APPENDIX B

PROTOCOLS FOR FIELD SURVEYS AT GAGE STATIONS

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I. INTRODUCTION

The U.S. Fish and Wildlife Service (Service) and Maryland State Highway Administration (SHA) entered into a cooperative agreement to develop regional curves showing bankfull dimensions versus drainage areas for physiographic provinces in Maryland. The short-term goal of the agreement was to develop appropriate relationships of stream characteristics on a statewide basis. The long term goal is to provide the SHA with the information needed to develop improved hydraulic designs of culverts and small bridges which will minimize disturbances to stream channels and their associated flood plains and wetlands.

This document is the procedural protocol to conduct the field data collection. It is divided into two main sections: 1) reconnaissance survey and 2) full field survey. The purpose of the reconnaissance survey is to evaluate and select gage stations for the full field survey. The purpose of the full field survey is to collect all the field data necessary to develop the regional curves and classify the channel using the Rosgen Stream Classification System. Sample field data sheets for all data are provided in Section VI. Field Data Sheets.

II. METHODOLOGY

The methods and procedures presented within this protocol are drawn from several sources, including:

- Annable, W. K., 1994. Morphologic relationships of rural water courses in Southwestern Ontario and selected field methods in fluvial geomorphology. Credit Valley Conservation Authority, Meadowvale, Ontario, Canada.
- Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO; U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.
- Leopold, L. B. 1994. A view of the river. Harvard University Press, Cambridge, Massachusetts.
- Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.

III. RECONNAISSANCE SURVEY

A. Acquisition of Gage Data

1. Identify the available gage stations on streams with at least ten years of record and unregulated flow in the geographic area of interest. Locations, identifying names, and gage numbers can be found in the U.S. Geological Survey Water-Data Reports published for each state.
2. Contact the central state office of the Geological Survey and, for each gaging station of interest, request copies of the following:
   - Gage Description and Station Analysis (including any maps and sketches),
   - Form 9-207 (the record of discharge measurements),
   - current or most recent Rating Table,
   - log-Pearson Type III Flood Frequency Distribution (for the annual maximum series),
   - peak discharges above base, and
   - the most recent Level Notes.

B. Preliminary Analyses

1. Review Gage Description, Station Analysis, and Level Notes for each station. Gage descriptions should provide bench mark, reference marks, or reference point information in gage datum (if not, contact USGS for relevant datums). Note any unusual information regarding the channel (channelization, stage for weir control, discharge augmentations, etc.).
2. The Gage Description should contain directions to the gage. If not, plot the location of each gage from the latitude and longitude given in the published record, or otherwise determine the location.
3. For each gaging station, plot the Log-Pearson Type III (WRC) flood frequency distribution on log-log paper from the plotting positions provided by the USGS. If the USGS provides exceedence probabilities, convert these to return intervals by calculating the reciprocal. Also, plot the 95% confidence interval for the WRC estimates.
4. Determine the land-use characteristics of the drainage basins for selected gage sites using the MD-SHA’s GIS HYDRO program (or if unavailable, use aerial photos). GIS HYDRO is a geographic information system structured for hydrologic analysis that allows users to quickly assemble land use, soil, and slope data for watersheds and then run the SCS-TR-20 hydrologic model for existing and proposed watershed conditions. SHA staff delineate the study watersheds on 7.5 minute USGS topographic maps, and use the GIS HYDRO program to determine the proportion of each basin represented by the characteristics listed below:

- Urban
  * Low density residential
  * Medium density residential
  * High density residential
  * Commercial
  * Industrial
  * Institutional
  * Extractive
  * Open urban
- Agriculture
  * Cropland
  * Pasture
  * Orchards
  * Feeding operations
  * Row crop
- Forest
  * Deciduous
  * Evergreen
  * Mixed
  * Brush
- Open water
- Wetlands
- Barren land
  * Beaches
  * Exposed rock
  * Bare ground

Based on these characteristics, SHA provides an estimate of the percent imperviousness for each watershed, and produce peak run-off estimates (2, 5, 10, 25, 50, and 100 year recurrence intervals) for existing conditions using TR-20 modeling capabilities and USGS regression equations contained in the GIS Hydro program.

C. Initial Gage Reconnaissance

1. The equipment list includes:
   - laser level, laser receiver, and rod,
   - 100 meter or 300-foot tape,
   - colored plastic ribbon and wire flags,
   - field data sheets and pencils,
   - topographic quadrangle maps and aerial photography (if available)of the area,
   - bank pins and cam line,
   - gage description, station analysis, level notes, and plotted data for each gage.
2. Minimum criteria for gage station inclusion:
   - Intact staff plate or recoverable benchmarks referenced to gage datum.
   - Condition and function of the artificial control not affecting medium and high stages.
   - Unarmored channel capable of adjusting to the flow regime. Natural bedrock vertical and horizontal controls are acceptable.
   - Sufficient length (10 – 20 bankfull widths) of channel for a longitudinal profile survey through the gage location.
   - Ten years of record from gage.
3. At the gage site, locate and verify reference marks described in the gage station description. The Level Notes provided by the USGS record the most recent surveyed

gage datum elevation for the reference points, and often contain more precise information on the location of the references.

4. Use the gage key (if available from USGS) to open the gage house or gage box, and read the water surface elevation in gage datum on the water level recorder. Also read and record the gage-datum water-surface elevation on the outside staff gage, and time of reading.
5. Identify a study reach upstream and/or downstream of the gage site. If the stream channel in the vicinity of the gage has been altered appreciably, it may be necessary to extend the survey to include a sufficient length for the study reach The selection of a study reach should consider but not be limited to the following (after Leopold, 1994):
   - The stream should reside within a homogeneous large-scale geologic unit. That is, within the study reach the geology, which influences the channel, should be consistent. For example, a stream meandering in a compacted till would be a homogeneous geologic reach whereas a river passing from a compacted silty till to an outwash sand plain has more than one dominant geologic unit which should be avoided.
   - The topographic relief longitudinal and orthogonal to the channel should remain generally consistent throughout the study reach.
   - The same channel morphology (Rosgen Classification stream type) should be present through the entire study reach.
   - Regions with hydraulic controls such as waterfalls, weirs, bridges, culverts, check dams etc. should be avoided as part of the study reach. Possible exceptions to this criterion might include structures over deeply entrenched (Rosgen Classification A- or F-type) streams where the structure completely spans the channel bed and its banks.
   - Bank and valley vegetation should remain consistent throughout the study reach.
   - The channel length should be no less than two full meander wave lengths (four riffles and four pools) for alluvial type channels and seven to eight successive step-pool series for step pool channels. This equates to a channel length that is approximately 20 times the bankfull width. Exceptions made be made where gage stations are limited and the stream type changes over less than 20 bankfull widths (but should be at least ten bankfull widths).
   - The reach should begin and end on the same type of morphologic feature, i. e., if the reach begins at the top of a riffle, it should end at the top of a riffle.

     Avoid sites with evident impacts (active lateral adjustment, downcutting or aggrading, channelized streams) and fully document any factors on or near the site that influence stream character. It will often be necessary to locate the study reach at some distance from the gage, to minimize the effects of road crossings or other artificial hydraulic features. At the same time, the study reach must be close enough to the gage that significant increases in bankfull discharge are not introduced. Typically, study reaches should be within 20 - 40 widths of the gage. In no case should there be a major tributary confluence between the gage and the study reach. Small tributaries may be present within the reach if the basic parameters of cross-sectional area, bed and bank material composition, and slope do not change upstream or downstream of the confluence.

6. Preliminary Bankfull Calibration
   - Walk the gage and study reaches, and flag several bankfull indicators (consult Section V for guidance on identifying bankfull indicators).
   - Measure the vertical distance between the indicator and water surface. A consistent set of indicators with the same or nearly the same distance above water surface should be apparent. In some locations a lower and upper set of indicators may appear.
   - To find the gage datum associated with a particular set of features, use the vertical distance between the indicator and water surface, and add to the water surface at the gage station to obtain the gage datum or survey the set of indicators through the gage station location using laser level or total station survey. If the gage and study reaches are similar channel types, these bankfull stage estimates should be similar in the two reaches.
   - Using the gage datum, determine the corresponding discharge on the rating table (stage-discharge) provided by the USGS. Determine the recurrence interval for this discharge with the plot of the Log-Pearson Type III flood frequency distribution.
   - If other geomorphic features are identified at different elevations, determine the discharge and recurrence interval for each feature. As a preliminary, and rough, check on the reasonableness of these features, compare them to the discharge predicted by the graph of bankfull discharge versus drainage area for the Eastern United States *(FIGURE 1 – REGIONAL CURVES)* (Dunne and Leopold, 1978).
   - Measure cross-sectional area to determine if the estimated discharge is reasonable for the give cross-sectional area.

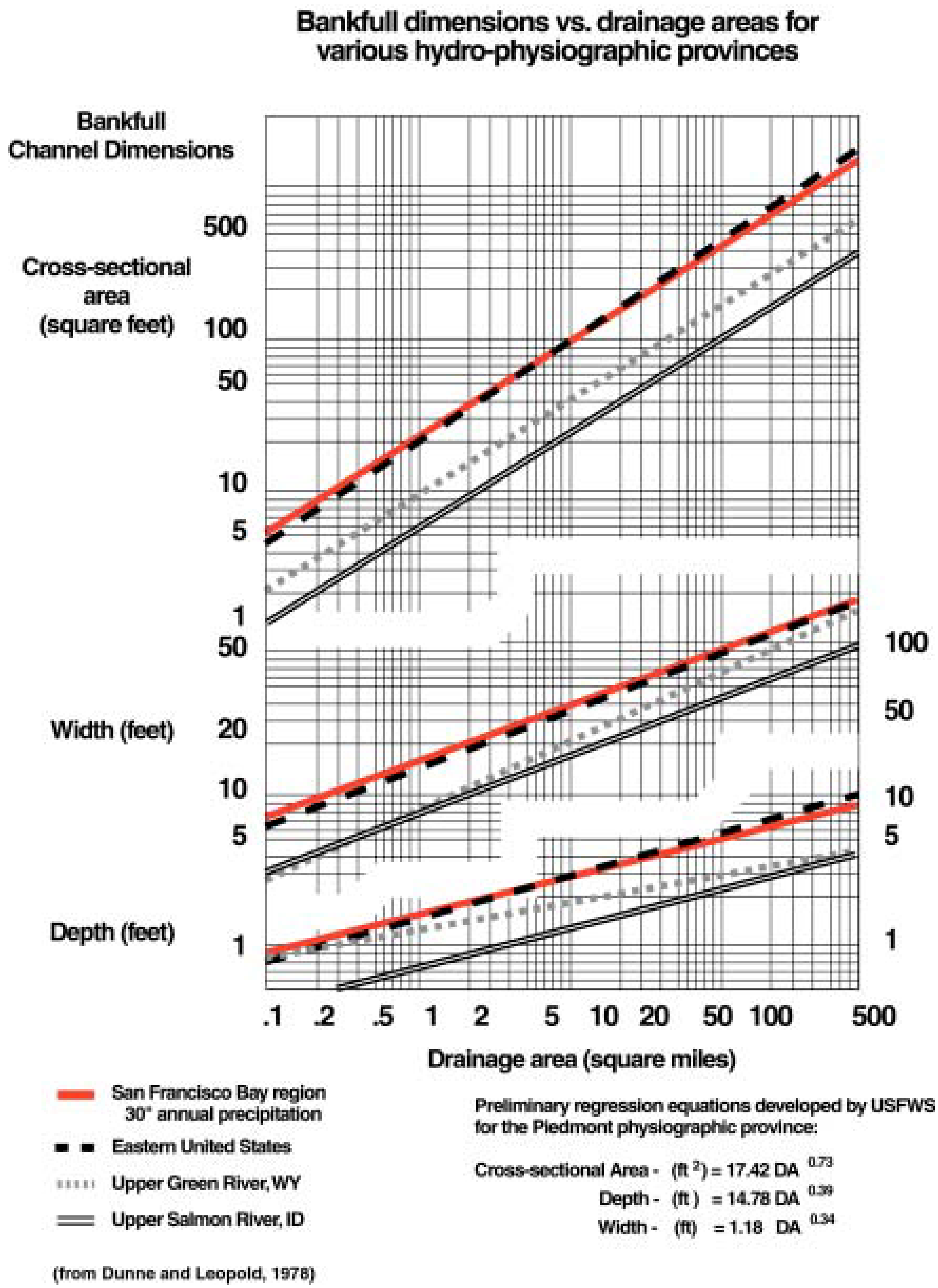


FIGURE 1 – REGIONAL CURVES

IV. FULL FIELD SURVEY

A. Survey Procedures

Conduct a survey to collect data for a longitudinal profile through the gage and study reach, a Rosgen Stream Type Classification cross-section in the study reach, and additional reach average cross-sections.

1. Longitudinal Profile

This survey will document the overall and facet slopes of the bed, water surface, bankfull, and top of bank along the stream. The longitudinal profile of the study reach is used to calculate the following parameters:

- Stream length: the longitudinal distance along the thalweg of the stream from the beginning to the end of the study reach.
- Stream gradient: the net change in water-surface elevation over the entire study reach divided by the stream length - measured from the same location on the same type of feature. (i.e. top of riffle to top of riffle).
- Riffle length: the thalweg distance between the top and bottom of a riffle.
- Riffle gradient: the change in elevation from the top to the bottom of the riffle divided by the length of the riffle.
- Riffle interval: the longitudinal distance between the beginning of successive riffles. Measured along the thalweg of the channel.
- Inter-step length: the longitudinal distance between the tops of successive steps, measured along the centerline of the channel.
- Step height: the change in elevation between the top and toe of a step.
- Inter-step gradient: the change in elevation between successive steps divided by the inter-step length.
- Maximum pool depth: the maximum depth, measured from the bed to the bankfull elevation, in a pool.

2. Rosgen Stream Type Classification Cross-Section
Survey one cross-section in each study reach to provide the cross-section data (bankfull width and depth, cross-sectional area, and floodprone width) needed to classify the reach according to Rosgen Classification System (Rosgen, 1996). Locate classification cross-sections across the middle of riffles and runs or at the top of steps where the distribution in velocity is considered the most uniform *(FIGURE 2 - CROSS-SECTION LOCATION*). Establish the classification cross-section perpendicular to the direction of flow, and extending laterally beyond the bankfull channel to one foot above the floodprone elevation. Before measuring the cross-section, install and label rebar monuments for the cross-section. The monuments should be included in the survey and be located sufficiently back from the top of the bank to prevent them from being lost due to bank erosion.

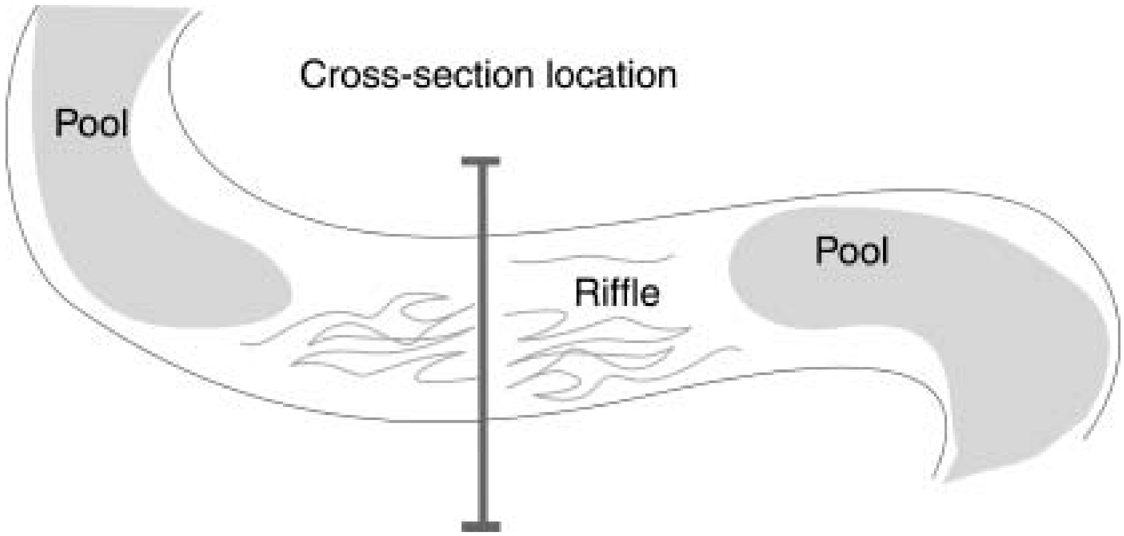


FIGURE 2 – CROSS-SECTION LOCATION

3. Reach Average Cross-sections

Survey, as time permits, additional cross-sections throughout the entire study reach to obtain the average morphological characteristics of the stream in the study reach. Identify reach average cross-section locations during the study reach walk. At a minimum, survey one additional cross-section across the midpoint of a meander bend or at the maximum. depth of the pool. Survey additional cross-sections at mid-riffle or -run, at transitions between riffles and pools and at points of significant change in channel width and slope. The additional cross-sections should include data points at top of bank, bankfull, water surface, toe of bank, and thalweg. For channels with non-uniform bottoms, additional measurements may be required at points of significant slope change, and at enough intermediate points to adequately represent the cross-section. Do not monument these cross-sections with rebar.

B. Survey Setup

1. Refer to the notes from the reconnaissance visit for an estimate of bankfull stage (gage datum). Determine the difference in stage between the bankfull estimate and water surface (be sure to account for differences in water surface from reconnaisance visit and current stage).
2. Walk the entire reach to flag bankfull elevations and other features at tops and bottoms of riffles and runs and other additional locations along the channel with clear bankfull field indicators. Use a laser level or a level line to assist in identifying bankfull field indicators. Also, flag points of maximum pool depths, classification cross-section, and reach average cross-sections. If surveying morphological features in the field, also flag radius of curvature points and the outside bank apexes of meander bends. Use different colored flags to distinguish the longitudinal profile, classification cross-section, and reach average cross-sections from one another.

3. At locations selected for classification cross-sections, install rebar monuments at appropriate distances back from the top of bank on both sides of the stream. Mark these monuments with pin flags and flagging.
4. Also at classification cross-sections, determine the maximum bankfull depth. Then find the points of elevation on both sides of the valley corresponding to a height above the thalweg equal to twice the maximum bankfull depth. These points mark the endpoints of the floodprone width. Mark them prominently with pin flags.
5. Set up the total station or laser level in a location where the benchmarks or reference marks, gage staff plate, and several potential bankfull field indicators can be surveyed. The best location will be that which provides stable footing for the instrument, minimizes the rod extensions, and covers the greatest stream length. Consider setting up in the stream channel if visibility is limited and if the depth and bottom conditions make this feasible (the stream bottom should be stable and the level must not get wet). Having to move the instrument often adds time and complexity to the survey; take the time to select instrument positions carefully.
6. If the study reach does not include the gage, rebar monuments should be installed as reference marks for the survey. The monuments need to be surveyed and elevations and locations obtained in gage datum.

C. Field Data Collection – this may be a laser level survey or a full total station survey. The following description is for total station surveys.

1. Start the survey at one end of the study reach. Determine the ground elevation of the first station relative to the gage datum to begin the survey of the study reach.
2. Once the total station is set there should be one person operating the total station and one or two people with rods and prisms surveying the study reach. The team leader sketches a profile of each bank at all facet features. The sketches include all surveyed points and their elevations. Survey all points for the longitudinal profile, classification cross-section and reach average cross-sections in a sequential pattern, zigzagging back and forth across the stream. Additional points may have to be taken to accurately show the planform of the stream.
3. Maintain close communication between rod-holders and total station operators via two-way radios. Rod-holders will inform the operator of the specific points being surveyed for each shot. Code all data points surveyed according to the total station code card, which all members of the survey team will carry. Rod-holders should inform the total station operator of beginning and end points of linked data sets (i.e., bankfull, thalweg, and water surface). In addition, the team leader will carry a field book noting distance and elevation at facet stations, and describe the bankfull indicator. The team leader will also make notes at the cross-section location on distance, elevation, and describe the bankfull indicator and other geomorphic features, vegetation line, type of vegetation, etc.
4. For the longitudinal profile, survey the points corresponding to top-of-bank (lowest bank), bankfull, active channel, water surface, and thalweg at changes in facet features (i. e., tops and bottoms of riffles) and at the maximum depth locations of pools *(FIGURE 3 – LONGITUDINAL PROFILE)*.

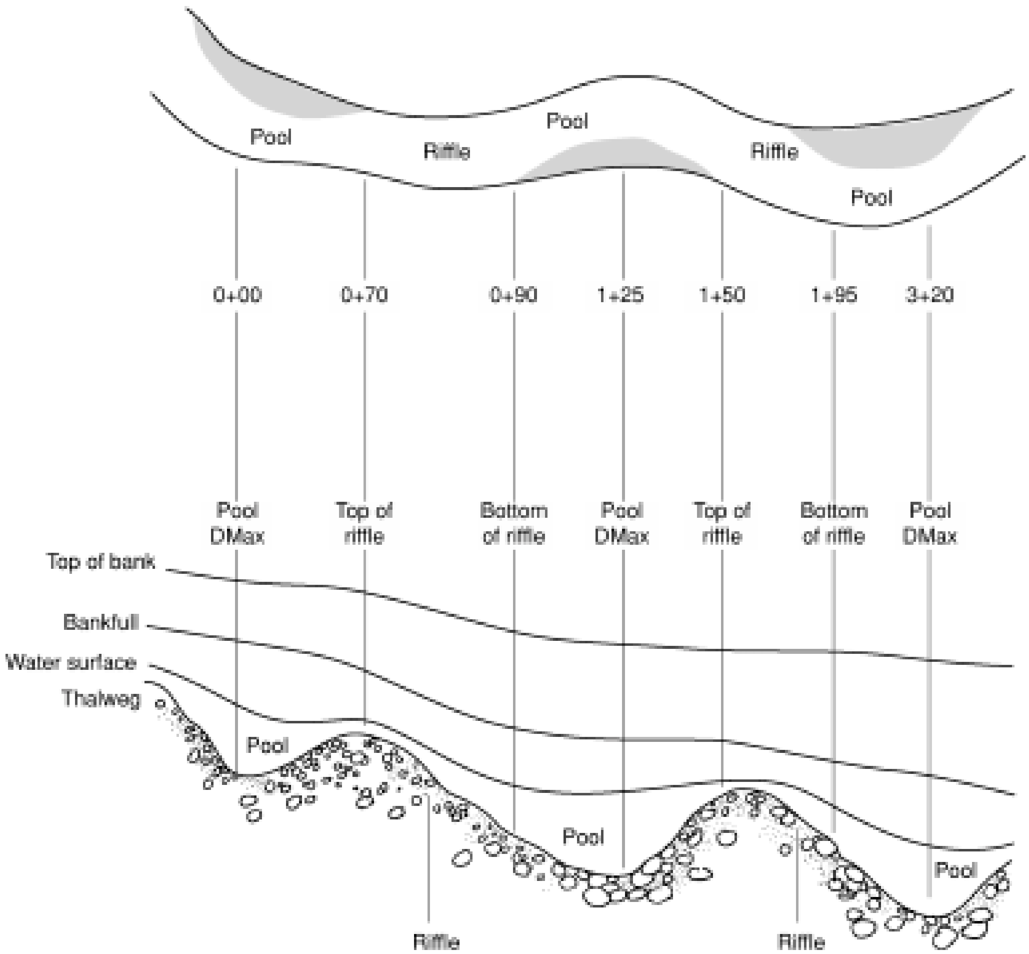


FIGURE 3 – LONGITUDINAL PROFILE

5. On the cross-section survey, note the elevations for the following features *(FIGURE 4 – CROSS-SECTION COLLECTION)*:

- Top and ground surface at monuments
- Slope breaks
- Bankfull stage
- Water surface at the edge of water
- Thalweg

Also survey several points across the floodplain between, and including, the flood-prone elevation points.

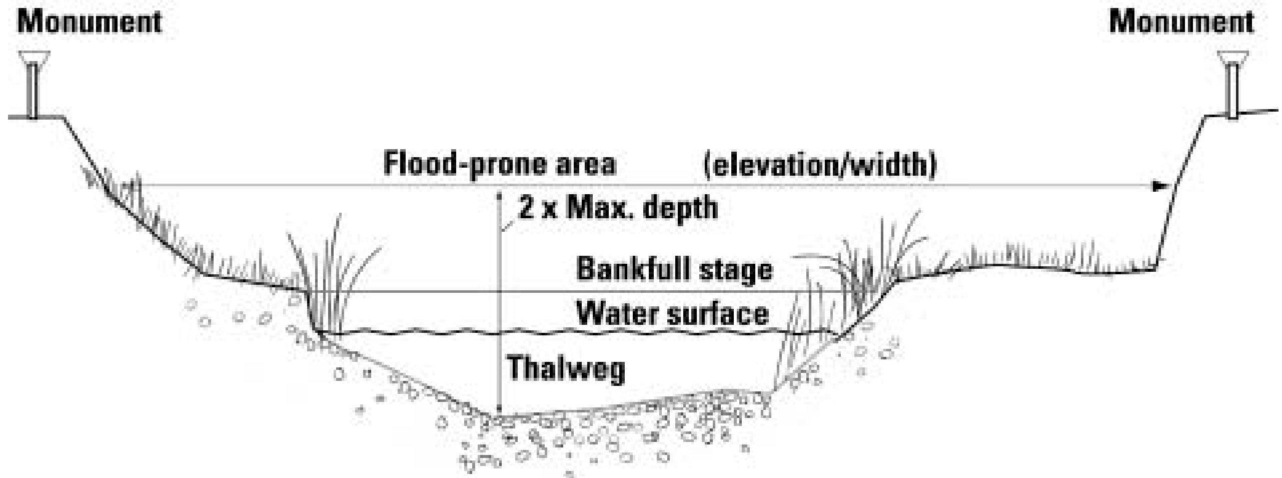


FIGURE 4 – CROSS-SECTION COLLECTION

6. Take photos upstream, downstream, and both banks; include the entire channel cross-section with a vertical survey rod in the frame. If possible, show a survey team member standing at the bankfull elevation. Use a wide-angle lens to show the relative extent of floodplain or confinement on both sides of the channel. Record the camera, lens focal length, frame number and film type on the photo data sheet.

D. Bed and Bank Material Characterization

The work at each study reach includes a basic characterization of bed and bank material, using a combination of pebble counts and bulk samples. Specifically, characterize bed material through the use of a reach average pebble count and a riffle pebble count The collection of bank material data will involve a semi-quantitative description of the bank characteristics and bulk samples.

1. Stream Bed

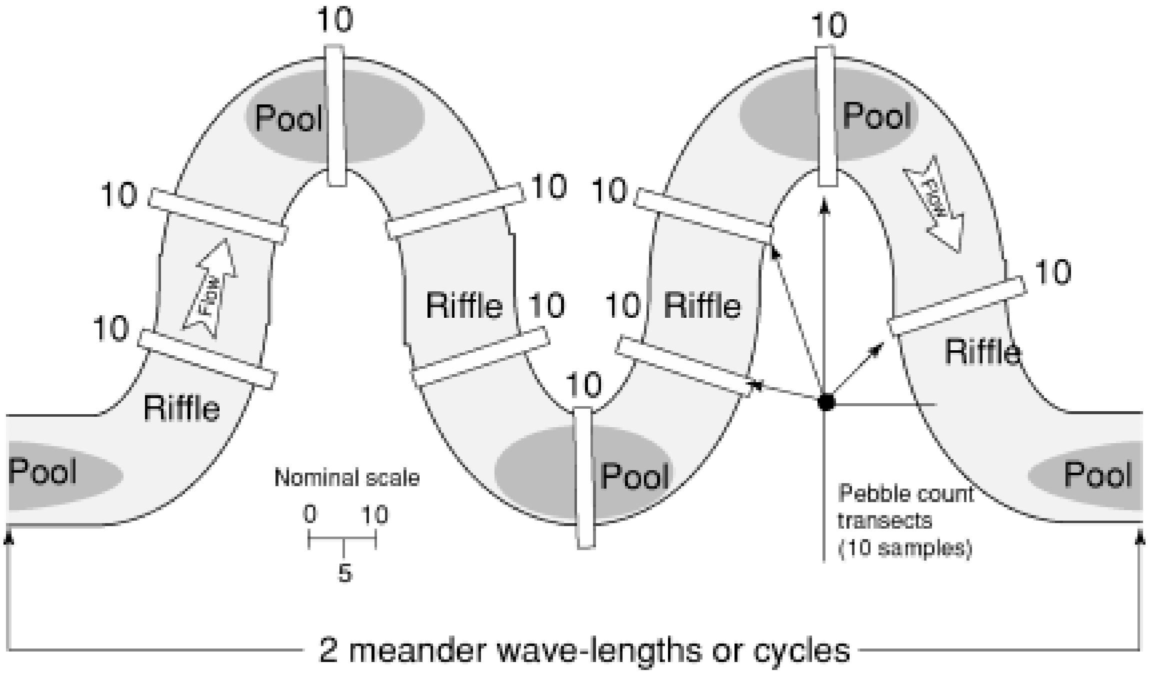
Use the Wolman Pebble Count procedure to conduct one reach-averaged and one riffle pebble count. This procedure requires an observer with a metric ruler or calipers that wades the stream and a note-taker. The reach-averaged pebble count characterizes the size distribution of the bed materials comprising the total perimeter of the bankfull channel. The riffle pebble count characterizes the size distribution of particles making up the bed of the riffle, and is used to determine the relative roughness of the channel (mean depth of flow divided by a representative diameter of the bed particles).

a. Reach-averaged Pebble Count Procedure

Conduct a reach averaged pebble count of 100 samples as follows:

1. Determine the proportion of the lineal reach represented by major channel unit types (riffle, pool, run/glide, step, etc.).

2. Distribute ten transects through the entire reach according to the proportion of channel features. For example, if 30% of the reach length is in pools, and 70% is in riffles, then locate three transects in pools and seven transects in riffles *(FIGURE 5 – PEBBLE COUNT LOCATION)*. If there are more individual features than needed for the number of transects, locate the transects in features by numbering the units and using a random number table to select those specific features to be sampled. Locate the transects within features by measuring the length of the feature, and use a random number table to select at which distance into the feature the transect is positioned.



(From Wildland Hydrology, 1998, The Reference Reach Field Book)

FIGURE 5 - PEBBLE COUNT LOCATION

3. Position a taut tape measure across the channel and determine the bankfull width. Divide the distance by nine to determine the interval distance between sample locations. Select the first particle at the zero point of the tape, and the tenth particle at bankfull on the opposite bank. Select the remaining particles at the sampling interval locations along the tape. Avert gaze, and reach straight down at each sampling point along the tape, pick up the first particle touched by the tip of index finger. If the first particle encountered is a sand grain or smaller and is part of a thin sprinkling of particles on the top of a larger particle of gravel, cobble, or boulder, measure the larger particle. If the smaller particles constitute a discrete layer on top of the larger particles, measure the smaller particles.
4. Measure the intermediate axis (neither the longest nor shortest of the three mutually perpendicular sides of each particle picked up). Measure embedded particles or those too large to be moved in place. For these, measure the smaller of the two exposed axes. Call out the measurement. The note taker tallies each

sampled particle by size class and repeats the measurement back for confirmation. A Reach-Averaged Pebble Count Data Sheet is in Section VI – Field Data Sheets. For sand and silt, determine the size class of particles at sample points by visual and textural comparison using the Sand-gauge (available from W. F. McCollough, Beltsville, MD). Classify material as clay when a wet sample readily forms a cohesive ribbon when rolled between fingers or palms. Count the number of particles measured for each transect, there should be ten.

5. Move to the next transect position and repeat the procedure. After ten transects, the sample size should total 100 particles.

b. *Riffle Pebble Count Procedure*

For streams with riffles, conduct a pebble count at one riffle. If the classification cross-section is located at a riffle, that should be the location for the riffle pebble count.

1. Determine the length of the riffle.
2. Divide the length of the riffle by nine to determine the interval distance between transect locations. Position the first and tenth transects at the start and end of the riffle, respectively, and the other eight transects at the calculated intervals.
3. Measure the sampled particles as in the reach averaged pebble count procedure described above.
4. Record the data on the Riffle Pebble Count Data Sheet (Section VI – Field Data Sheets). On the data sheet, denote bed samples with a dot and bank samples with a slash.

2. Stream Bank

To a limited extent, the reach-average pebble count data characterizes the composition of the material making up the stream banks because the transects for these counts span the complete bankfull channel. However, because measurement includes only a few samples from the bank in the region between the toe and bankfull elevations, conduct additional description of this area as follows:

a. *Sample Procedure*

1) At the classification cross-section, note the type and extent of vegetation covering the banks.
2) Sketch the bank profile for both banks on the bank characterization data sheet. Include the position, thickness, and general composition (i. e., silt, sand, small gravel, gravel/cobble, etc.) of any layering of materials between the toe and bankfull elevations.
3) If vegetation is present, use a square blade spade to scrape a fresh face down the entire bank height.
4) From both right and left banks, collect equal volume bulk samples from the center of each identified layer. The sample size depends on the particle sizes in the identified layers. If bank materials are predominantly larger than gravel, do

not collect a sample; simply describe the general size class as small cobble, large boulder, etc.

5) Record all bank data on the Bank Sample Data Sheet in Section VI – Field Data Sheets.
6) Bag and label the samples separately. Complete the sample sheets and put it in the sample bag. Label the sample bag with stream name, type of sample (i.e., left bank lower stratum), and date.

b) *Dry Sieving for Particle-size Analysis*

1. Upon return to the office, transfer bulk sediment samples from collection bags to pre-weighed drying trays. Make sure the sample tag is transferred with the sediment sample. Allow the sample to air dry for at least 48 hours (stirring at least twice) or until well dried.
2. Pick all visible organic material (leaves, sticks, wood chips, etc.) out of sample.
3. During the drying period, carefully break up the sample using fingers or rubber stopper until it is fine grained and contains no clumps.
4. Calculate, for the left and right bank separately, the proportion of each bank material horizon. Both the left and right banks should each have a sub-sample of 100 grams. Example: If the #1 horizon on the left bank is 2 feet thick and the entire left bank is 8 feet in elevation, then horizon #1 represents 20% of the left bank. Therefore, horizon #1 sample is represented by 20 grams of material. Extract the correct amount by taking blind scoops of each horizon sample until the correct weight is obtained. Place each horizon sub-sample in a pre-weighed container and again make certain that the sub-samples are sufficiently broken down using fingers or a rubber stopper, ensuring no clumps exist.
5. Combine the left and right bank horizon sub-samples into one pre-weighed container. The total sample should now be 200 grams. Weigh the conglomerate and record the data on the Dry Weight Sieve Analysis Data Sheet found in Section VI.
6. If possible, use calipers to measure the intermediate axis (neither the largest or smallest) of largest particle in the composite sample. Use this measurement to select either the 8-inch or 12-inch diameter sieves for sieving the bank sample. If the largest particle in the sample is larger than 16 mm, use the 12-inch diameter sieves. Manually shake until particles have been sieved down to a particle size of less than 16 mm.
7. Once the sample size has a largest particle size of less than 16 mm, use the 8-inch diameter sieves for particle sieving. The first sieve in the nested stack should have a screen size larger than the measurement obtained from the largest particle in the sample. Arrange the sieves in descending order by screen size using no more than five sieves at one time. Place a sieve pan on the bottom and add the dry sample to the top sieve.
8. Place a Ro-Tap lid (mechanical sieve shaker) on the top sieve, load the nested stack into the Ro-Tap machine, and shake the sample for 7.5 minutes. Remove the lid; gently brush each sieve with a nylon brush in descending order. Replace the Ro-Tap lid and shake for another 7.5 minutes.

9. Empty the contents of each sieve into a pre-weighed pan; tap the sieve gently and brush with a nylon brush. Weigh the sample and enter the weights in the "pan" and "pan + sediment" columns of the data sheet (sample in Section VI – Field Data Sheets).
10. Transfer the remaining sediment, if any, from the bottom sieve pan to a temporary container. Arrange the next smallest sieves in descending order with a sieve pan at the bottom. Add the remaining sediment from the temporary container to the top sieve. Repeat steps 8 and 9 until no sediment reaches the sieve pan or the smallest sieve (.062 mm) is used. If the smallest sieve is used and there is still sediment in the sieve pan, weigh the sediment and record it as silt/clay particle size.
11. Subtract the "pan" weight from the "pan + sediment" weight to determine the weight of sediment in each size class, and enter this data in the "sediment" column of the dry sieve data sheet.
12. Sum the sediment weights, subtract the sum from the bulk sample weight to determine the weight of sediment lost, and enter this in the data sheet.

E. Planometric and Meander Geometry Characteristics

The following stream characteristics were obtained from field surveys and/or aerial photographs:

- Meander length - The meander length is the axial distance of one complete sinusoidal wave pattern of the river. For example, if the measurement starts at the midpoint of a bend, the distance of one wavelength is the straight-line distance to the midpoint of the second bend upstream or downstream from the starting point.
- Sinuosity - The ratio of the stream channel length to the valley length. Alternatively, calculate sinuosity as the ratio of valley slope to average stream slope.
- Belt Width - The belt width is the horizontal distance, measured perpendicular to the axis of the valley length and from bankfull to bankfull, which encompasses the limits of the bends of the stream. Where several different belt widths are present in a stream reach, measure all to determine the maximum, average, and minimum values. The Rosgen Stream Classification uses the larger value.
- Meander Width Ratio - This is the ratio of the meander belt width to the bankfull width.
- Radius of Curvature - The constant radius of an arc described around a meander bend. In the field, radii will be measured using one of the following methods:
  - * The cord and median distance method for the centerline of the stream ($R_c = C^2 / 8M$ where C is the length of a straight line between two points along the curve and M is the distance from the midpoint of C to the curve). An alternative way to measure radius of curvature is to use the cord and median distance method for the bankfull on the outside of a meander. The equation for that method is $R_c = C^2 / 8M + M/2$.
  - * Where site conditions permit, direct measurement via the two-tape method. Two survey team members position themselves in the centerline of the stream at the entrance and exit of the bend. Pull tape measures from each person to a counterpoint equidistant from both, and note the distance. Measure the distance

from the counterpoint to the centerline of the stream at the bend apex. Estimate the radius of curvature as the average of the three measured radii.
* A total station survey of the bend for planform geometry.

V. DETERMINATION OF BANKFULL STAGE

Bankfull discharge largely controls the form of alluvial channels. In many cases, bankfull discharge closely corresponds to the effective discharge or to the flow that transports the largest amount of sediment over the long-term under current climatic conditions. This may also be the channel maintaining flow. Bankfull discharge is that discharge of stream water that just begins to overflow into the active floodplain. The active floodplain is defined as a flat area adjacent to the channel constructed by the river and overflowed by the river at a recurrence interval of about 2 years or less. Erosion, sediment transport, and bar building by deposition are most active at discharges near bankfull. The effectiveness of higher flows, called overbank or flood flows, does not increase proportionally to their volume above bankfull, because overflow into the floodplain distributes the energy of the stream over a greater area.

If you observe the stream at bankfull discharge, the water level will be obvious, but this discharge is infrequent. The average discharge, which you are more likely to encounter, fills about 1/3 of the channel, and is reached or exceeded only 25% of the time. Finding indicators of bankfull stage (or elevation) in order to calculate stream discharge is crucial, but this may be difficult in the field. Stream-types and indicators vary, and the process requires many separate judgments; a lack of consistency by a single person or among several people can yield poor results.

The active floodplain is the flat, depositional surface adjacent to many stream channels. It is the best indicator of bankfull stage. Floodplains are most prominent along low-gradient, meandering reaches (e.g., Rosgen Classification type C and E channel). They are often hard or impossible to identify along steeper mountain streams (Rosgen Classification types A and B). They may be intermittent on alternate sides of meander bends or may be completely absent. Steep, confined streams in rocky canyons often lack distinguishable floodplains, so other features must be used. Recently disturbed systems may give false indications of bankfull.

Where floodplains are absent or poorly defined, other indicators may serve as surrogates to identify bankfull stage. The importance of specific indicators varies with stream type. Several indicators should be used to support identification of the bankfull stage; use as many as can be found. Useful indicators include:

- Top of Point Bars. The point bar consists of channel material deposited on the inside of meander bends. They are a prominent feature of Rosgen C type channels but may be absent in other types. Record the top elevation of point bars as the lowest possible bankfull stage since this is the location where the floodplain is being constructed by deposition.
- Change in Vegetation. Look for the low limit of upland, perennial vegetation on the bank, or a sharp break in the density or type of vegetation. On surfaces lower than the floodplain, vegetation is either absent or annual. During a series of dry years, such as 1985-1990 in much of the western United States, perennial plants may invade the formerly active floodplain. Large

magnitude floods may likewise alter vegetation patterns. On the floodplain (above bankfull stage) vegetation may be perennial but is generally limited to typical streamside types. Willow, alder, or dogwood often form lines near bankfull stage. The lower limit of mosses or lichens on rocks or banks, or a break from mosses to other plants, may help identify bankfull stage.

- Change in Slope. Changes in slope occur often along the cross-section (e.g., from vertical to sloping, from sloping to vertical, or from vertical or sloping to flat at the floodplain level). The change from a vertical bank to a horizontal surface is the best identifier of the floodplain and bankfull stage, especially in low-gradient meandering streams. Many banks have multiple breaks; examine banks at several sections of the selected reach for comparison. Slope breaks also mark the extent of stream terraces, which may be measured and mapped in your survey. Terraces are old floodplains that have been abandoned by a downcutting stream. They will generally have perennial vegetation, definite soil structure, and other features to distinguish them from the active floodplain. Most streams have three distinct terraces at approximately 2 to 4 feet, 7 to 10 feet, and 20 to 30 feet above the present stream. Avoid confusing the level of the lowest terrace with that of the floodplain; they may be close in elevation.
- Change in Bank Materials. Any clear change in particle size may indicate the operation of different processes (e.g., coarse, scoured gravel moving as bedload in the active channel giving way to fine sand or silt deposited by overflow). Look for breaks from coarse, scoured, water-transported particles to a finer matrix that may exhibit some soil structure or movement. Changes in slope may also be associated with a change in particle size. Change need not necessarily be from coarse to fine material but may be from fine to coarse.
- Bank Undercuts. Look for bank sections where the perennial vegetation forms a dense root mat. Feel up beneath the root mat and estimate the upper extent of the undercut. (A pin-flag may be inserted horizontally and located by touch at the upper extent of the undercut as a datum for the rod.) This is usually slightly below bankfull stage. Bank undercuts are best used as indicators in steep channels lacking floodplains. Where a floodplain exists, the surface of the floodplain is a better indicator of bankfull stage than undercut banks that may also exist.
- Stain Lines. Look for frequent-inundation water lines on rocks. These may be marked by sediment or lichen. Stain lines are often left by lower, more frequent flows, so bankfull is at or above the highest stain line.

Deposits of pine needles, twigs, and other floating materials are common along streams, but they are seldom indicators of bankfull stage. A receding stream may leave several parallel deposits. Floods may also leave organic drift above bankfull stage.

If stream gage data is available for the stream, observations of indicators at or near the gages may help to identify the indicators most useful for a particular area. Ratios of present to bankfull discharge can be used to estimate bankfull stage at nearby sites. Bankfull discharges tend to have similar flow-frequency (approximately 1.5 years) and flow-duration characteristics among sites in a given climatic region. Use this ratio and observations of bankfull stage at local stream gages to test the reliability of the various indicators for your geographic area. Compare your calculation of bankfull discharge to the regional averages by drainage area. If it is different, refer to the USGS peak flow procedures for the area to determine if a significantly different area-runoff relationship exists. In the absence of other reasonable explanations, examine your methods.

Marking Indicators of Bankfull Stage

The field determination of bankfull stage is basically detective work. Crew members walk the selected reach and mark probable indicators (using pin flags, flagging tied on shrubs, etc.). This usually involves discussion and even some disagreement as to the significance of individual marks. Wade the center of the channel to view bankfull stage along both banks. During the process, visualize the water surface at bankfull and note channel features such as bars, boulders, and rootwads that may affect water surface elevation or direct the current. The final test of bankfull indicators is measuring their elevation as part of the survey and plotting a longitudinal profile of bankfull elevation for the entire reach. A line drawn through the points represents the sloping plane of bankfull flow. Significant scatter of bankfull elevations is normal. Outlying points will be evident and may be rechecked to see what sort of indicator gives the most useful and consistent results for the selected reach.

VI. FIELD DATA SHEETS (Follow)

- Longitudinal Profile
- Cross-Section
- Reach Average Pebble Count
- Riffle Pebble Count and Largest Particle on Bar
- Cross-Section Bank Characterization
- Dry Weight Sieve Analysis

MARYLAND STREAM STUDY
LONGITUDINAL PROFILE

STREAM: DATE: CREW:

USGS # ALL MEASUREMENTS IN FEET UNLESS OTHERWISE NOTED.

FWS # REFERENCE POINT ELEVATION AND DESCRIPTION:

Identifier	Backsight	Height of Instrument	Station	Bed Surface Foresight	Bed Surface Elevation	Water Surface Foresight	Water Surface Elevation	Bankfull Foresight	Bankfull Elevation	Top of Bank Foresight	Top of Bank Elevation	Other Foresight	Other Elevation

MARYLAND STREAM STUDY

CROSS SECTION

STREAM	DATE
USGS #	CREW
FWS #	

Begin on left, facing downstream (all measurements are in feet unless otherwise noted)

NOTE	DIST.	ELEV. / DEPTH	NOTE	DIST.	ELEV. / DEPTH

STATION OR DISTANCE FROM GAGE

DIRECTION FROM GAGE

NOTATIONS

NOTE	ABBREV
Left	L
Right	R
Pin	P
Edge of Water	EW
Water Surface	WS
Active Channel	AC
Scour Line	SL
Bankfull	BF
Top of Bank	TOB
Monument	MON

ENTRENCHMENT

FLOODPRONE WIDTH

BANKFULL WIDTH

ENTRENCHMENT

GPS Coordinates

Left Monument

Latitude

Longitude

Error

Right Monument

Latitude

Longitude

Error

Instrument (Prop.#)

MARYLAND STREAM STUDY
REACH AVERAGE PEBBLE COUNT

STREAM		**DATE**	
USGS #		**CREW**	
FWS #			

PARTICLE TALLY COUNTS BY TRANSECT

FEET	PARTICLE	MILLIMETERS		1	2	3	4	5	6	7	8	9	10	TOT#	ITEM%	%CUM
	Silt/Clay	< .062	S/C													
	Very Fine	.062 - .125	S													
	Fine	.125 - .25	A													
	Medium	.25 - .50	N													
	Coarse	.50 - 1.0	D													
	Vry Coarse	1.0 - 2	S													
	Very Fine	2 - 4														
	Fine	4 - 6	G													
	Fine	6 - 8	R													
	Medium	8 - 12	A													
	Medium	12 - 16	V													
	Coarse	16 - 24	E													
	Coarse	24 - 32	L													
	Vry Coarse	32 - 48	S													
	Vry Coarse	48 - 64														
0.21-0.31	Small	64 - 96	C													
0.31-0.42	Small	96 - 128	O													
0.42-0.63	Large	128 - 192	B													
0.63-0.84	Large	192 - 256	L													
0.84-1.26	Small	256 - 384	B													
1.26-1.68	Small	384 - 512	L													
1.68-3.36	Medium	512 - 1024	D													
3.36-6.72	Lrg	1024 - 2048	R													
6.72-13.43	Vry Lrg	2048-4096														
	Bedrock	>4096	BDRK													
CHANNEL WIDTH AT TRANSECT																

	LENGTH	PROPORTION	NO. UNITS	SAMPLED
REACH				
POOL				
RIFFLE				
RUN				

TRANSECT	FEATURE	LENGTH	LOCATION	COUNT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

MARYLAND STREAM STUDY
RIFFLE PEBBLE COUNT AND LARGEST PARTICLE ON BAR COUNT

STREAM			**DATE**	
USGS #			**CREW**	
FWS #		**RIFFLE LOCATION (ALSO MARK ON REACH SKETCH):**		

				PARTICLE TALLY COUNTS BY TRANSECT										**TOTALS**	
FEET	**PARTICLE**	**MILLIMETERS**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Tot #**	**% Cum**
	Silt/Clay	< .062	S/C												
	Very Fine	.062 - .125	S												
	Fine	.125 - .25	A												
	Medium	.25 - .50	N												
	Coarse	.50 - 1.0	D												
	Vry Coarse	1.0 - 2	S												
	Very Fine	2 - 4													
	Fine	4 - 6	G												
	Fine	6 - 8	R												
	Medium	8 - 12	A												
	Medium	12 - 16	V												
	Coarse	16 - 24	E												
	Coarse	24 - 32	L												
	Vry Coarse	32 - 48	S												
	Vry Coarse	48 - 64													
0.21-0.31	Small	64 - 96	C												
0.31-0.42	Small	96 - 128	O												
0.42-0.63	Large	128 - 192	B												
0.63-0.84	Large	192 - 256	L												
0.84-1.26	Small	256 - 384	B												
1.26-1.68	Small	384 - 512	L												
1.68-3.36	Medium	512 - 1024	D												
3.36-6.72	Lrg	1024 - 2048	R												
6.72-13.43	Vry Lrg	2048-4096													
	Bedrock	>4096	BDRK												
		CHANNEL WIDTH AT TRANSECT													

LARGEST PARTICLES ON BAR

BAR LOCATION (ALSO MARK ON REACH SKETCH):

Bar Length:	**Part. #**	**A mm**	**B mm**	**C mm**	**Part. #**	**A mm**	**B mm**	**C mm**	**Part. #**	**A mm**	**B mm**	**C mm**	
Bar Width (Thalweg - Bnkfl):	**1**				**9**				**17**				
Sketch bar profile (thalweg - bnkfl)	**2**				**10**				**18**				
	3				**11**				**19**				
	4				**12**				**20**				
	5				**13**				**21**				
	6				**14**				**22**				
	7				**15**				**23**				
	8				**16**				**24**				

MARYLAND STREAM STUDY

CROSS SECTION

STREAM	DATE
USGS #	CREW
FWS #	

Begin on left, facing downstream (all measurements are in feet unless otherwise noted)

NOTE	DIST.	ELEV. / DEPTH	NOTE	DIST.	ELEV. / DEPTH

STATION OR DISTANCE FROM GAGE

DIRECTION FROM GAGE

NOTATIONS	
NOTE	**ABBREV**
Left	L
Right	R
Pin	P
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Water Surface	WS
Active Channel	AC
Scour Line	SL
Bankfull	BF
Top of Bank	TOB
Monument	MON

ENTRENCHMENT

FLOODPRONE WIDTH

BANKFULL WIDTH

ENTRENCHMENT

GPS Coordinates

Left Monument

Latitude

Longitude

Error

Right Monument

Latitude

Longitude

Error

Instrument (Prop.#)

DRY WEIGHT SIEVE ANALYSIS

Stream:	**Sample Type:**	**Pavement** **Subpavement**	**Bank**	**Bar**
USGS #:	**Location:**			
FWS#:				

Date:	**PRE-SIEVE BULK WEIGHT**	
Collected By:	**"PAN + SEDIMENT"**	
Sieved By:	**"PAN"**	
	"SEDIMENT"	

INCHES	**PARTICLE**	**MILLIMETERS**		**"PAN"**	**"PAN + SEDIMENT"**	**"SEDIMENT"**	**ITEM%**	**%CUM**
	Silt/Clay	< .062	S/C					
	Very Fine	.062 - .125	S					
	Fine	.125 - .25	A					
	Medium	.25 - .50	N					
	Coarse	.50 - 1.0	D					
	Vry Coarse	1.0 - 2	S					
.08 - .16	Very Fine	2 - 4	G					
.16 - .31	Fine	4 - 8	R					
.31 - .63	Medium	8 - 16	A					
.63 - 1.26	Coarse	16 - 32	V					
1.26 - 2.5	Vry Coarse	32 - 64	L					
Sum of "Sediment" Weights:								

% LOSS = (BULK WT SEDIMENT - SUM SEDIMENT WTS)/BULK WT SEDIMENT X 100 =