• EWI method is easily learned and implemented for sampling small streams. • Generally, less time is required onsite if the EWI method can be used and the information required to determine locations of sampling verticals for the EDI method is not available.
EDI method	Advantages of the EDI method
EDI is used when information required to determine locations of sampling verticals for the EDI method is available. Use EDI whenever: • Small, nonhomogeneous increments need to be sampled separately from the rest of the cross section. The samples from those verticals can be analyzed separately or appropriately composited with the rest of the cross-sectional sample. (Have the sampling scheme approved.) or • Flow velocities are less than the isokinetic transit-rate range requirement. A discharge-weighted sample can be obtained, but the sample will not always be isokinetic. or • The EWI sampling method cannot be used. For example, isokinetic samples cannot be collected because stream velocities and depths vary so much that the isokinetic requirements of the sampler are not met at several sampling verticals. or • Stage is changing rapidly. (EDI requires less sampling time than EWI, provided the locations of the sampling verticals can be determined quickly.)	• Fewer increments are necessary, resulting in a shortened sampling time (provided the locations of sampling verticals can be determined quickly and constituents are adequately mixed in the increment). • Sampling during rapidly changing stages is facilitated by the shorter sampling time. • Subsamples making up a sample set may be analyzed separately or may be proportionally composited with the rest of the cross-sectional sample. • The cross-sectional variation in constituent discharge can be determined if subsample bottles are analyzed individually. • A greater range in velocity and depths can be sampled isokinetically at a cross section. • The total composite volume of the sample is known and can be adjusted before sampling begins.

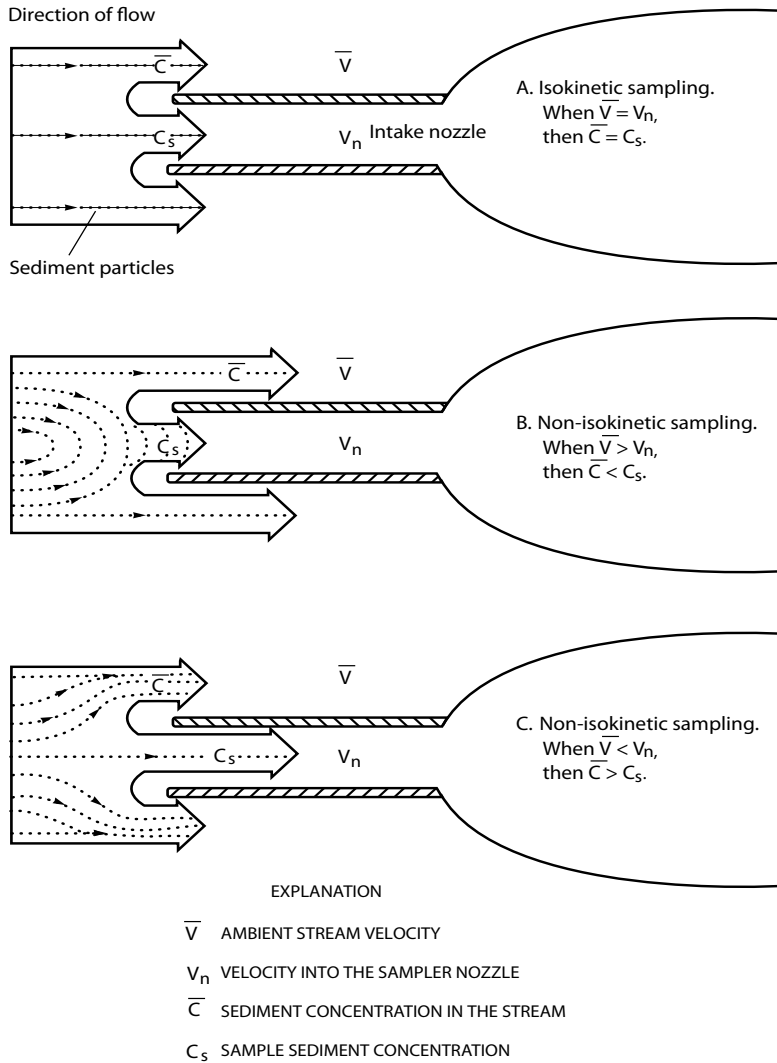


Figure 4-3. Relation between intake velocity and sediment concentration for isokinetic and nonisokinetic collection of water samples that contain particulates greater than 0.062 millimeters (modified from Edwards and Glysson, 1999, p. 14).

- ▶ Collect isokinetic, depth-integrated samples by using a standard depth- and width-integrating method if analysis of a representative sample from a cross section of flowing water is required for discharge computations. Appendix A4-A and Edwards and Glysson (1999, figures 39-43), provide detailed information about isokinetic, depth-integrating transit rates for collecting samples.
- ▶ For isokinetic sampling, the mean velocity of the vertical that is sampled must exceed the minimum-velocity requirement of an isokinetic sampler—the minimum velocity requirements are 1.5 ft/s for a bottle sampler, 2 ft/s for a 1- or 3-liter bag sampler, or 3 ft/s for a 6-liter bag sampler (Appendix A4-A).
 - The transit rate (the rate at which the sampler is lowered or raised) used to collect an isokinetic, depth-integrated sample is mainly a function of the nozzle diameter of the sampler, volume of the sampler container, stream velocity, and sampling depth (Appendix A4-A). The maximum allowable transit rate for a bag sampler is 0.4 multiplied by the mean stream velocity.
 - An error in concentrations of suspended particulates coarser than 62 μm can be important when the velocity of the sample entering the nozzle and the stream velocity differ significantly. Too fast a transit rate will cause a sampler to undersample sand-sized particulates (Edwards and Glysson, 1999).
 - The transit rate must be kept constant during sampler descent through a vertical and also during sampler ascent through a vertical.

The number of increments needed in order to get a discharge-weighted sample at a site is related primarily to data objectives (for example, the accuracy needed) and how well-mixed or heterogeneous the stream is with respect to the physical, chemical, and biological characteristics of the cross section. The recommended number of increments for EWI and EDI methods are discussed in the sections to follow. Edwards and Glysson (1999) describe a statistical approach for selecting the number of increments to be used, based on sampling error and suspended-sediment characteristics.

Selecting the number of increments

- ▶ Examine the variation in field-measurement values (such as specific electrical conductance, pH, temperature, and dissolved oxygen) along the cross section (NFM 6).
- ▶ Consider the distribution of streamflow (discharge), suspended-materials concentration and particle-size distribution, and concentrations of other targeted analytes along the cross section. Consider whether the streamflow distribution or analyte concentrations will change during sample collection.
- ▶ Consider the type of sampler that will be used and the volume of sample that will have to be collected for the analysis of the target analytes.
- ▶ Avoid side-channel eddies. EDI and EWI methods cannot be used at locations with upstream eddy flow.

 **RULE OF THUMB:** For isokinetic, depth-integrating sampling, do not exceed the designated maximum transit rate.

Equal-width-increment (EWI) method

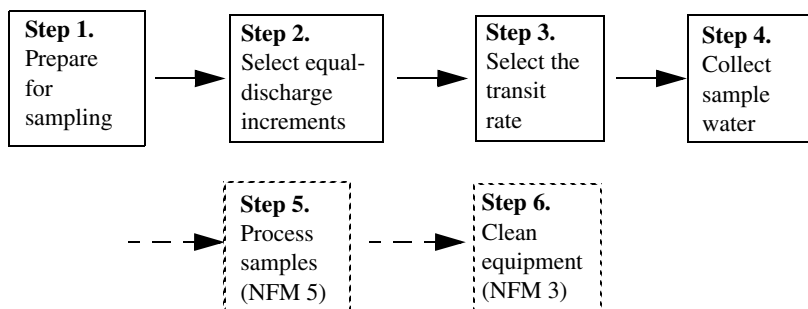
For the EWI sampling method, the stream cross section is divided into a number of equal-width increments (fig. 4-4). Samples are collected by lowering and raising a sampler through the water column at the center of each increment. (This sampling location is referred to as the vertical.) The combination of the same constant transit rate used to sample at each vertical and the isokinetic property of the sampler results in a discharge-weighted sample that is proportional to total streamflow.

- ▶ **Isokinetic sampling is required for the EWI method.** Use isokinetic, depth-integrating sampling equipment (NFM 2.1.1.A).
 - **Use the same size sampler container (bottle or bag) and nozzle** at each of the sampling verticals (fig. 4-4).
 - **Collect samples using the same transit rate** at each vertical during descent and ascent of the sampler. The transit rate must be constant and within the operational range of the sampler (Appendix A4-A).
- ▶ Composite the subsamples from all verticals in a churn splitter or process subsamples through the cone splitter (NFM 2.2.1 and NFM 5.1.1).

Equal-discharge-increment (EDI) method

The objective of the EDI method is to collect a discharge-weighted sample that represents the entire flow passing through the cross section by obtaining a series of samples, each representing equal volumes of stream discharge. The EDI method requires that flow in the cross section be divided into increments of equal discharge. Equal-volume, depth-integrated samples are collected at the centroid of each of the equal-discharge increments along the cross section (fig. 4-5). Centroid is defined as that point in the increment at which discharge is equal on both sides of the point.

Steps for the EDI sampling method



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies.

Example: Sampler D95; nozzle size 3/16 inches ID (inside diameter); 1-liter sampler bottle; width, 57 feet; maximum depth, 12 feet; maximum velocity, 6.1 feet per second (ft/s); width of section containing 20 percent of flow is variable, 5 to 22 feet; 20 percent of flow per section will give 5 sampling verticals; transit rate variable, 0.2 to 0.8 ft/s.

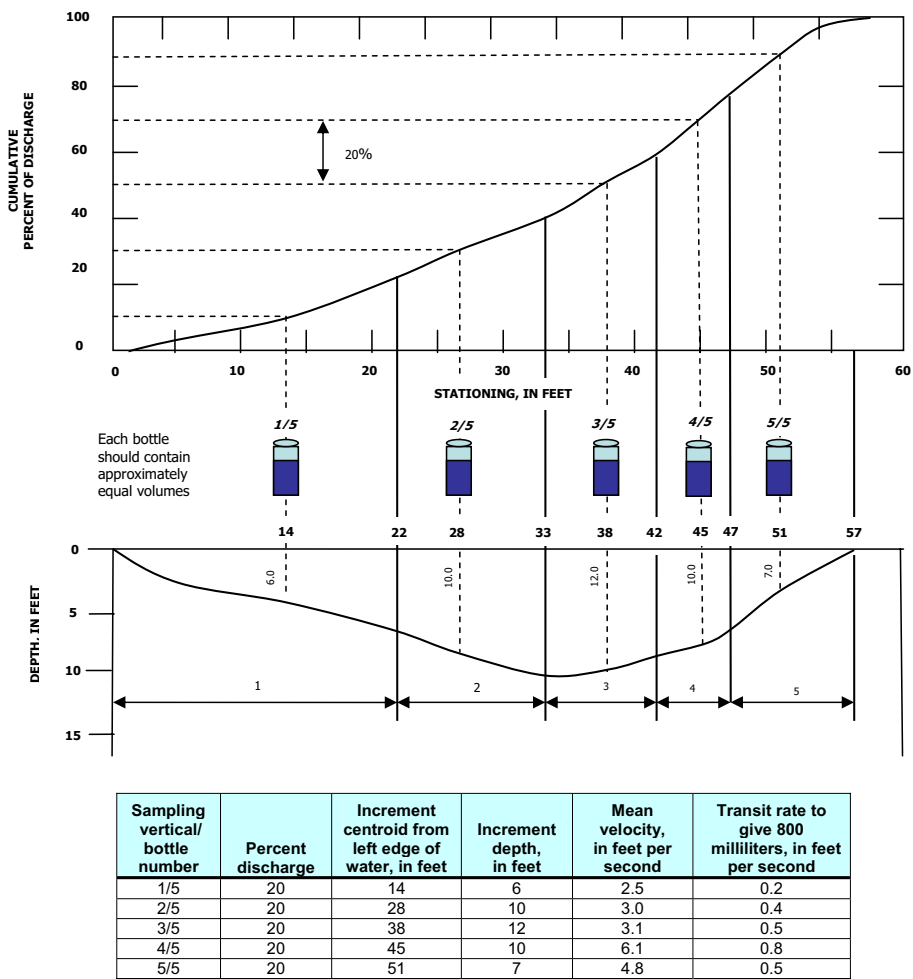


Figure 4-5. Equal-discharge-increment method for collection of water samples (modified from Bruce Ringen, U.S. Geological Survey, written commun., 1978).

Step 1. Prepare for sampling for inorganic and organic analytes.⁸

- a. Upon arrival at the field site, set out safety equipment such as traffic cones and signs. Park vehicle in a location and direction so as to prevent sample contamination from vehicle emissions.
- b. Assemble equipment needed and set up a clean work space.
 - **Organic compounds.** Select equipment with fluorocarbon polymer, glass, or metal components if components will directly contact samples to be analyzed for organic compounds. **Do not use plastics other than fluorocarbon polymers.**
 - **Inorganic constituents.** Select equipment with components made of fluorocarbon polymer or other relatively inert and uncolored plastics or glass if components will directly contact samples to be analyzed for inorganic constituents. **Do not use metal or rubber components for trace-element sampling.**
 - **Microbiological analyses.** Collect samples for microbiological analyses using equipment and techniques described in NFM 7.

Step 2. Select the number and location of equal-discharge increments.

The number and location of equal-discharge increments should not be determined arbitrarily. Selection of increments for a sampling site is governed by factors described in a, d, and e below.

- a. Visually inspect the stream from bank to bank, observing velocity, width, and depth distribution, as well as apparent distribution of sediment and aquatic biota along the cross section. Document location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other obstructions along the cross section.
- b. Determine stream width from atagline or from distance markings on bridge railings or on a cableway.

⁸Preparations for water sampling are described in NFM 2 and 3. Consult NFM 5 for sample processing, NFM 6 for field measurements, NFM 7 for biological indicators, NFM 8 for bottom-material sampling, and NFM 9 for field safety.

- c. At sites with little sampling history—measure, record, and review the cross-sectional variation of field measurements (for example, specific electrical conductance, pH, temperature, and dissolved oxygen).
- d. Measure discharge at the cross section to be sampled or use an existing EDI graph prepared from current or historical discharge measurements (fig. 4-5) (Edwards and Glysson, 1999). An existing EDI graph can be one prepared for the site that shows, for example, cumulative discharge or cumulative percent of discharge versus stationing.
- e. Determine volume of discharge that will be represented in each EDI, based on data objectives for the study, variation in field measurements, flow and stream-channel characteristics along the cross section, and volume of sample required for analyses of target analytes.
- f. Divide the cross section into equal-discharge increments.
 - When determining the number of increments to be sampled, keep in mind that the subsample collected at the centroid of each EDI must represent the mean streamflow measured for that increment. If mean streamflow for the increment is not represented, increase the number of increments by decreasing the volume represented by each discharge increment until the mean streamflow value for the increment is represented.
 - As a guide, a minimum of 4 sampling increments is recommended; the number of increments is usually less than 10.
- g. Determine the location of the centroid of flow within each increment from the discharge measurement by (1) constructing a curve using cumulative discharge or cumulative percentage of discharge (fig. 4-5) plotted against cross-section stationing, or (2) determining EDI locations directly from the discharge measurement sheet (fig. 4-6; an explanation of this method and definition of midpoint are described in Edwards and Glysson, 1999). Centroid-of-flow locations also can be determined from an EDI graph, as described below and in the TECHNICAL NOTE that follows the example below.

Station: 11482500 Redwood Creek at Orick, CA

Far-Mid Point	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity		Adjusted for hor. angle or	Area	Discharge	
							At point	Mean in vertical			Q	ΣQ
	0	4	0	.6	LEW		0			0	0	0
4	8	8	1.00		30	47	1.41			8.0	11.3	11.3
12	16	8	1.80		30	44	1.51			14.4	21.7	33.0
20	26	8	2.00		50	44	2.50			16.0	40.0	73.0
28	32	8	2.00		60	45	2.92			16.0	46.7	119.7
36	40	8	2.30		50	48	2.29			18.4	42.1	161.8
44	50	48	8	2.25	40	44	2.00			18.0	36.0	197.8
52	56	8	2.25		40	40	2.20			18.0	39.6	237.4
60	64	8	2.30		40	40	2.20			18.4	40.5	277.9
68	74	72	8	2.30	50	45	2.44			18.4	44.9	322.8
76	80	8	2.20		40	45	1.96			17.6	34.5	357.3
84	88	8	2.00		40	43	2.05			16.0	32.8	390.1
92	96	8	1.90		50	47	2.34			15.2	35.6	425.7
100	102	104	8	2.00	40	42	2.10			16.0	33.6	459.3
108	112	8	2.00		40	40	2.20			16.0	35.2	494.5
116	120	8	1.90		30	43	1.54			15.2	23.4	517.9
124	128	8	1.80		40	40	2.20			14.4	31.7	549.6
132	134	136	8	1.70	50	44	2.50			13.6	34.0	583.6
140	144	8	1.60		50	44	2.50			12.8	32.0	615.6
148	152	8	1.00		20	54	.827			8.0	6.6	622.2
156	160	4	0	.6	REW		0			0	0	622.2
160	160	160								290.4	622.2	
EDI Centroid Location											EDI Cumulative Discharge	

Figure 4-6. Example of discharge-measurement field notes used to determine the equal-discharge-increment centroid locations based on cumulative discharge and far-midpoint stationing (from Edwards and Glysson, 1999, p. 45).

Example:

In this example, each EDI equals 20 percent of discharge.

- i. If the stream cross section will be divided into five equal-discharge increments, divide stream discharge by five to determine the discharge increment.
- ii. Locate the centroid of the initial EDI where cumulative discharge equals half the discharge increment (10 percent). This is the location of the vertical from which the first subsample is collected.
- iii. Locate each of the remaining centroids (four in this example) by adding the discharge increment (20 percent) to the previous centroid discharge ($20 + 10 = 30$) and determining where that cumulative discharge occurs along the cross section.
- iv. The EDI centroids will correspond to locations of 10, 30, 50, 70, and 90 percent of the cumulative discharge along the cross section. In figure 4-5, these percentages of cumulative discharges correspond to locations at 14, 28, 38, 45, and 51 ft from the left edge of the water, whereas in figure 4-6, the centroid locations of the equal-discharge increments are at 26, 50, 74, 102, and 134 ft.

TECHNICAL NOTE: If the stream channel is stable at the cross section to be sampled, graphs of cumulative discharge or percentage cumulative discharge at various stages can be based on historical discharge measurements. Location of EDI centroids can be determined from these EDI graphs so that discharge measurements do not have to be made before each sampling. Linear interpolation based on discharge can be made between curves for different discharges on the EDI graphs. **EDI graphs require periodic verification by being compared to recent discharge measurements.**

Step 3. Select the transit rate.

- a. Determine the sampling depth and the mean stream velocity at the centroid of each equal-discharge increment.
- b. Determine the transit rate for each centroid that will yield subsamples with approximately the same volume (within 10 percent) using sampling depth, mean stream velocity, and information in Appendix A4-A. When compositing subsamples, the minimum volume for every equal-discharge increment is the minimum volume for the deepest vertical.

Guidelines for selecting the transit rate for EDI sampling

- Collect samples of equal volumes at each centroid. This is required for EDI if the sample will be composited (fig. 4-5). Generally, transit rates vary from centroid to centroid in order to collect equal volumes.
- Keep the transit rate unidirectional, constant, and within the isokinetic transit range of the sampler when collecting isokinetic samples at each centroid.
- **Do not exceed the maximum transit rate** (Appendix A4-A). The maximum transit rate will be exceeded if the minimum sample volume associated with stream velocity and the selected nozzle and bottle size is not collected. Exceeding the maximum transit rate will affect the concentration of particulates ≥ 0.062 millimeters.

Step 4. Collect sample water.

The procedures are the same whether you are wading or using a reel-and-cable suspension method. **Use CH/DH techniques, as required (section 4.0.2), and implement safety procedures (NFM 9).**

- ▶ Collect microbiological samples using equipment and techniques as described in NFM 7.
- ▶ Collect subsamples at EDI centroids as many times as necessary to ensure collection of sufficient sample volume for analysis. If the sample is to be composited, care must be taken to obtain approximately the same total volume (± 10 percent) from each EDI centroid so that the composited cross-sectional sample will be proportional to flow at the time of sampling.
- ▶ Stay within the isokinetic transit-rate range of the sampler at each centroid. If flow velocity is less than the isokinetic transit-rate range of the sampler, a discharge-weighted sample still can be obtained by collecting equal volumes at each centroid; however, this sample will not be isokinetic.
 - a. Move sampling and support equipment to the centroid of the first increment to be sampled. Field rinse the sampling equipment (section 4.1.3). Collect the rinse water at the edge of the stream in a section of low stream velocity, to minimize including suspended sediment.
 - b. Read and record the starting gage height. Record sampling start time.

- c. Lower the sampler at the predetermined transit rate until slight contact is made with the streambed.
 - **Do not pause upon contacting the streambed.** Raise the sampler immediately at a constant transit rate to complete the vertical traverse. The descending transit rate does not have to equal the ascending transit rate, but each rate must be unidirectional, constant, and within the isokinetic transit range of the sampler.
 - Take care not to disturb the streambed with the sampler. Disturbing the streambed could cause bed material to enter the nozzle, resulting in erroneous data.
 - Ensure that the sampler container has not overfilled. Overfilling will result in enrichment of the sample with heavy particulates due to secondary circulation of water through the sampler (from nozzle through air exhaust). This enrichment will result in an artificially increased sediment concentration and will bias particle-size distribution towards heavier and larger particulates.
- d. Inspect each subsample, looking for overfilling and (or) the presence of anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. If you note either or both of these conditions, discard the sample, making sure there are no residual particulates left in the container, and resample.
- e. Ensure that the sampler container is not underfilled (that the minimum volume indicated in Appendix A4-A has been collected). Underfilling will result in a subsample that is not isokinetically collected—usually because the maximum transit rate has been exceeded.
- f. Depending on study objectives, either process and (or) analyze the subsample collected at the initial centroid as a separate sample, composite this subsample with other subsamples collected along the cross section, or split the subsample for further processing.
 - If the total volume of the subsamples that will be collected will exceed the operational capacity of the churn or cone splitter, decrease the number of increments or use a smaller nozzle.
 - Ensure that all particulates in the sampler bottle or bag are transferred with the sample by swirling the sample gently to keep particulates suspended, and quickly pouring the sample into the churn or cone splitter.

- g. Move equipment to the next vertical.
- Determine the transit rate for this vertical. If the subsamples are composited, the total volume collected at each centroid must be equal.
 - Repeat procedures, steps 4 c-f.
 - Repeat this process at the remaining verticals along the cross section.
- h. Record the following information after all samples have been collected:
- Sampling end time.
 - Ending gage height.
 - All field observations and any deviations from standard sampling procedures.

Step 5. Process samples → Refer to NFM 5.

Step 6. Clean equipment → Refer to NFM 3.

- If the sampler will not be reused during a field trip, rinse the components with deionized water before they dry and place them into a plastic bag for transport to the office laboratory to be cleaned.
- If the sampler will be reused during the field trip, rinse the components with deionized water while still wet from sampling, and then follow the prescribed cleaning procedures while at the sampling site (NFM 3). Reassemble the sampler.
- Collect a field blank, if required, after sampling equipment has been cleaned at the sampling site.
- Place cleaned sampler into a plastic bag and seal for transport to the next site.

Single vertical at centroid-of-flow (VCF) method

Samples may be collected at a single vertical at the centroid of streamflow if the section is known to be well mixed laterally and vertically with respect to concentrations of target analytes.

The VCF method for collecting water samples is identical to the EDI method except that there is one centroid of flow for the stream cross section and therefore only one vertical is sampled.