Protocol for Field Surveys of Stream Morphology in Michigan

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Michigan's Stream Team

2/19/2010

Michigan's Stream Team

Michigan's Stream Team consists of representatives of the following agencies.

- Michigan Department of Transportation (MDOT)
- Michigan Department of Natural Resources and Environment (MDNRE)
- Michigan Department of Agriculture (MDA)
- U. S. Army Corps of Engineers (USACE)
- U. S. Department of Agriculture's Natural Resources Conservation Service (NRCS)
- U. S. Fish and Wildlife Service (USFWS)
- U. S. Forest Service (USFS)
- U. S. Geological Survey (USGS)
- Calhoun Conservation District (CCD)
- Michigan State University (MSU)

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www.michigan.gov/streamteam

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Table of Contents

I. Introduction

Representatives of the Michigan Department of Environmental Quality (MDEQ), Michigan Department of Transportation (MDOT), Michigan Department of Natural Resources (MDNR), U. S. Department of Agriculture Natural Resource Conservation Service (NRCS), U. S. Fish and Wildlife Service (USFWS), U. S. Forest Service (USFS), and U. S. Geological Survey (USGS) developed the Michigan Stream Team, which agreed to develop regional curves showing bankfull dimensions versus drainage area for physiographic provinces in Michigan. The short-term goal of the Stream Team was to develop appropriate relationships of stream characteristics on a statewide basis for the State of Michigan where appropriate gage data is available. The long term goal is to provide those who are conducting stream restorations and installing culverts and bridges to have more information to improve hydraulic design and minimize disturbances to stream channels and their associated floodplains and wetlands.

This document serves as the procedural protocol to conduct 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 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 (Rosgen 1996).

II. Methodology

The methods and procedures presented within this protocol are drawn from several sources.

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> Everett, R., Tamara McCandless, 2002. Bankfull discharge and channel characteristics of streams in the Piedmont hydrologic region. CBFO-SO2.01. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office.
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> Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy, 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. General Technical Report RM-245. Fort Collins, CO; USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.
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> Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.
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> Wolman, M.G., 1954. A method of sampling coarse river-bed material. Transactions of American Geophysical Union 35.

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 Michigan or on the USGS web page at http://waterdata.usgs.gov/nwis.

2. Contact the Geological Survey or go to the web page and, for each gaging station of interest, obtain copies of the following:
    - Gage description, station analysis, and most recent level notes (including any maps and sketches)
    - List of discharge measurements (recent years are available on the USGS webpage)
    - current or most recent rating table
    - log Pearson Type III flood frequency distribution (for the annual maximum series); analysis for Michigan's Stream Team is available at www.michigan.gov/documents/deq/lwm-nps-mist-qpeak_219303_7.pdf

B. Preliminary Analysis

1. Review gage description, station analysis, and level notes for each station. Gage descriptions should provide bench marks, reference marks, or reference point information in gage datum (if not, contact USGS for relevant datum). Note any unusual information regarding the channel (channelization, stage for weir control, discharge augmentations, etc.). If available, print out the last 7 days of stage and discharge readings from the USGS website at http://waterdata.usgs.gov/nwis.

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. Read and record the gage-datum water-surface elevation on the outside staff gage, and time of reading. If the gage house is opened, you must contact the USGS.

4. For each gaging station, calculate the Log Pearson Type III flood frequency using the form on page A-1. Plot the flood frequency distribution using the log-log graph on page A-2.

C. Initial Gage Reconnaissance

Equipment

The equipment list includes:
- Laser level or total station, laser receiver, and rod
- 300-foot tape
- colored plastic ribbon and wire flags
- field data sheets and pencils

- topographic quadrangle maps and aerial photography of the area (http://ims.rsgis.msu.edu/viewer.htm)
- bank pins and cam line (i.e. steel cable or non-stretch tape)
- gage description, station analysis, level notes, and plotted data

Gage Criteria

The minimum criteria for gage station inclusion are:

- Intact staff plate or recoverable benchmarks referenced to gage datum
- Condition and function of the control does not affect the near-bankfull or bankfull flows
- 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
- Do not use gage stations located below hydro dams

At the Gage Site – Study Reach

At the gage site, locate 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.

Identify a study reach upstream and/or downstream of the gage site. Ideally the study reach would flow through the gage location. 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. This selection of a study reach should consider, but not be limited to, the following (after Leopold 1994):

- The stream should reside within a homogenous 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 homogenous 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 throughout 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 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 may be made where gage stations are limited and the stream type changes over less than 20 bankfull widths (but should be at least 10 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, down cutting or aggrading, or 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.

- Major islands should be avoided in the study reach by moving upstream or downstream as necessary to exclude the island from the reach. Streams that are naturally braided should not be selected for study since this could indicate instability due to recently increased sediment load. Small islands that are usually submerged completely during bankfull flow may be included in the reach if a good alternative reach is not available. In this case cross sections should be selected so as not to include the island. The longitudinal profile should follow the deeper of the two channels. If time permits the longitudinal profile can include both channels. If moving the reach to avoid islands puts the gage outside of the study reach then you should verify that the stream flow in the study reach is the same as at the gage (no significant tributaries enter between the gage and the study reach) and be sure to tie all elevations in the study reach to the gage datum.

- Obtain permission from any landowners adjacent to the stream reach to be on their land.

At the Gage Site – Preliminary Bankfull Calibration

Bankfull discharge largely controls the form (plan, pattern and profile) of alluvial channels. Alluvial channels are those whose form is established by the erosion, transport, and deposition of mobile alluvium (silt, sand, gravel, etc.). Most Michigan rivers have alluvial channels; exceptions include incised bedrock channels found in portions of the Upper Peninsula. Nonalluvial channels do exhibit bankfull indicators and measurable bankfull dimensions, but the comparability of their bankfull dimensions to those of alluvial channels is questionable. It is possible for a single watershed to contain both alluvial and nonalluvial channel reaches. 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 in 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 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 over bank 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.

When bankfull discharge is observed in the field, the water level is obvious, but this discharge is infrequent. The average discharge, which one is more likely to encounter, fills about 1/3 of the channel and is reached or exceeded 25 percent 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 prominent along low gradient, meandering reaches (e.g. Rosgen Classification type C and E channel). They are often difficult or impossible to identify along steeper, high gradient streams (Rosgen Classification 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 indicators 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.

Stream gage data can 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 of 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 significantly different area runoff relationship exists. In the absence of other reasonable explanations, examine your methods.

It is recommended that bankfull measurements to be used for regional reference curves be made in riffles, or runs where riffles are not present. Riffles are the most geomorphically stable feature in a stream channel. Locations to avoid when making bankfull measurements include those in close proximity to bridges, in stream reaches influenced by reservoirs (upstream and downstream), recently channelized streams, armored channels (gabions, rip rap, etc.), near the downstream end of ‘buried’ streams, or within meander bends.

When identifying bankfull stage on the streambank, walk the gage and study reaches, and flag several bankfull indicators. Following is a list with a description of potential bankfull indicators that may be observed in the field.

- Floodplain break: A discrete transition from near vertical to near horizontal; used on straight reaches or on bends lacking point bars. In some cases (where the stream is not entrenched or incised), the floodplain break may also be the top of bank.

- Inflection point: Where the transition from near vertical bank to near horizontal floodplain is not easily identified, but instead occurs over a transitional zone often composed of one or more obtuse slope breaks over a vertical distance of several tenths of a foot, the inflection point is the lowest identifiable break in slope.

- Depositional bench: The flat surface, or highest elevation, of a lateral depositional surface other than a point bar. This may also be referred to as the active channel.

- Point bar: The transition point from inclining point bar surface to horizontal floodplain surface. 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, perennial plants may invade the formerly active floodplain. Large magnitude floods may likewise alter the 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 forms 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.

  Vegetation can sometimes be used by observing changes from annual to perennial vegetation; however, much caution should be used, since in Michigan many species of trees (silver maple, sycamore, and others) may grow well below bankfull elevations. Vegetation is quite variable, and it is best to determine bankfull elevation using morphological characteristics.

- 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 stream. Many banks have multiple breaks; examine banks at several sections of the selected reach for comparison. Slope breaks also mark the extent of the stream terraces, which may be measured and mapped in your survey. Terraces are old floodplains that have been abandoned by a down cutting 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

- 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.

- Scour line: A wear mark on a vertical bank, or discrete break in slope (acute or obtuse) of the channel bank, distinguished from an inflection point by being further down from the top of bank.

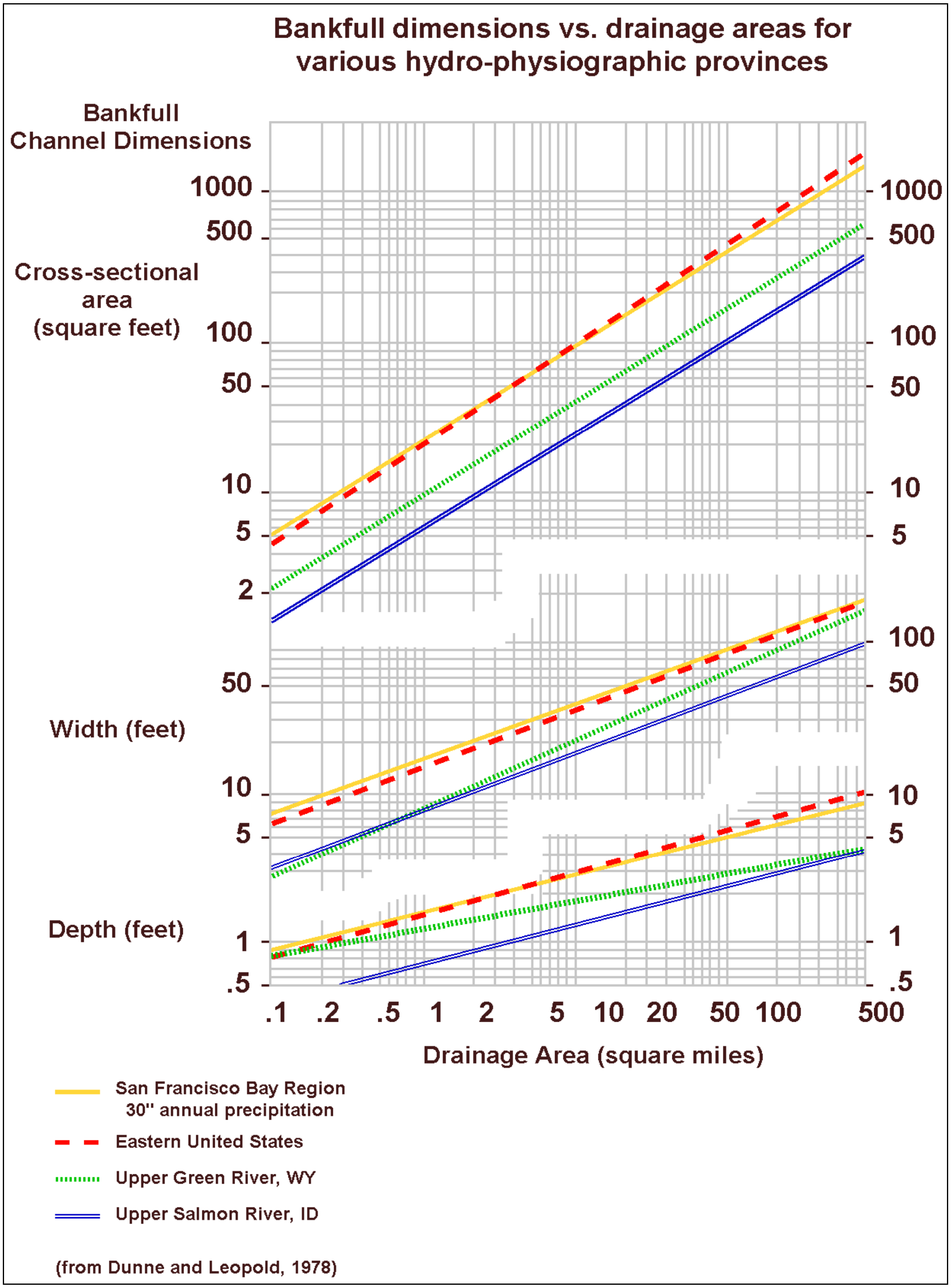
Measure the vertical distance between the indicator and water surface. A consistent set of indicators with the same or nearly the same distance above water surface should be apparent. In some locations, a lower and upper set of indicators may appear.

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, 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 the cross-sectional area to determine if the estimated discharge is reasonable for the given cross-sectional area.



(from Dunne and Leopold, 1978)

From US Fish and Wildlife Service, 2002, Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Region

Figure 1 – Regional Curves

D. At an Ungaged Site – Study Reach Selection

Reference curve surveys may also be performed on ungaged stream reaches which previously (within approximately the last 5 to 10 years) were sampled for macroinvertebrates by the MDEQ using the Procedure 51 (P51) sampling protocol, and received a score of “Excellent” (i.e., ≥ + 5 on the P51 scale of -9 to +9). Biosurveys employing P51 are conducted by MDEQ-Water Bureau staff on every major watershed in Michigan, in a 5-year rotating cycle. The rationale for considering these high-quality biosurvey locations for inclusion in the reference curve database is that abundant, diverse macroinvertebrate populations are unlikely to occur in hydrologically and morphologically unstable channels. It should be noted that “Excellent” macroinvertebrate communities are not present in every watershed.

Selection of the study reach shall be subject to the same reconnaissance described in Section III-C, and consider the same factors described in the eight bulleted considerations described in the “At the Gage Site – Study Reach” section, above. In addition, the stream stability assessment tools described in MDEQ’s Stream Stability Assessment Guidelines for NPS Grant Applicants document (MDEQ, 2008) may also be used to assist with selecting a study reach. Particularly useful would be the qualitative indicators of channel stability.

It would be desirable if the surveyed reach included the reach on which the biosurvey was conducted, if that can be identified. Identification of bankfull dimensions should consider the same 10 bulleted potential bankfull indicators described in the “At the Gage Site – Preliminary Bankfull Calibration” section, above.

IV. Full Field Survey

A. *Survey Procedures Overview*

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. Mark the longitudinal distance of the study reach identified in the Reconnaissance Survey using one or more 300-foot tapes. Run the tape along the stream edge or the thalweg with the beginning of the tape at the upstream end.

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 over 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 root wads that may affect water surface elevation or direct 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 elevation is normal. Outlying points will be evident and may be reached and may be rechecked to see what sort of indicator gives the most useful and consistent results for the selected reach.

Longitudinal Profile

This survey will document the overall and facet slopes (pool, run, riffle, glide) 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 stream bank 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-Pool Reaches
    - 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 riffle divided by the length of the riffle.
    - Riffle interval: the longitudinal distance between the beginnings of successive riffles. Measured along the thalweg of the channel.

- Step-Pool Reaches
    - 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 bankfull elevation, in a pool.

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 flood prone 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 Measurement Location). Establish the classification cross-section perpendicular to the direction of the flow, and extending laterally beyond the bankfull channel to one foot above the flood prone 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. Lay a tape of sufficient length across the cross section beginning from the left bank as you look downstream.

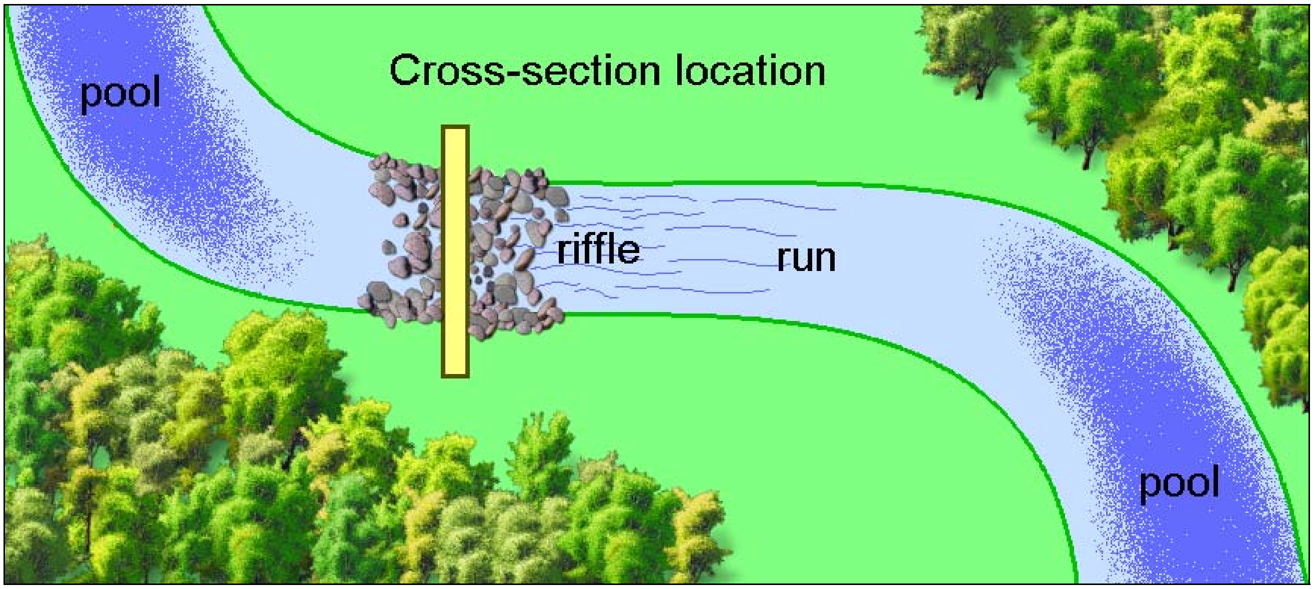


Figure 2 – Cross-Section Measurement Location

Reach Average Cross-Sections

Survey, as time permits, additional cross-sections throughout the entire study reach to represent the range in morphological characteristics of the stream in the study reach. Clearly document for each additional cross section what it represents and how it was selected. Identify these additional cross-section locations during the study reach walk. For example, additional cross-sections could be surveyed across the midpoint of a meander bend or at the maximum depth of the pool, 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 changes, and at enough intermediate points to adequately represent the cross-section. Monumenting these cross-sections with rebar is not necessary.

To represent total measurement variability for the Rosgen Stream Type Classification Cross-Section discussed above, you could select a second cross-section in the reach that is as good as the primary classification cross-section and then use this second cross-section as a replicate measurement.

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 reconnaissance visit and current stage.

2. Walk the entire reach to flag bankfull elevation 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. When 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 flood prone width. Mark them prominently with pin flags. Flood prone widths greater than 2.2 times the width at bankfull stage may be estimated.

5. Set up total station or laser level in a location where the bench marks or reference marks, gage staff plate, and several potential bankfull 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

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.

1. Start the survey at the upstream end of the study reach. In the course of the survey, determine the ground elevations of the first station relative to the gage datum to begin the survey of the study reach. The gage datum can be obtained from the USGS site description for the gage.

2. Once the survey equipment is in place, one person at minimum should have a stadia rod surveying the study reach relating elevation data back to the survey equipment operator. The team leader should sketch the survey reach, including a profile of each bank at all facet features, using the map on page A-4. The sketch should include all significant 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-holder(s) and survey equipment operator. Rod-holders will inform the operator of the specific points being surveyed for each shot. 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). Record the measurements on the longitudinal profile form, pages A-5 and A-6.

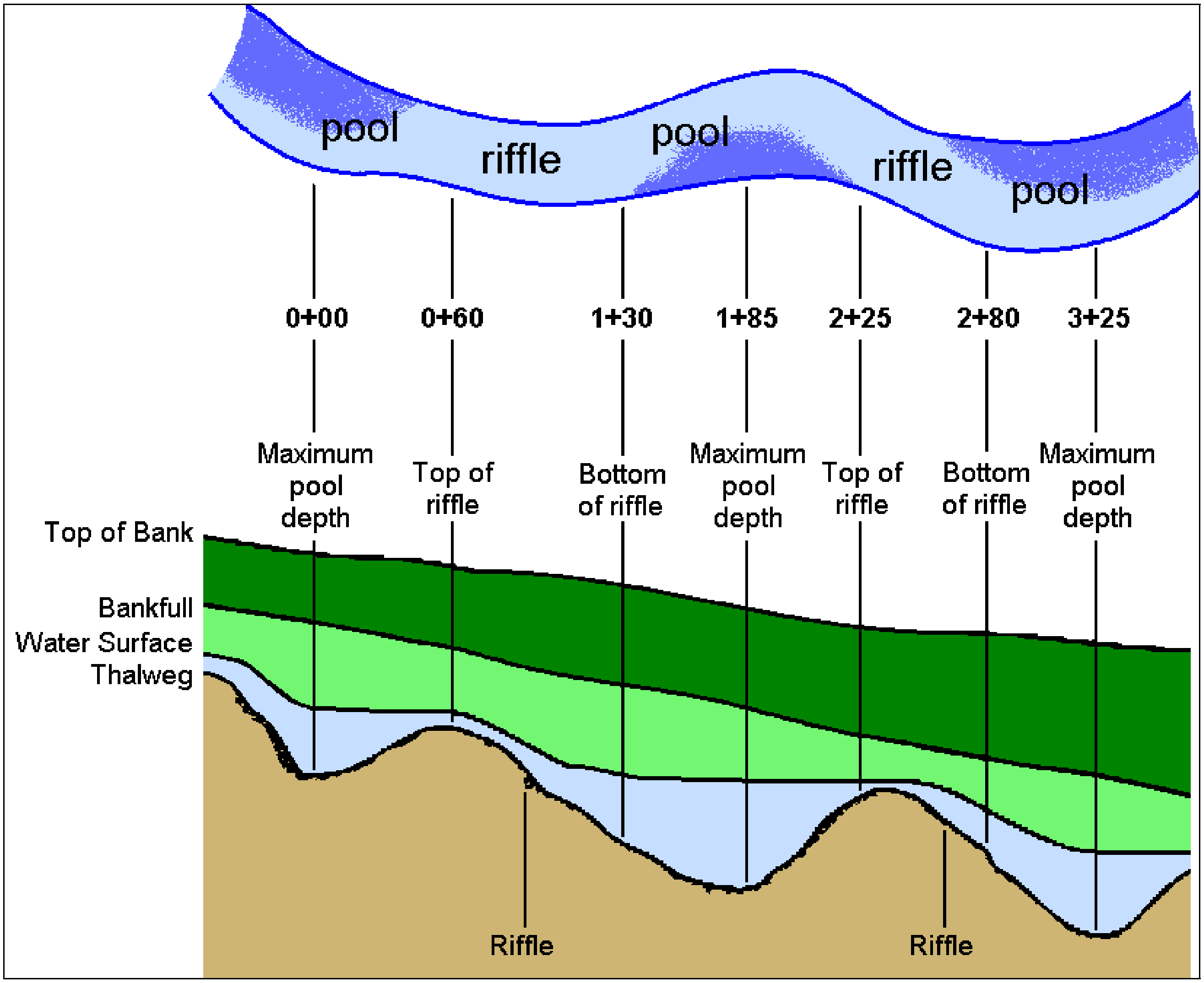


Figure 3 – Longitudinal Profile

5. On the cross-section survey, note the elevations for the following features (Figure 4 – Cross-Section Measurements).

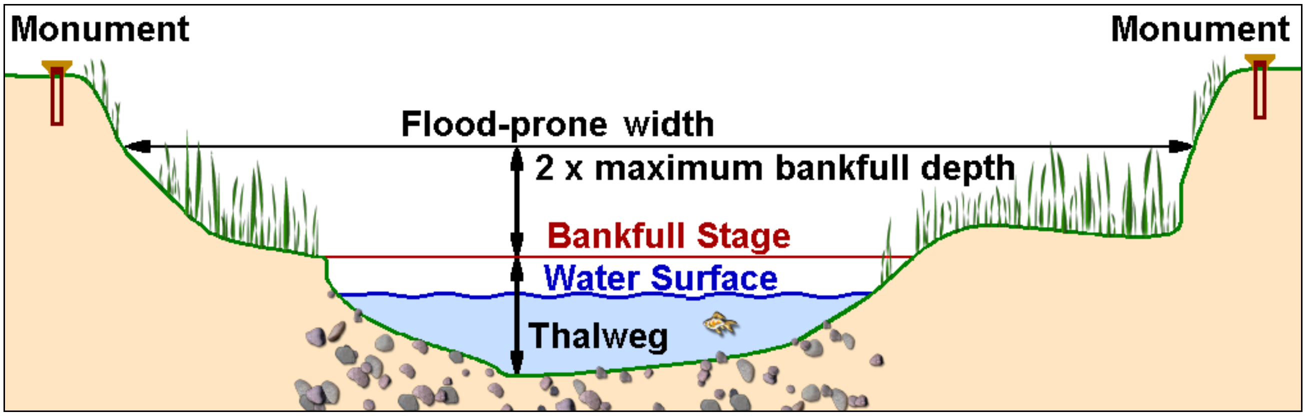


Figure 4 – Cross Section Measurements

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

Record the measurements on the cross-section form, pages A-7 and A-8.

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.

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 riffle pebble count. The collection of bank material data will involve a semi-quantitative description of the bank characteristics and bulk samples.

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).

Reach-averaged Pebble Count Procedure

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

1. Determine the proportion of the linear 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 percent of the reach length is in pools, and 70 percent is in riffles, then locate three transects in pools and seven transects in riffles (Figure 5 – Reach Averaged 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.

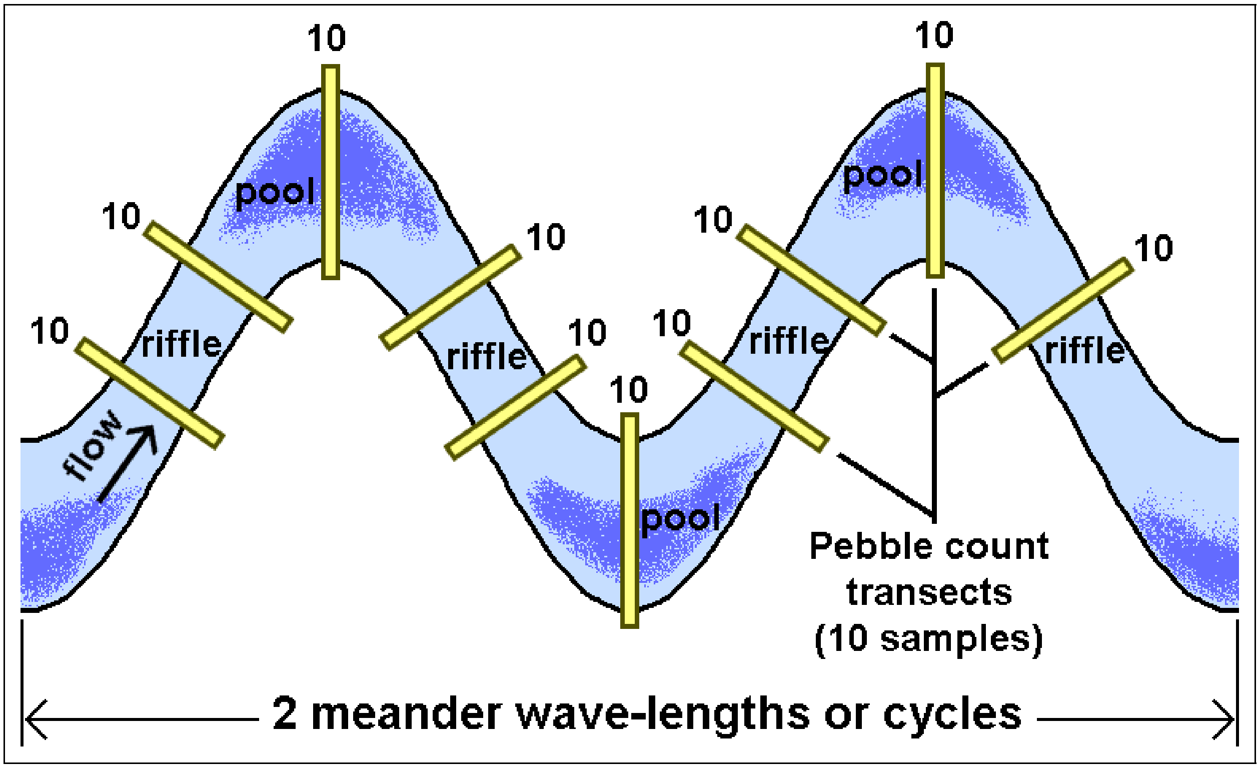


Figure 5 – Reach Averaged Pebble Count Location

3. Position a taut tape to measure across the channel and determine the bankfull width. Divide the distance into nine approximately equal sections. 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 and 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 the shortest of the three mutually perpendicular sides of the each particle picked up) in millimeters. 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 on the pebble count form, page A-9, and repeats the measurement back for confirmation. For sand and silt, determine the size class of particles at sample points by visual and textural comparison using a Sand-gauge (available at Forestry Supply). Classify material as clay when a wet sample readily forms a cohesive ribbon when rolled between fingers. Count the number of particles measured for each transect.

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

Riffle Pebble Count Procedure

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

1. Position a taut tape to measure across the channel and determine the bankfull width of the riffle.

2. Divide the bankfull width of the riffle into approximately equal sections. Position the first and last transects at the start and end of the riffle, respectively. Sample 100 pebbles across equally divided intervals of the transect as in the reach averaged pebble count above.

3. Measure the sampled particles as in the reach averaged pebble count procedure described above.

4. Record the data on the Pebble Count Data Sheet, page A-12.

E. Planimetric and Meander Geometry Characteristics

The following stream characteristics will be 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 valley length. Alternatively, sinuosity can be calculated 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: 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 is $R_c=(C^2/8M)+M/2$ 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.

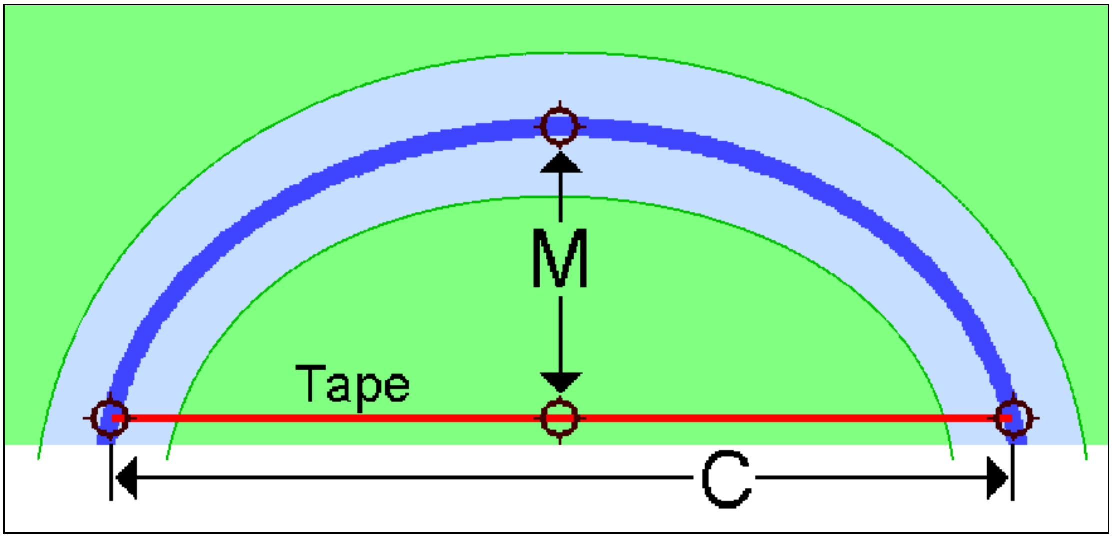


Figure 6 – Cord and Median Distance Method of Measuring Radius of Curvature

- Where site conditions permit, perform 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 a bend. Pull tape measures from each person to a counterpoint from both, and note the distance. Measure the distance from the counterpoint of the stream at the bend apex. Estimate the radius of curvature as the average of the three measured radii.

V. Quality Assurance/Quality Control

Quality is controlled and assured through the use of appropriate professional staff, training of staff, following detailed written procedures, thorough documentation of results, and closing survey loops to within acceptable limits.

A. Training

All personnel conducting surveys are trained in a consistent manner to ensure that the surveys are conducted properly and in standardized fashion. At least one investigator for each survey should be experienced with this procedure.

B. Standard Protocols

The standard protocols described in this document are followed in all surveys. Any deviations from the procedures should be documented and the reasons for deviation described.

C. Measuring Survey Errors

All surveying that involves leveling is done in a loop, which ends at the same point where the survey began. This allows a comparison of starting and ending elevations and provides a way to calculate error. No survey is complete until it has been closed within acceptable levels of error. The difference and the new or calculated elevation is the error. Very small errors may result from rounding and are acceptable; however, typically a closure of 0.02 feet is preferred. Closure error must be recorded with the longitudinal profile, appendix B, and included with the reporting of collected data.

If cross-section transects are surveyed for multiple riffles in a single study reach, prior experience indicates that the bankfull widths will be fairly similar. Specifically, the precision of multiple measurements as expressed by their relative standard deviation (RSD; standard deviation of multiple measurements divided by the mean) will be approximately 10 percent. RSD for multiple pools in a single study reach has not been investigated, but is suspected to be greater than for riffles.

D. Stream Analysis and Classification

Software such as RIVERMorph, http://www.rivermorph.com/, or the Ohio DNR's stream morphology spreadsheets, http://www.dnr.state.oh.us/soilandwater/streammorphology.htm, can be used in lieu of paper forms to enable faster analysis of the field data.

Bed Material Analysis

Plot the pebble count data on the semi-log graph, page A-12.

Bankfull Velocity Check

A velocity calculation form, page A-13, is provided to compare the bankfull velocity determined from the USGS rating curve with other methods of calculating bankfull velocity. At least two of the four methods should be used for the comparison. Similar velocities provide some assurance that the associated calculations are correct.

Data Summary/Stream Classification

Plot the bankfull channel dimensions on the log-log graph, page A14. Complete the Summary of USGS Gage Station Data/Records for Stream Channel Classification form, pages A-15 and A-16.

E. Documentation

The field data sheets are filled out as completely and accurately as possible. Field data sheets and final reports, Appendix C, are filed with the Surface Water Assessment Section, Water Bureau, MDEQ.

VI. Field Data Sheets

Log Pearson Type III Flood Frequency Analysis form (Appendix A)
Annual Peak Flow Frequency Analysis graph (Appendix A)
Field Survey Map form (Appendix B)
Longitudinal Survey Part I and II forms (Appendix B)
Cross-section Survey Part I and II forms (Appendix B)
Pebble Count Survey form (Appendix B)
Graph/notes page (Appendix B)
Pebble Count graph (Appendix C)
Velocity calculation form (Appendix C)
Bankfull Channel Dimensions graph (Appendix C)
Summary of USGS Gage Station Data/Records for Stream Channel Classification (Appendix C)

VII. Literature Cited

Dunne, T. and L.B. Leopold, 1978. Water in Environmental Planning. W.H. Freeman and Company, New York, New York.

Leopold, L.B., 1994. A View of the River. Harvard University Press. Cambridge, Massachusetts. 298 pp.

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Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Wolman, M.G., 1954. A method of sampling coarse river-bed material. Transactions of American Geophysical Union 35

Appendix A: Pre-Field Survey Forms

Appendix A consists of:

- Log Pearson Type III Flood Frequency Analysis form
- Annual Peak Flow Frequency Analysis graph

Log Pearson Type III Flood Frequency Analysis

Rank, m	Discharge, Q (cfs)	Probability, P	Return Interval, (years)
		(m/(n+1))*100	(1/P)*100
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
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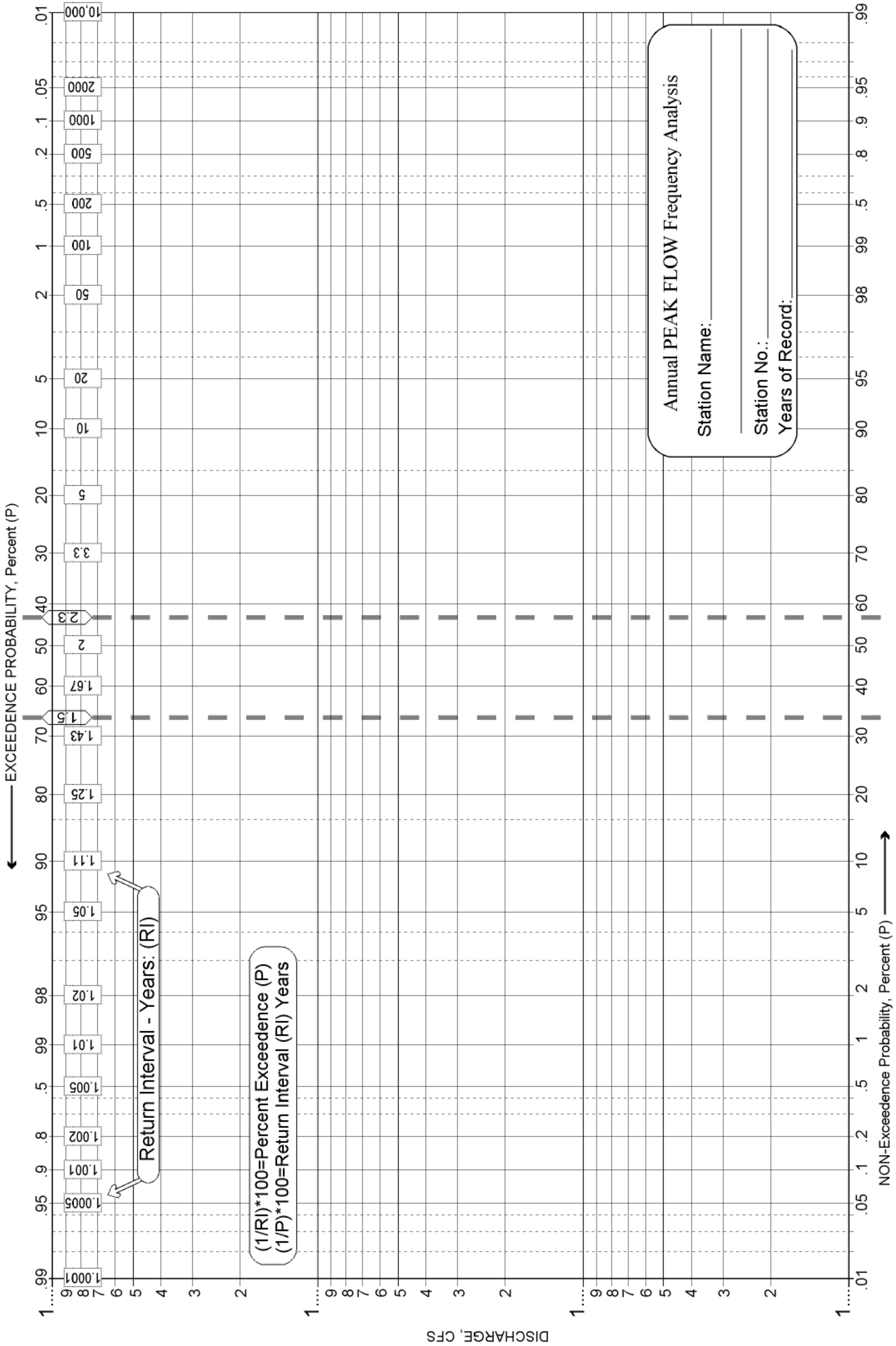
40			

n = total number of measurements, which will vary

Reference Reach Field Form



Appendix B: Field Survey Forms

Appendix B consists of:

- Field Survey Map form
- Longitudinal Survey Part I and II forms
- Cross-section Survey Part I and II forms
- Pebble Count Survey form
- Graph/notes page

Reference Reach Field Form

Area-Site Location....Reach Map

Stream/Drainage:______________________ Site/Reach:__________

Drawn By:______________________ Date:__________

Reference Reach Field Form

Survey Data	**Longitudinal Profile**	**Part I**
Site:		
Location:		
Staff/Notes:		

Item	Distance; Point; or **Station** ft.	Back-Sight **B S** ft.	Height of Instrument **H I** ft.	Fore-Sight **F S** ft.	Height; depth; or **Elevation** ft.	**Notes, Comments, Remarks**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
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Reference Reach Field Form

Survey Data	**Longitudinal Profile**	**Part II**
Site:		

	Station	**B S**	**H I**	**F S**	**Elevation**	**Notes, Comments, Remarks**
Item	ft.	ft.	ft.	ft.	ft.	
36						
37						
38						
39						
40						
41						
42						
43						
44						
45						
46						
47						
48						
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51						
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67						
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69						
70						
71						
72						
73						
			Closure Error =			

Reference Reach Field Form

Survey Data	**Cross-Section**	**Part I**

Site:

Location:

Staff/Notes:

Item	Distance; Point; or **Station** ft.	Back-Sight **B S** ft.	Height of Instrument **H I** ft.	Fore-Sight **F S** ft.	Height; depth; or **Elevation** ft.	**Notes, Comments, Remarks**
1						
2						
3						
4						
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7						
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35						

Reference Reach Field Form

Survey Data	**Cross-Section**	**Part II**
Site:		

Item	**Station** ft.	**B S** ft.	**H I** ft.	**F S** ft.	**Elevation** ft.	**Notes, Comments, Remarks**
36						
37						
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Reference Reach Field Form

Pebble Count

Site:	Reach:
Staff:	Date:

Riffle (100 minimum)	% Cum.																								
	Item %																								
	Total #																								
	Count																								
Longitudinal (100 total at 10 transects)	% Cum.																								
	Item %																								
	Total #																								
	Count																								
Millimeters		< .062	.062 - .125	.126 - .25	.26 - .50	.51 - 1.0	1.1 - 2.0	2.1 - 4.0	4.1 - 5.7	5.8 - 8.0	8.1 - 11.3	11.4 - 16.0	16.1 - 22.6	22.7 - 32	33 - 45	46 - 64	65 - 90	91 - 128	129 - 180	181 - 256	257 - 362	363 - 512	213 - 1024	1024 - 2048	Bedrock
		Silt/ Clay	Sand					Gravel									Cobble				Boulder				

Reference Reach Field Form

Appendix C: Stream Analysis and Classification Forms

Appendix C consists of:

- Pebble Count graph
- Velocity calculation form
- Bankfull Channel Dimensions graph
- Summary of USGS Gage Station Data/Records for Stream Channel Classification

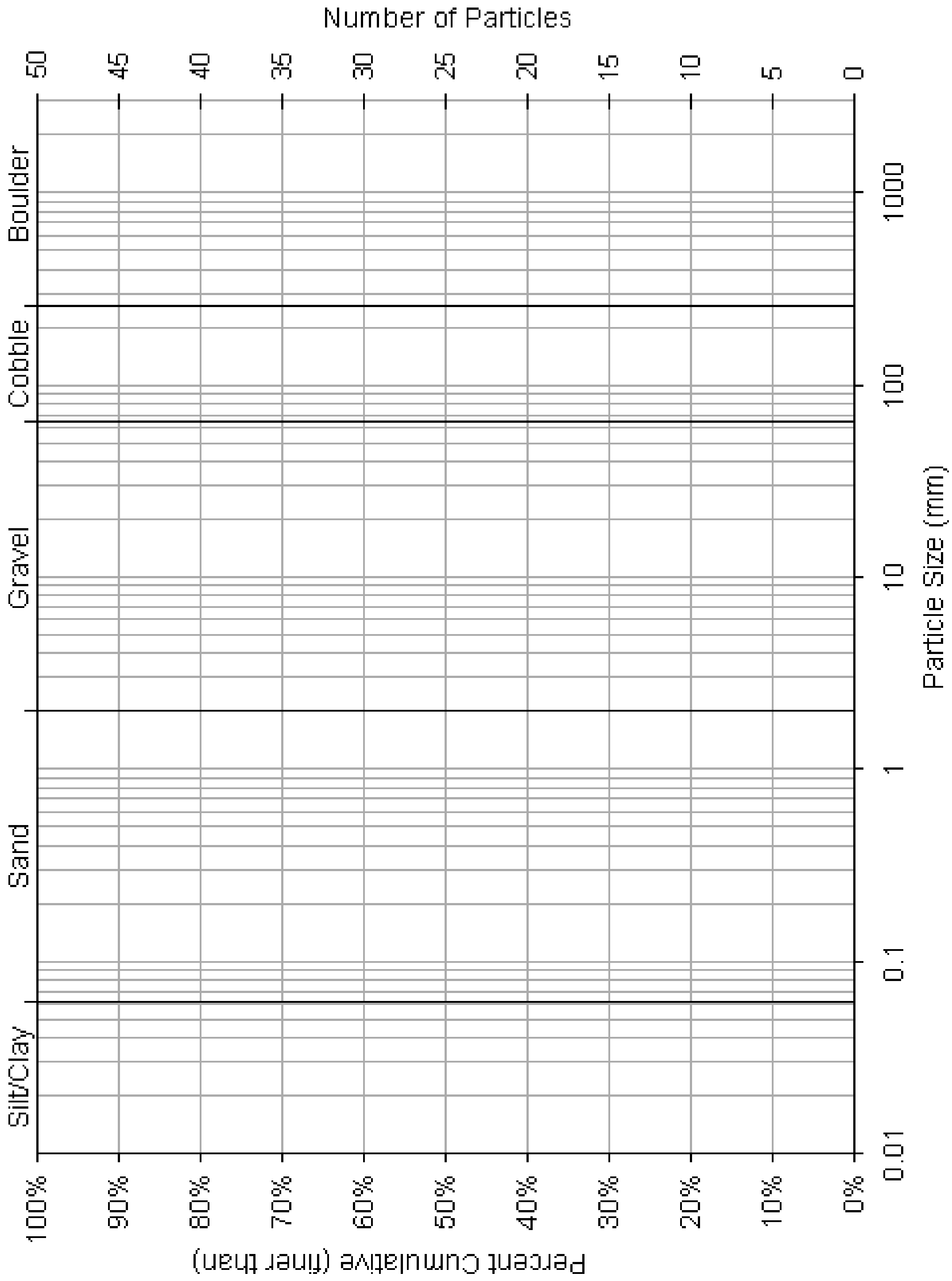
Note: Software such as RIVERMorph, http://www.rivermorph.com/, or the Ohio DNR's stream morphology spreadsheets, http://www.dnr.state.oh.us/soilandwater/streammorphology.htm, can be used in lieu of paper forms to enable faster analysis of the field data.

Reference Reach Field Form

Pebble Count Data

Gage: No:

Reach: Date:



Site:

Location:

Staff: Date:

Input Variables			Output Variables	
Bankfull Cross Sectional Area (A_{BKF})		ft^2	Bankfull Mean Depth $D_{BKF}=(A_{BKF}/W_{BKF})$	ft
Bankfull Width (W_{BKF})		ft	Wetted Perimeter (WP) $(\sim(2*D_{BKF})+W_{BKF})$	ft
D_{84} (Riffle)		mm	D_{84} (D_{84} in mm/304.8)	ft
Bankfull Slope (S)		ft/ft	Hydraulic Radius (R) (A_{BKF}/WP)	ft
Gravitational Acceleration (g)	32.2	ft/s^2	R/D_{84} (use D84 in feet)	ft/ft

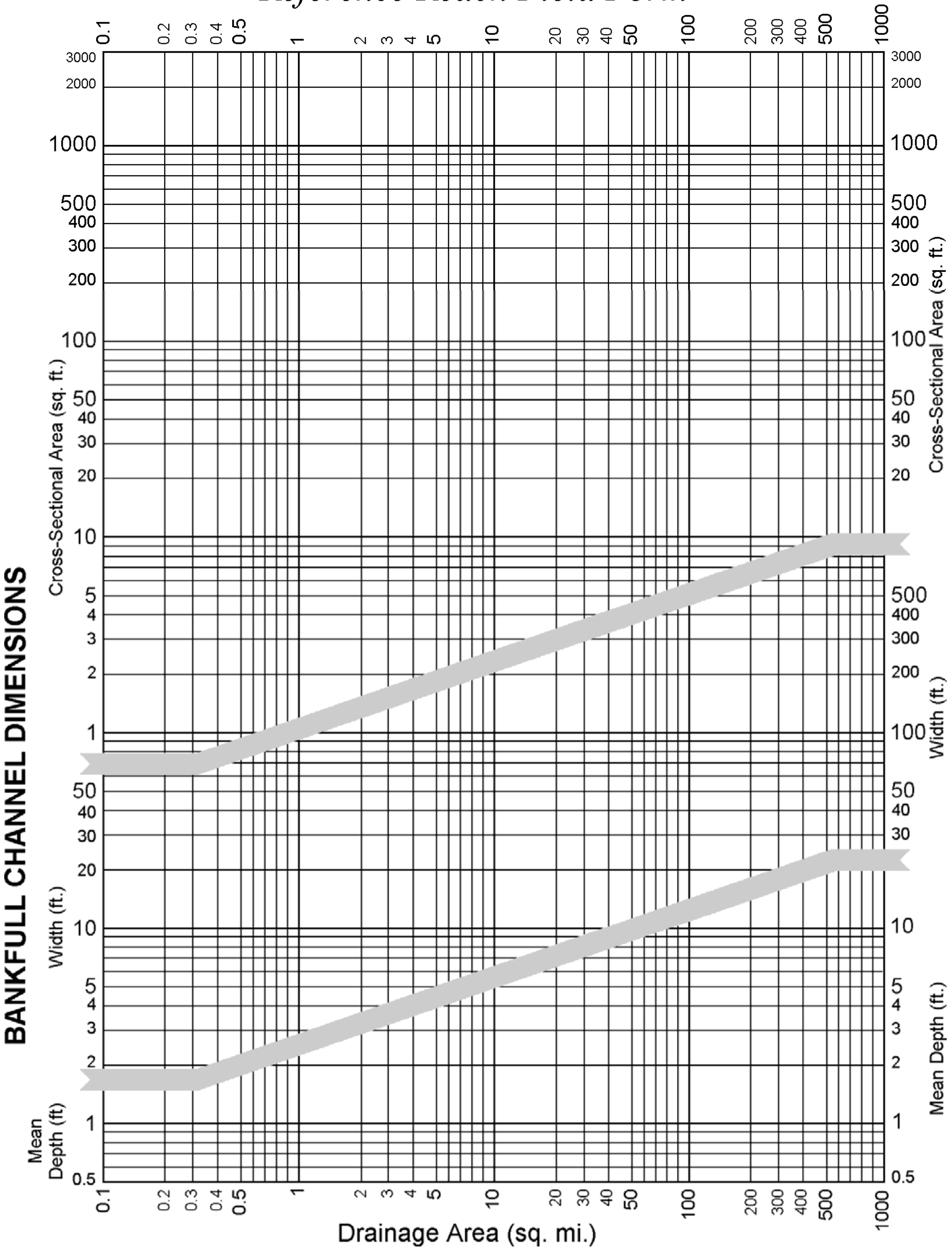
R/D₈₄, u/u*, Manning's n	
u/u* (using R/D_{84}: See Reference Reach Field Book, p. 188; River Field Book, p. 233)	ft/s/ft/s
Manning's n: (Reference Reach Field Book, p. 189; River Field Book, p.236)	$ft^{1/6}$
Velocity: from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$	ft/s

u/u*=2.83+5.7logR/D₈₄	
u*: $u^*=(gRS)^{0.5}$	ft/s
Velocity: $u=u^*(2.83+5.7\log R/D_{84})$	ft/s

Manning's n by Stream Type	
Stream Type	
Manning's n: (Reference Reach Field Book, p. 187; River Field Book, p.237)	$ft^{1/6}$
Velocity: from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$	ft/s

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	cfs
Velocity: (u=Q/A or from stream gage hydraulic geometry)	ft/s

Reference Reach Field Form



Summary of **USGS Gage Station** Data/Records for
Stream Channel Classification

Station Name:	Station Number:
Location:	Period of Record: years
Drainage area: acres sq. mi.	Mean Annual Discharge (QA): cfs

Classification Parameters

Staff:	Field Work Date(s):

Stream Type:

Entrenchment Ratio (ER):

Ratio of the flood-prone area width divided by bankfull channel width (Wfpa/Wbkf) (riffle section)

Width/Depth Ratio (W_{bkf}/d_{bkf}):

Bankfull width divided by the mean depth in a riffle section

Channel Sinuosity (K):

the ratio of stream length divided by valley length or estimated from a ratio of valley slope divided by channel slope

Water Surface Slope (S): feet/foot

Riffle to riffle water surface slope for a reach approximately 20 - 30 bankfull channel widths in length

Channel Material (Particle Size Index) D_{50}: mm.

Mean diameter of channel material sampled from the channel surface between the bankfull stage and thalweg elevations

Bankfull Characteristics

Determined by Field Measurement		**Determined from Gage Data Analysis**	
Bankfull Width (W_{bkf}):	ft.	Bankfull Width (W_{bkf}):	ft.
Bankfull Mean Depth (d_{bkf}):	ft.	Bankfull Mean Depth (d_{bkf}):	ft.
Bankfull Xsec Area (A_{bkf}):	sq. ft.	Bankfull Xsec Area (A_{bkf}):	sq. ft.
Wetted Perimeter (W_p):	ft.	Wetted Perimeter (W_p):	ft.
Bankfull Stage: (gage height):	ft.	Bankfull Stage: (gage height):	ft.
Est. Mean Velocity (u):	ft./sec.	Est. Mean Velocity (u):	ft./sec.
Est. Bankfull Discharge (Q_{bkf}):	cfs	Est. Bankfull Discharge (Q_{bkf}):	cfs

Maximum Depth (d_{mbkf}): feet

Maximum depth of the bankfull channel, or distance between the bankfull stage and thalweg, in a riffle section

Width of the Flood-Prone Area (W_{fpa}): feet

*Floodplain width at twice maximum depth (width @ 2 * D_{mbkf})*

Bankfull Discharge associated with field-determined bankfull stage (Q_{bkf}): cfs

(From gage height reading at staff gage plate and tabular stage-discharge curve data)

Recurrence Interval (Log-Pearson) associated with field-determined bankfull discharge (R.I.): years

From the Annual Peak Flow Frequency Analysis data for the Gage Station, determine:

1.5 year R.I. Discharge:	cfs	10 year R.I. Discharge:	cfs
2 year R.I. Discharge:	cfs	25 year R.I. Discharge:	cfs
5 year R.I. Discharge:	cfs	50 year R.I. Discharge:	cfs

Meander Geometry

Meander Length (L_M):	feet	Radius of Curvature (R_C):	feet
Belt Width (W_B):	feet	Meander Width Ratio (W_B/W_{BKF}):	

Hydraulic Geometry

Based on USGS Discharge Summary Notes data (Form 9-207) and regression analyses of measured discharge (Q) with the hydraulic parameters of Width (W), Area (A), Mean Depth (d), and Mean Velocity (u); determine the Intercept Coefficient (a) and the Slope Exponent (b) values for a power function of the form $Y = aX^b$ when Y is one of the selected hydraulic parameters and X is a given discharge value (Q)

	Width (W)	Depth (d)	Area (A)	Velocity (u)
Coefficient (a):				
Slope Exponent (b):				

include labeled copies of three photos of each cross-section - upstream, downstream, and both banks; include the entire channel cross section with a vertical survey rod in the frame