Instruction Manual

STREAM ATTRIBUTE ASSESSMENT METHODOLOGY (SAAM)
(Piedmont Physiographic Region)

U.S. Army Corps of Engineers, Norfolk District

<u>Stream Attribute Assessment Methodology Instructions</u>

For use in the Virginia Piedmont Physiographic Province on Wadeable Streams

<u>CONTENTS:</u>

<u>1. General Notes and Information:</u>

A. <u>General</u>: The <u>Stream Attribute Assessment Methodology</u> (SAAM) utilizes a subset of variables and protocols from the EPA's <u>Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: periphyton, benthic macroinvertebrates, and fish (RBPs)</u>. The RBPs are a synthesis of methods employed by numerous state water resource agencies and have been extensively peer reviewed and field-tested across a wide variety of environmental gradients. The SAAM ranks the relative condition of streams based on five of the RBP variables plus one additional attribute to describe the condition of specific streams. The SAAM attributes are: Channel Incision, Riparian Area, Bank Stability, Instream Habitat, Sediment Deposition and Channel Alteration. The SAAM is a regulatory tool used to quantify impacts and guide decisions regarding the appropriate amount of compensatory mitigation required for permitted impacts. It does not replace the overall decision-making authority and responsibility of the Corps.

B. <u>Service Area:</u> This version of the SAAM is intended for use in the **<u>Piedmont Physiographic Region</u>** of Virginia (see Figure 1). Efforts are currently underway to calibrate the SAAM for use in the Coastal Plain Physiographic Region.

C. <u>RCI and SAR</u>: Fundamental to use of the SAAM is the <u>Stream Assessment Reach</u> (SAR) and the Reach Condition Index (RCI). The SAR is used in conjunction with the RCI to determine mitigation requirements or the amount of mitigation provided by a proposal.

1. The SAR is the total length of stream being evaluated with the SAAM for any purpose. SAR could refer to either the length of proposed stream impacts or the length of proposed stream mitigation. The SAAM is used to

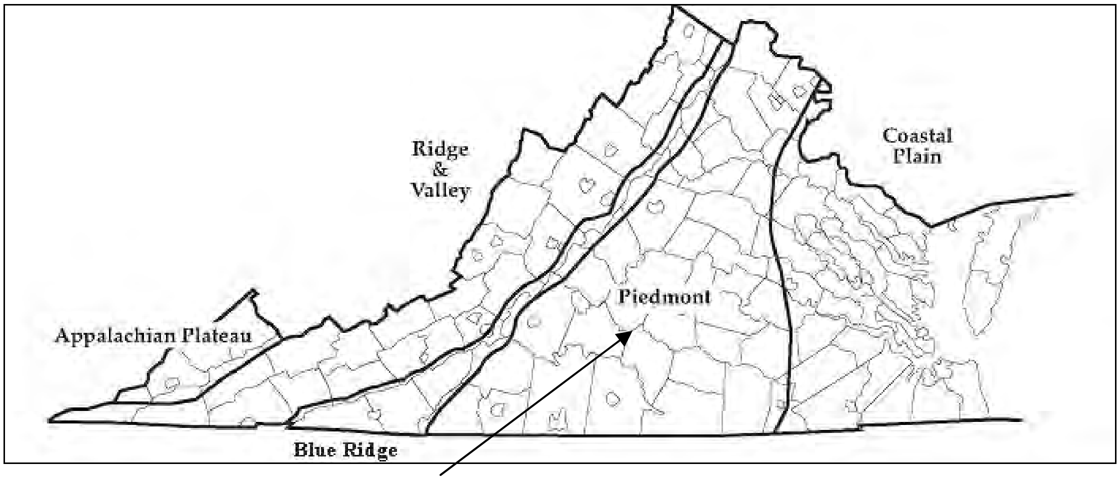

Figure 1. Piedmont Physiographic Region

quantify those impacts or calculate the amount mitigation lift possible in the SAR that is evaluated. Some streams may require segregation into several different SARs, requiring more than one SAAM Form if there is significant variation in attributes within the stream. For example, a substantial change in Bank Height Ratio (see definition and explanation below) within a SAR may warrant a separate form. On the other hand, a SAR that is relatively homogenous should require only one form regardless of its overall length.

2. The RCI is the overall score assigned to each SAR by use of the SAAM. The RCI is the summation of the CIs for the 6 attributes. Streams proposed as mitigation for impacts are similarly assessed in order to determine their pre-mitigation baseline condition or RCI. Conceptual mitigation plans target one or more attributes for restoration or improvement and the net increase above the baseline RCI condition becomes the basis for overall mitigation credit; otherwise referred to as mitigation lift. For preservation projects, the SAAM is applied to the proposed preservation stream and its existing RCI is determined. A preservation ratio of 5:1 is applied to the preservation stream's mitigation equation. A ratio of 3:1 may be applied to proposals that will preserve an entire watershed. Generally streams with an RCI of 3 or greater are candidates for preservation credit.

D. When to use the SAAM: The SAAM is intended for use on any stream projects which will require mitigation for permitted impacts, except as noted in 1-4 below.

1. Projects typically covered by a nationwide permit that are non-reporting (generally less than 300 linear feet of stream impacts) will generally not require mitigation or assessment by use of the SAAM.

2. Impacts to ephemeral streams are generally excluded from assessment using the SAAM.

3. Impacts to non-wadeable 3rd Order or larger streams are generally outside the purview of the methodology and assessment with the SAAM is not required. However, the SAAM may be used on non-wadeable 3rd order and larger streams as a tool to provide information or guide mitigation decisions.

4. With respect to ephemeral streams and non-wadeable 3rd Order and larger streams, impacts and mitigation will be considered on a case-by-case basis.

E. <u>Forms:</u> Stream impact assessment and mitigation crediting involves the use of 3 forms, which are EXCEL spreadsheets:

1. SAAM Form 1 is the form for assessment of impact streams, pre-restoration streams, and preservation streams. Use of Form 1 on impact streams determines the relative condition or value of a stream being impacted. Use of Form 1 on pre-restoration or preservation streams establishes the baseline condition of the mitigation stream and serves as the basis for determining which attributes can be improved along with the degree of improvement, or the value of condition of streams to be preserved. There is a blank copy of Form 1 (gray title box) that can be printed for field assessments and an electronic version (green title box) into which field data can be entered. The electronic form automatically calculates the CIs and the RCIs when the field data are entered.

2. SAAM Form 2 is the form for evaluating restoration/enhancement proposals (hereafter referred to as "restoration"). It serves as the foundation for the conceptual mitigation plan (see below). After SAAM Form 1 is run on the pre-mitigation stream, SAAM Forms 1 and 2 can be used to identify which attributes can be improved and the predicted degree of improvement. For example; Form 1 shows that > 60 % of the pre-mitigation stream's banks are eroding, which scores a 2 (Poor condition). The mitigation goal targets restoration of the banks to an optimal post-mitigation condition based on repairing the 60% bank erosion. A post-mitigation score of 10 for right and left banks is then indicated on SAAM Form 2. Each attribute targeted for improvement is scored on the form in similar fashion and a post-mitigation RCI is calculated for the mitigation SAR. <u>**Note:**</u> When the mitigation proposal is preservation only, Form 2 is <u>not</u> used. Only Form 1 is necessary to establish the preservation stream's existing RCI.

3. SAAM Form 3 is the mitigation calculation form. Once the stream impact RCI and the pre- and post- mitigation stream RCIs are determined, these data, along with the impact stream length, are entered into Form 3. Form 3 automatically calculates the mitigation stream length necessary to compensate for the impacts. In those cases where preservation only is the proposed mitigation, the impact stream length, impact stream RCI and the preservation stream RCI (Form 1, only) are

entered into Form 3. Form 3 automatically calculates the preservation stream length necessary to compensate for the impacts.

F. Definitions: A list of **DEFINITIONS** is located at the end of this document.

2. General Instructions For Use of the SAAM:

A. Determine the Stream Assessment Reach (SAR) for proposed stream impacts. The SAR is the linear feet of stream proposed for impact and typically identified in the Joint Permit Application under Wetlands/Waters Impact Information. For example: A proposed relocation and piping of 520 linear feet of stream. The SAR in this case is the 520 feet of proposed stream impacts.

B. Walk the length of the SAR and make note of the general condition of the stream. At this stage, determine if segregation of the stream into more than one SAR is necessary. As pointed out above, one form is adequate for streams that are fairly homogeneous in overall condition. More than one form may be necessary, however, if there are marked differences within the overall stream reach. For example, if part of the reach has been channelized, one might consider running a separate SAAM on that section; or, if Channel Incision changes dramatically; i.e., above and below a head-cut, separate forms may be warranted. Whether or not the reach is broken into sub-reaches, each with its own assessment will require best professional judgment and the rationale for using one form or multiple forms should be documented.

C. For Attribute 1 (Channel Incision), locate a suitable representative location to measure bankfull depth and top-of-lowest-bank; note significant changes, such as head-cuts, that may warrant additional forms. Measure Channel Incision and enter the raw data on the SAAM Form 1. Within each reach, multiple Bank Height Ratios taken from different locations should be fairly consistent, unless a significant change in stream condition is present; i.e., above and below a head-cut. Checking multiple locations is a good way to check for accuracy.

D. For Attribute 2 (Riparian Area), evaluate the Riparian Area condition within a 100 foot wide buffer from the top of the right and left banks along the entire length of the SAR.

E. For Attributes 3, 4, 5, and 6, walk along the reach, and evaluate the Bank Stability, Instream Habitat and Available Cover, Sediment Deposition, and Channel Alteration. It is important to carefully read EACH description in each condition category (Optimal, Suboptimal, Marginal or Poor) and determine which block best describes that particular attribute for the stream being evaluated. Once the appropriate condition category is decided, determine its score. If the attribute strongly represents the high quality end of the description, score it at the HIGH end of the range. If the attribute represents the low quality end of the description, score it at the LOW end of the range. If it is marginal, or you cannot decide high or low, choose the middle score.

3. Completing SAAM Form 1 Field Measurements for the 6 Attributes:

The following is a general summary of how to complete the field measurements for each of the six attributes (Section A); steps to approach a conceptual mitigation plan and determine mitigation length required (Section B), and how to complete the data field on the electronic version of the form (Section C).

A. Measuring/Scoring the Six Attributes

1. Channel Incision

A. The degree of channel incision is evaluated by determining the Bank Height Ratio (BHR) of a representative section of the SAR. The BHR is calculated by dividing the Top of Lowest Bank (TOLB) by the Maximum Bankfull Depth (BFD). Both the TOLB and BFD are measured in a riffle, from the thalweg, and at the same cross-section. Be sure that the survey rod remains stationary for both measurements. The lowest bank refers to the lower of the left or right bank (where the bank intersects the floodplain or terrace) on any given cross-section, and is not a low bank or bar within the channel cross-section. There may be instances whereby an incised stream has reestablished a stable pattern, profile and dimension at a lower elevation and stable bankfull benches are apparent. In these instances, the bankfull bench should be considered as the new TOLB (Figures 3, 6). Figures 2-6 show the relationship between BFD and TOLB. Appendix 2 provides information on identifying field indicators of bankfull stage.

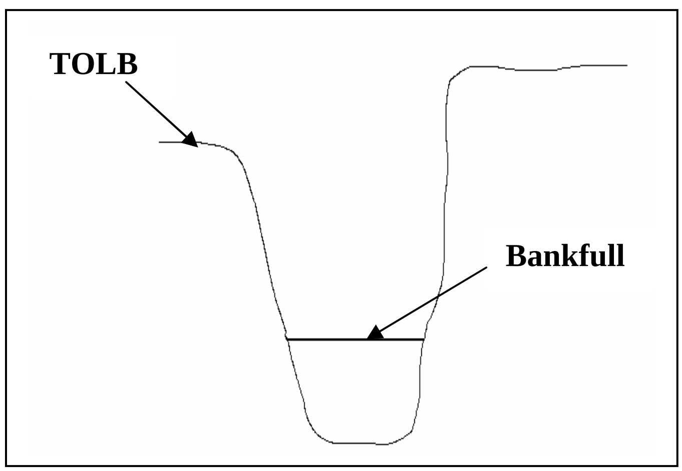

Figure 2. Relationship between Bankfull and TOLB in an incised channel without a bankfull bench.

B. On the SAAM Form 1, enter the Maximum Bankfull Depth (BFD) and Top of Lowest Bank (TLB) in inches in the blue cells. The Bank Height Ratio (BHR) is calculated by dividing the TOLB by the BFD. The CI is calculated by dividing 1.0 by the BHR. Additional forms may be necessary in the event the BHR changes significantly within the SAR; for example, above and below a head-cut (Figure 7).

C. For actively incising streams, where BFD is difficult to locate, make your best estimate of bankfull based upon watershed size and condition, and in stream features. Note: keep in mind that streams with large watersheds will have bankfull stage indicators at a higher elevation on the bank than streams with smaller watersheds. If necessary, walk upstream and downstream of the SAR and locate other indicators of bankfull stage (Figure 8).

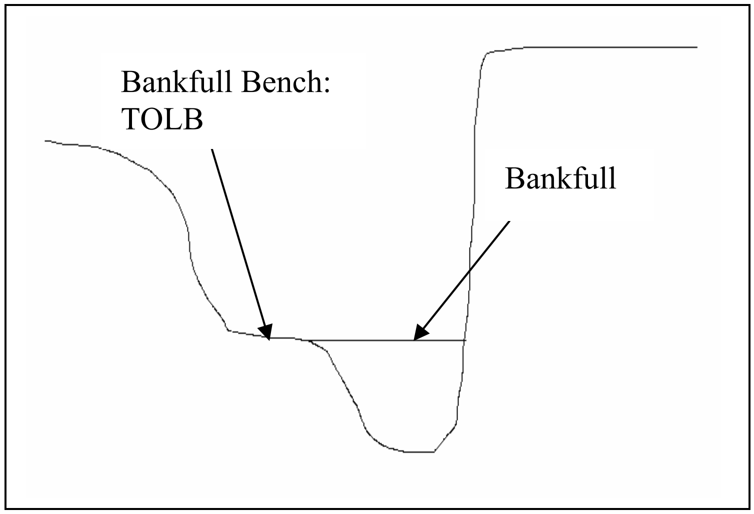

Figure 3. Relationship between Bankfull and TOLB in an incised channel with a bankfull bench.

2. Riparian Areas

A. The riparian zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, bare soil, rocks, or buildings are installed near the stream banks. Residential developments, urban centers, golf courses, and rangeland are the common causes of anthropogenic degradation of the riparian zone. Conversely, the presence of "old field" (i.e., a previously developed field not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone and may be given relatively high scores.

B. This form is designed to account for variability in the riparian area conditions along both stream banks, for a width of 100 feet, for the entire SAR. Each bank is evaluated separately and the cumulative scores (right and left banks) are used for this attribute's CI.

Figure 4. Channel Incision: without bankfull bench - TOLB -

Figure 5. Channel Incision: Early channel evolution of bankfull bench within incised channel

Figure 6. Channel Incision: Channel has stabilized at a new base-elevation with an established bankfull bench

Figure 7. Channel Incision: Change in BHR due to head-cut

Figure 8. Looking upstream and downstream to establish bankfull stage from field indicators

C. Evaluate the Riparian Area condition within a 100 foot wide buffer from the top of each bank and along the entire length of the SAR. The SAR Area may be homogeneous (for example: all pasture land on both banks) or heterogeneous (example: 33% forested, 33% cropland, and 33% pavement). It is possible that the SAR could contain multiple condition categories; each with one or more scores. In that case, each condition category present within the SAR is scored and weighted by the percent it occupies within the SAR. Percentages and scores are determined separately for Right and Left banks. For example: Suboptimal comprises 30% of the Right Bank SAR and its score is 7; Marginal comprises the other 70% of the Right Bank SAR and its score is 3. The electronic version of the SAAM form calculates a weighted sub-condition index for each bank and then the total Riparian Area Condition Index for the SAR.

D. Determine the left bank (LB) and right bank (RB) by facing downstream. Visually estimate the percent canopy cover using the guide in Appendix 3 and assess the quality of the riparian areas on both sides of the stream within a 100-foot wide buffer from the top of each bank and along the entire length of the SAR. Each Riparian Area condition category (Optimal, Suboptimal, Marginal, Poor) present should be categorized and scored accordingly, based upon the verbiage in the Riparian Areas attribute. An estimate of the condition categories may be made from aerial photographs, visual estimates made on-the-ground or by measuring each different area to obtain its dimensions. Visual estimates should be avoided and more detailed measurements employed when the Riparian Area land use cover types are diverse and complex. For example, multiple intrusions of roads, parks, houses, etc., into the 100-foot zone may require more detailed measurements to determine percentages.

E. Enter the percent for the appropriate condition category and its score in the respective block(s) on the SAAM Form 1. The electronic version of the SAAM form calculates a weighted sub-condition index for each bank and then the total Riparian Area Condition Index for the SAR.

3. Bank Stability

A. This attribute measures active stream bank erosion. Signs of erosion include raw, exposed soil that is sloughing, crumbling, or otherwise unstable. Some banks may exhibit exposed soil, but are "crusted/healed over" and are not actively eroding (Figure 9). Such banks may exhibit early signs of stabilizing that include colonization by lichens and mosses, herbaceous vegetation establishing at the toe of the bank, etc. Such banks should not be included in this calculation. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately and the cumulative score (left and right) is used for this parameter.

B. Bank Stability is based on the relative amount of erosion observed along the entire SAR. Determine left/right bank by facing downstream and score each bank separately based upon the length of erosion divided by the overall SAR. Circle the score that best describes the conditions of the SAR on the SAAM Form 1. Add the left and right bank scores and divide the results by 10 to calculate the CI. This converts the raw score to an index ranging from 0 (poor) to 1.0 (optimal). The automated form automatically performs this calculation.

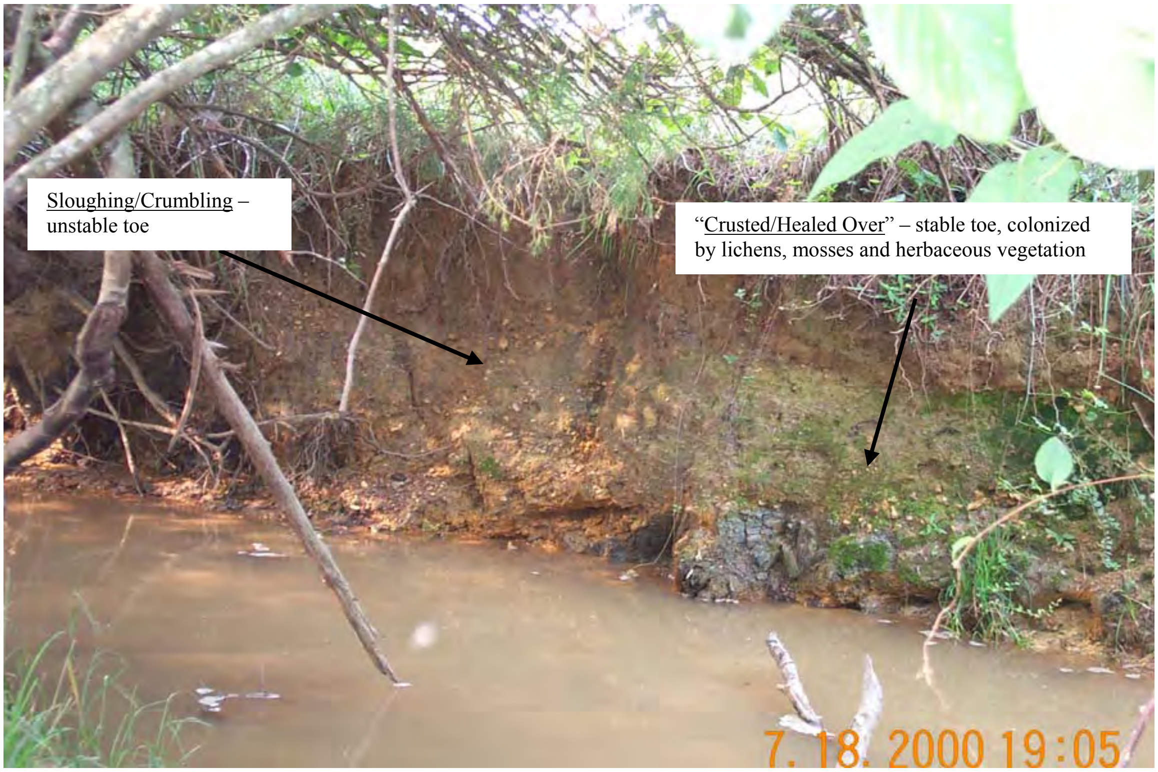

Figure 9. Bank Stability

4. Instream Habitat / Available Cover

A. This attribute includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, persistent leaf packs, and undercut banks; available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna. A wide variety and/or abundance of instream habitat features in the stream provide macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases. Riffles and runs are critical for maintaining a variety and abundance of insects and serve as spawning and feeding refugia for certain fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition. Riffles and runs offer a diversity of habitat through variety of particle size, and will provide the most stable habitat. Snags and submerged logs are also productive habitat structures for macroinvertebrate colonization and fish refugia.

B. Visually estimate the percent Instream Habitat and Available Cover using the guide in Appendix 4 and circle the score that best describes the conditions of the SAR on the SAAM Form 1. Examples of optimal and poor Instream Habitat/Available Cover are shown in figures 10 - 12.

C. Sedimentation of stream reaches can greatly affect the condition of habitat available. Habitat features buried by sediments provide little to no refuge for stream fauna. Also important is the diversity in hydrologic flow provided by structures in streams. Often referred to as eddies or dead-water areas, places where current slows, reverses, or stops are vital. Many macro fauna faced with no place to escape the constant flow of current cannot remain in the subject sections of a stream.

Figure 10. Instream Habitat/Available Cover: Optimal – pools, large woody debris and other habitat features > 50%

Figure 11. Instream Habitat/Available Cover: Poor – pools, large woody debris and other habitat features < 10%

Figure 12. Instream Habitat/Available Cover: Poor – unstable habitat

5. Sediment Deposition

A. This attribute measures the amount of sediment that has accumulated in pools and the stream bottom, and the changes that have occurred to the stream bottom as a result of the deposition. Deposition occurs from large-scale movement of sediment. Sediments, in this context, may include coarse gravels and fine silts (Figures 13, 14). Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of runs and pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow decreases, such as pools and bends. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms

B. Circle the score that best describes the conditions of the SAR on the SAAM Form 1. Divide the score by 11 to calculate the CI. This converts the raw score to an index ranging from 0 (poor) to 1.0 (optimal). The automated form automatically performs this calculation.

Figure 13. Sediment Deposition: fine sediments and enlarged point-bar formation

Figure 14. Sediment Deposition: shifting gravels; bottom frequently changing, increased bar development

6. Channel Alteration

A. This attribute is a measure of large-scale, artificial changes, including stormwater inputs that affect the pattern, profile and/or dimensions of the stream channel (Figures 15-17). Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control or irrigation purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants than do naturally meandering streams. Channel alteration is present when artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; when the stream has been excavated or straightened for significant distances; when dams, culverts, and bridges are present; and when other such changes have occurred. Scouring is often associated with channel alteration.

B. Circle the score that best describes the conditions of the SAR on the SAAM Form 1. Divide the score by 11 to calculate the CI. This converts the raw score to an index ranging from 0 (poor) to 1.0 (optimal). The automated form automatically performs this calculation.

Figure 15. Channel Alteration: Mechanical modification changes channel pattern, profile and dimension

Figure 16. Channel Alteration: Mechanical modification changes channel dimension.

Figure 17. Channel Alteration: hydrologic modification of channel pattern, profile and dimension by increased flow and volume.

4. Calculating the Reach Condition Index (RCI) for Impact Streams and Mitigation Streams

A. The sum of all of the CI's for a particular SAR is the Reach Condition Index or, RCI. This is the overall numeric ranking of the stream being evaluated. The higher a stream's RCI, the better its condition is relative to another stream with a lower RCI. This is an important number because it provides the foundation for impact assessment and mitigation requirements. Steps for determining impacts and mitigation are:

Step 1. Use Form 1 to determine impact stream's RCIs.
Step 2. Locate a potential mitigation stream and formulate a conceptual mitigation plan (see Appendix 1).
Step 3. Use Form 1 to obtain the mitigation stream's pre-restoration condition RCI.
Step 4. Using the results from Step 3 (and Form 2), determine which attributes on Form 1 have improvement potential prior to any detailed design or plan development. For example, potential improvement to the Riparian Area attribute exists if livestock pasture occurs on both banks of the mitigation stream (Poor category) and the proposal is to replant a 100 foot wide forested riparian community on both banks having > 60% canopy cover and multiple forest layers (Optimal category).
Step 5. Determine linear feet of mitigation required.

B. Table 1 shows a project with impacts to 400 linear feet of a stream located in Prince William Forest National Park (Prince William County) with an RCI of 5.59; and a restoration project located on a stream in Cheswick Park (Henrico County) as the proposed mitigation stream having a pre-mitigation RCI of 1.95. (Watersheds were not considered in this example.) The table identifies the impact stream and its RCI (mitigation liability), the pre-restoration existing condition of the mitigation stream RCI, the attribute(s) targeted for improvement, the net increase in the mitigation stream's RCI based on those improvements, and the linear feet of mitigation stream necessary to compensate for the impacts. (Restoration/enhancement both referred to as "restoration".)

TABLE 1				
STEP 1: Prince William Forest Park Stream Impacts				
Linear Feet		**Reach Conditon Index (RCI)**		
400		**5.59**		
STEPS 2&3: Cheswick Park Stream Pre-Restoration Condition				
Attribute		**Condition**	**Score**	**CI**
1	Incision	BHR 2.1		0.47
2	Riparian	Mature Forested (LBci*%Cond.)+(RBci*%Cond.)] (0.8+0.8)/2	1.6/2	0.8
3	Erosion	480'/800' = 60% Eroding [RTB+LTB]/20 = CI	(3+3)/20	0.3
4	Habitat	400' @ <10%	1	0.1
5	Sediment	400' @ <20%	1	0.1
6	Chan Alt	400' @ Suboptimal	2	0.18
			RCI =	**1.95**
STEP 4: Proposed Mitigation Concept Plan Evaluation				
Attribute		**Proposed Restoration Work**	Score	CI
1	Incision	No change.	BHR 2.1	0.47
2	Riparian	No change.	1.6/2	0.8
3	Erosion	Restore bank erosion with bioengineering techniques [RTB+LTB]/20 = CI	16/20	0.8
4	Habitat	Increase habitat to > 50% of bottom	9	0.8
5	Sediment	Assume improvement based on work	9	0.8
6	Chan Alt	No change.	2	0.18
			RCI =	3.85
STEP 5: Concept Plan Mitigation Lift Calculation				
Cheswick Park Stream Pre-Mitigation RCI				**1.95**
Cheswick Park Stream Proposed Mitigation Concept Plan RCI				**3.85**
Mitigation Lift RCI (3.85-1.95)				**1.9**
Mitigation Liability- Pr William Park Stream RCI				**5.59**

In this example, there are 400 linear feet of impacts at Prince William scoring a 5.59. The mitigation lift provided by the proposed work at Cheswick is 1.9. The linear feet required can be determined by this equation:

(RCI impacted stream / RCI of mitigation lift) * Linear Feet of impacts = LF required), or

(5.59 / 1.9) *400 = 1,177

Therefore, 1,177 linear feet of restoration at the Cheswick site is required for 400 feet of Prince William stream impact. If a lower quality site were impacted, and a more favorable mitigation site was selected, the linear feet required would decrease proportionally.

Mitigation that is solely preservation of an existing stream will have a 5:1 preservation ratio applied to the preservation stream's RCI as determined by the SAAM (Note: a preservation ratio of 3:1 may be applied to mitigation projects that preserve entire watersheds). The calculation is as follows:

[(Impact Stream RCI/Preservation Stream RCI)*Preservation Ratio]*Linear Feet of Impact Stream = Preservation Stream Length Required

Using the example of 400 linear feet of impact to the Cheswick Stream (RCI = 1.95) and preservation at the Prince William Park stream (RCI = 5.59), the amount of preservation stream necessary is:

[(1.95/5.59)*5]*400' = 830 linear feet of preservation stream required.

As one can see, the preservation ratio will increase or decrease, depending on the RCI of the impact stream and the RCI of the preservation stream. If the RCIs between the impact stream and the preservation stream are equal, a straight 5:1 ratio would apply. For example:

[(3.2/3.2)*5]*400' = 2,000 linear feet of preservation stream

In general, only streams with an RCI $\geq$ 3.0 are acceptable for preservation.

Step 6. Once the Corps has accepted the conceptual mitigation plan and its potential credit, a detailed stream mitigation plan will be developed that will accomplish the goals and achieve the credit identified in the conceptual mitigation plan.

Step 7. The Corps will then review the final mitigation plan, determine if the commitments outlined in the conceptual plan are reflected in the final plan, and if its restoration features are properly designed and located. If not, applicant will modify the plan, or less credit will be provided.

Step 8. Approval of the final plan and credit provided.

Step 9. Construction of the restoration project.

Step 10. Monitoring as per the monitoring protocol in the final plan.

5. How to Enter Data in the Electronic Version of the SAAM Form

A. The field data from SAAM Form 1 (Field) can be entered into the appropriate cells in the automated Excel form. Only the blue cells should be populated or modified. When entering data into the blue cells, enter numeric data **ONLY** (i.e., do not enter "feet" or "ft."). The automated Excel form will automatically calculate the values.

6. Analysis of Stream Restoration Proposals

A. The SAAM is a tool used to assess stream impacts and the appropriate amount of required mitigation. It is a crediting tool and not a substitute for elements necessary for the proper design and construction of stream restoration projects or the evaluation and review necessary to determine if proposals will be successful.

B. Upstream conditions and changes weigh HEAVILY on the potential success of stream restoration and preservation proposals. If the future condition of the watershed is uncertain, the success of proposed mitigation plans are accordingly uncertain. Stream restoration projects, and stream preservation, designed or suited for a particular flow and volume regime may be dramatically altered and damaged by changes in upstream conditions that alter flow regimes.

C. Analyze the condition of the stream proposed for mitigation by use of the SAAM Form 1. Then use the SAAM Forms 1 & 2 to guide your analysis of the project being proposed and score each attribute. Determine the RCI for each reach and enter them on SAAM Form 3. Guidelines for assigning credit on SAAM Form 2 and based upon the conceptual mitigation plan, are as follows:

1. Channel Incision: Credit will be given to the degree that the channel is reconnected to the floodplain and that result in an improvement to the BHR. Generally, improvements to BHR are reserved for Priority 1 and 2 restorations (Figure 18).
2. Riparian Area: Planting plans that ensure vertical stratification of different forest layers can be credited with a maximum CI of 2.0 for a 200 foot wide riparian buffer (100 foot buffers would receive a CI of 1.0).
3. Bank Stability: Optimal credit is given for proposals to repair > 95% of the banks and that include re-vegetating with herbaceous and woody species, erosion control matting and temporary seeding, appropriate bank protection structures, and grading to achieve proper dimension and profile (Figure 19). Credit less than Optimal will be given to the extent that one or more of these measures are lacking in the mitigation proposal.
4. Instream Habitat and Available Cover: Instream habitat features appropriate for the stream and sufficient to cover > 50% of the channel bottom may score at the high end of the range. Optimal credit is given when instream habitat is coupled with Riparian Area restoration (see item 2, above) or site selection includes an existing Optimal Riparian Area condition, and measures to improve Bank Stability (item 3). Less than Optimal credit is given to proposals that result in < 50% coverage in habitat features and/or ones in which the Riparian Area (either proposed or existing) is less than Optimal, or those that do not include Bank Stability measures.
5. Sediment Deposition: Optimal credit is considered when measures to improve Riparian Area (item 2) and Bank Stability (item 3) are proposed. However, these measures primarily deal with in-situ sources of sediment but do not address upstream sources. If significant sources of sediment are identified upstream that are beyond the control of the applicant, one should consider another mitigation site or consider a lower condition category such as Marginal or Poor.
6. Channel Alteration: Optimal credit is given to proposals that restore stream pattern, profile and dimension (Figure 18). Less than Optimal credit may be given for proposals that affect channel dimension by

restoring the cross-sectional area of the channel, creating bankfull benches and stabilizing stream slope with appropriate grade control structures (Figure 19).

Figure 18. Channel Incision/Channel Alteration - mitigation: Restoration of stream channel pattern, profile and dimension that reconnects the stream to its floodplain

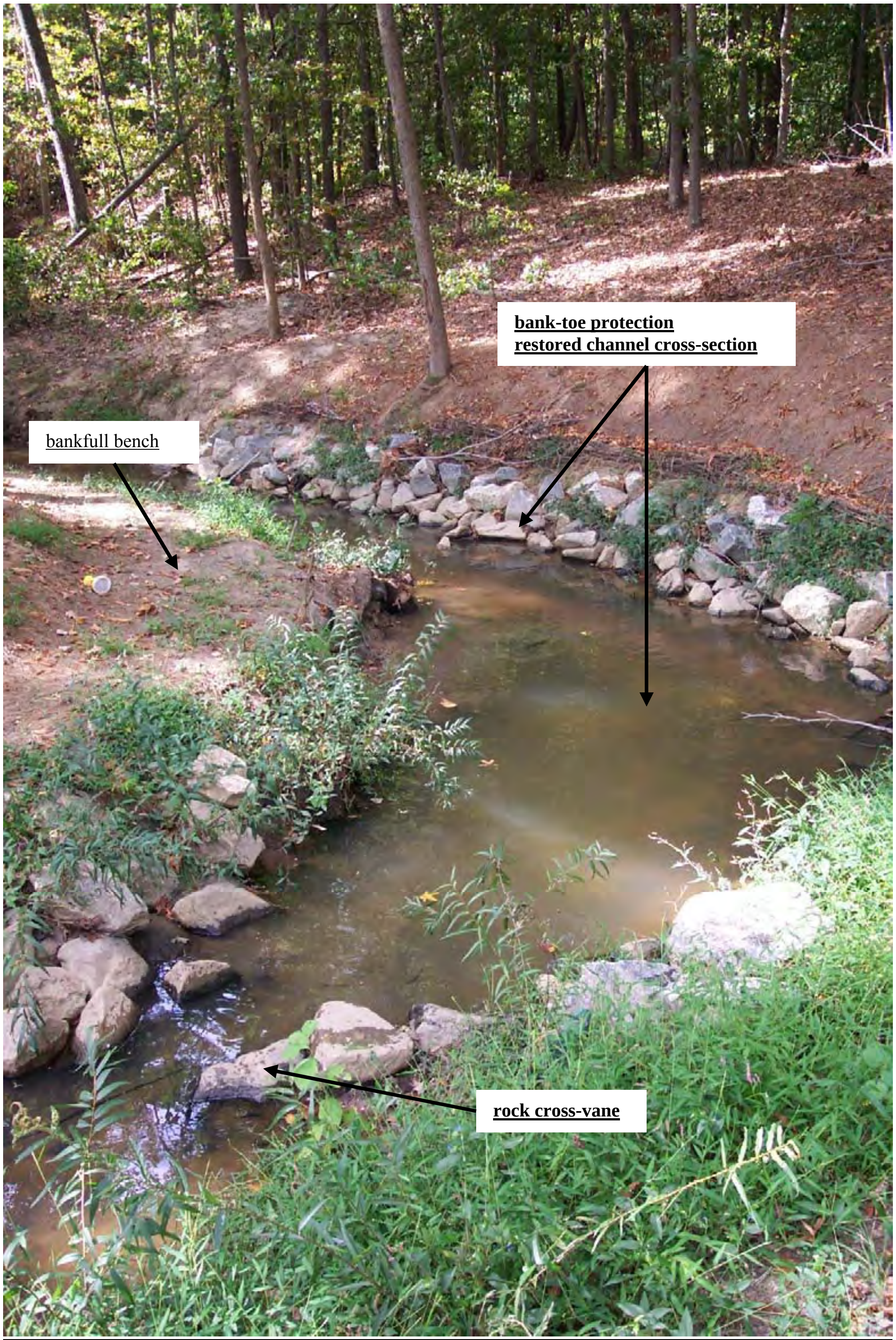

Figure 19. Channel Alteration/Channel Incision - mitigation: Restoring channel dimension within existing pattern; providing grade control

7. Analysis of Stream Preservation Proposals

A. Determine whether the proposed preservation is located on a stable stream, which should remain stable in the future. In general, only streams with an RCI $\geq$ 3.0 are acceptable for preservation.

B. Use the SAAM Form 1 to evaluate the condition of the stream proposed for preservation.

C. Credit may be given to the Riparian Area attribute out to 200 feet on each side of the stream for a maximum CI of 2.0.

D. If the entire watershed is not included in the preservation, the ratio is 5:1. If the entire watershed is preserved, credit may be given at a 3:1 preservation ratio.

8. Evaluating Stream Restoration/Enhancement Proposals with Form 2

A. This form is self explanatory and is designed to consolidate all impacts and mitigation in one place. Multiple forms will be needed for different combinations of mitigation reaches proposed.

B. Insert the linear feet of stream impact and RCI data into the appropriate blue cells on SAAM Form 3 for each field form completed or reach analyzed. This form will calculate the linear feet of stream mitigation for each SAR impacted.

9. DEFINITIONS:

Bankfull Depth (BFD): Maximum water depth as measured from the bottom of the channel in the thalweg (see below) portion of a riffle (that portion of the channel between an upstream pool and the next downstream pool) to bankfull stage elevation (Note: Measures of BFD should never be taken in a stream's pool zone).

Bank Height Ratio (BHR): The relationship between the top of the lowest bank (TOLB) and maximum bankfull depth (see below). Bank Height Ratio is a measure of channel incision (see below). Bank Height Ratio is determined by dividing the TOLB height by the maximum bankfull depth.

Bankfull Stage (BFS): A physical and/or biological indicator on the stream bank or in the stream channel that marks the elevation of ordinary high flows. These flows generally have a re-occurrence interval of 1.5 to 1.8 years and are the primary channel-forming flows. Bankfull Stage can be determined by such features as the elevation associated with the highest point bars/mid-channel bars, break in slope on the banks, particle size distribution (finer material that is associated with over-flow rather than more coarse material deposited in the active channel), water staining on rocks, trees, bridge abutments, exposed root hairs below an intact soil layer, the lower limit of woody vegetation on the channel banks, shelving, etc.

Channel Incision: The extent that a stream channel has down-cut through its floodplain. Bank Height Ratio, as described above, is a measure of channel incision. A BHR greater than 1 generally indicates that a stream has some degree of incision and that storm events in excess of 1.5 to 1.8 year events are necessary before the stream overtops its banks onto the floodplain.

Channelization: The process of artificially straightening a stream channel by using equipment to cut a new channel thereby eliminating a stream's natural meanders, or containing a stream by streambank filling or hardening. In some circumstances, channelized streams, over time, equilibrate to a new base elevation and re-establish stable dimension, pattern, and profile. As this occurs, new floodplains can evolve within the incised channel. While it may be evident that some streams were channelized in the past, they may not be considered channelized if they have evolved a new stable meander pattern and floodplain within a historic channelized section.

"CI": is the abbreviation for Condition Index. The CI for each attribute can not be greater than 1.0, except for the riparian attribute in mitigation proposals.

Left Bank/Right Bank: Left Bank and Right Bank designations are always determined while facing downstream.

Pool: the deeper, more still part of a stream or river (normally found in the bends of the stream or river).

Priority 1 Stream Restoration: A restoration project in which the old, incised channel is usually backfilled, and a new stream channel is constructed at the original floodplain elevation.

Priority 2 Stream Restoration: A restoration project in which the old, incised channel is usually backfilled, and a new channel and floodplain are created at the present stream elevation or higher, but not at the original floodplain elevation.

Priority 3 Stream Restoration: A restoration project in which the incised channel is stabilized in place, and small floodplain benches, but not a full floodplain, are created.

Priority 4 Stream Restoration: A restoration project in which the channel is stabilized in place, without floodplains or benches.

Reach Condition Index (RCI): The sum of CIs from the attributes in a particular SAR (Stream Assessment Reach).

Riffle: Riffles are the topographic highs between an upstream pool and a downstream pool generally characterized by "rapids" in a stream or river where shallow water flows swiftly over a rough or rocky surface.

Stream Assessment Reach (SAR): The linear feet of stream being evaluated for impacts or mitigation. While many stream projects may be evaluated with one SAR being assessed, some projects may need to be split into several SARs. Generally a new data form will need to be filled out for different SARs when significant variation of one or more attributes are encountered within the same project area.

Stream Slope: Slope is the difference in water surface elevation per unit length of stream. Percent slope should be determined from bed feature to bed feature, for example, from top of upstream riffle to top of downstream riffle. At a minimum, the length of stream for this determination should be at least 20 bankfull channel widths long.

Thalweg: The general meander line of deepest water in a stream when viewed from above. The thalweg is normally associated with the zone of greatest velocity and flow.

Top of Lowest Bank (TOLB): Bank height as measured from the bottom of the channel in the thalweg portion of a riffle (that portion of the channel between an upstream pool and the next downstream pool) to the top of the lowest bank. Top of Lowest Bank measurements in the stream channel are made at the same location in the thalweg as the Maximum Bankfull Depth. However, the location on the banks being measured may vary short distances up or down stream of the thalweg measurement location. The TOLB and the MBD are used to determine the bank height ratio; the BHR is a measure of channel incision as described above.

Wadeable Streams: Wadeable streams are defined by EPA as typically being Order 1 through 3 streams.

APPENDIX 1: CONCEPTUAL MITIGATION PLAN

Conceptual mitigation plans are developed to communicate the existing condition of, and mitigation potential for, streams where restoration (or preservation) is proposed for mitigation credit. Conceptual plans are intended to be developed prior to, and involving far less work than, full stream restoration plans. Conceptual plans are an efficient way to propose stream mitigation projects to the Regulatory Agencies to obtain preliminary approval before expending resources. They also provide mitigators with an idea of the potential credit available from a mitigation proposal if delivered as promised in the conceptual plan.

Conceptual plans should detail the pre-existing condition of streams proposed for mitigation (the mitigation stream), including the condition of each of the six attributes found in the SAAM, and the attributes that are proposed for improvement with detailed descriptions of the work proposed to correct each attribute. The Corps will allocate credit based on the net improvement in stream condition based upon each of the six attributes. The conceptual mitigation plan must include the following:

1. Location Map that shows where the proposed site is located on a regional basis.
2. Site Map showing where the mitigation Stream Assessment Reach (SAR) lies within the site or property.
3. A description of the watershed (rural, urban, percent developed, future build-out, etc.)
4. A copy of SAAM Form 1 and brief narratives for each of the 6 SAAM attributes describing the pre-restoration condition of the mitigation stream. (Rosgen channel type is one way to describe streams but is not mandatory.)

    A. Attribute specific information should include Form 1 plus:

    1. Incision: Form 1 should suffice.
    2. Riparian: A narrative of existing riparian condition.
    3. Bank Stability: Discuss the causes of the erosion.
    4. In-Stream Habitat: Discuss the causes of the habitat condition.
    5. Sedimentation: Discuss the sources and causes of sedimentation.
    6. Channel Alteration: Discuss the sources and causes of the alterations.

5. A copy of SAAM Form 2 plus brief narratives of the proposed methods and techniques you plan to employ to restore or achieve improvements to the targeted attributes, including the following:

    A. Describe the stream type or condition to which you plan to restore the stream. (see above regarding Rosgen types) Also, describe the stream design technique you plan to use. For example, the vast majority of projects should utilize natural stream design. If other techniques are selected, please justify why they are being proposed.
    B. Describe the Restoration Priority Level (1-4) you plan to utilize.

C. Describe the work proposed for each targeted attribute.

1. Incision: How will you correct incisions problems?
2. Riparian: How do you plan to restore riparian areas?
3. Erosion: How do you plan to correct erosion and provide for stable banks? Discuss in-stream structures proposed for bank protection
4. In-Stream Habitat: What measures do you propose to introduce habitat features to the mitigation reach? Discuss in-stream structures that will provide habitat. Discuss habitat changes or improvements you anticipate as the mitigation reach matures.
5. Sedimentation: Discuss how you will abate sedimentation and preclude it as the project matures.
6. Discuss how you plan to reverse or correct channel alteration.

D. Discuss the conditions upstream of the SAR including potential changes and how they may affect the proposed project.

6. The length of mitigation stream you propose as mitigation for impacts and to accomplish the goal of no net loss.

7. Discuss the site constraints that directly affect the choice of Priority Level of restoration & buffer establishment, as well as any that may decrease the value and thereby the score of the site (off site sediment sources, future development, utility line easements)

8. Discuss the presence or threat of invasive species and how you will address them.

RiverCourse

River Course is a fact sheet series developed to provide information and technologies related to the use of natural channel design in restoring impaired streams.

Finding Bankfull Stage in North Carolina Streams

nc stream restoration institute

Dominant, Effective, and Bankfull Discharge

Restoring streams to a stable form through natural channel design requires detailed information about surface water hydrology and the interactions between rainfall and overland flow or runoff. The channel-forming or dominant discharge is the most common method for sizing channel dimension if the stream restoration requires re-shaping the channel. Channel dimension is the cross sectional shape of the channel, including channel width, depth, and cross sectional area. **Dominant discharge** is a theoretical discharge that if constantly maintained in an alluvial stream over a long period of time will produce the same channel geometry that is produced by the long-term hydrograph. **Effective discharge** is defined as the discharge that transports the largest percentage of the sediment load over a period of many years. Effective discharge is the peak of a curve obtained by multiplying the flood frequency curve and the sediment discharge rating curve (Figure 1). **Bankfull discharge** is the discharge that fills a stable alluvial channel to the elevation of the active floodplain. This discharge is morphologically significant because it identifies the point where the active channel stops and the floodplain begins. In other words, it represents the breakpoint between the processes of channel formation and floodplain formation.

Since bankfull discharge is the only discharge that can be identified in the field using physical indicators, it is the one most commonly used in natural channel design. Most river engineers and hydrologists work under the assumption that dominant, effective, and bankfull discharges are approximately equal. This assumption has not been proven true in the Southeast; however, the differences will probably not significantly affect a natural channel design.

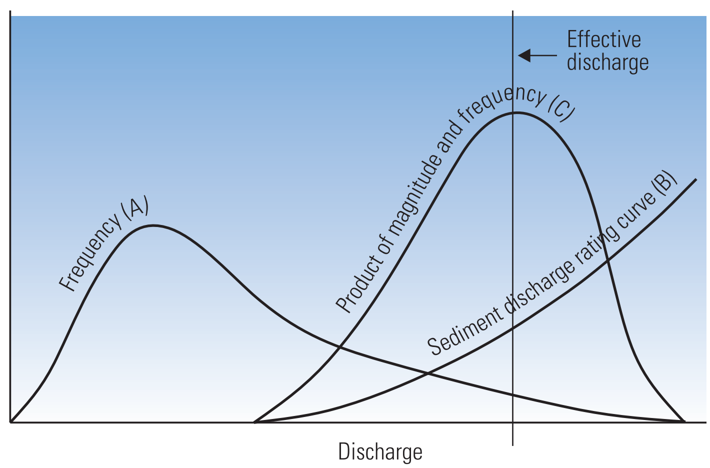

Figure 1. Effective discharge determination from sediment rating and flow duration curves. The peak of curve C marks the discharge that is most effective in transporting sediment. (Wolman and Miller, 1960)

Field Indicators of the Bankfull Stage

The height of water, or stage, during bankfull flow is the point at which flooding occurs on the floodplain. This may or may not be the top of the streambank. If the stream has downcut due to changes in the watershed or streamside vegetation, the floodplain stage indicator may be a small bench or scour line on the streambank. The top of the bank, which was formerly the floodplain, is called a terrace in this case. A stream with a terrace near the top of the banks is an incised, or entrenched, stream. If the stream is not entrenched, then

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bankfull is near the top of the bank. On average, bankfull discharge occurs approximately every 1.5 years. In other words, each year there is about a 67 percent chance of having at least one bankfull streamflow event. The bankfull event can occur any number of times per year.

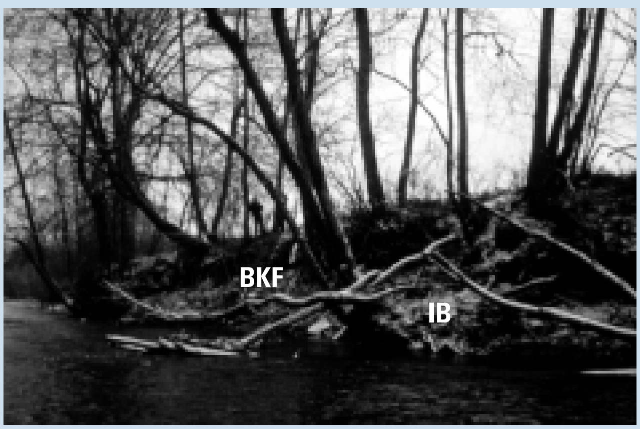
The Rosgen stream classification system uses bankfull stage as the basis for measuring the width/depth ratio and entrenchment ratio, two of the most important delineative criteria. Therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures. The Rosgen stream classification system is discussed in detail in *Application of the Rosgen Stream Classification System in North Carolina*, AG-590-2.

The most consistent bankfull indicator in North Carolina streams is the uppermost scour line. Other bankfull indicators include the back of a point bar, the upper break in slope of the bank, and occasionally the top of the bank. Often, there is another prominent feature known as the inner berm. The Army Corps of Engineers refers to the inner berm as the mean high water mark. This feature is usually identified as a scour line or small bench halfway between the low flow water surface and the bankfull stage. While this feature is morphologically significant, it is not the dominant discharge and should thus not be used for sizing a channel. Examples of bankfull indicators are included in Figure 2.

Regional Curves

Bankfull hydraulic geometry relationships, also called regional curves, first developed by Dunne and Leopold (1978), related bankfull channel dimensions to drainage area. Gage station analyses throughout the United States have shown that the bankfull discharge has an average return interval of about 1.5 years or 67 percent annual exceedence probability. The primary

Figure 2. Examples of the inner berm and bankfull indicators.



2a. Mills River Gage, Henderson County, C4 stream type. The break in slope at the lower bench is the inner berm (IB). Bankfull (BKF) is the upper scour line.

2b. Rocky Branch, Wake County, G4/F4 stream type. This stream is actively building a new floodplain. The front of the bench is the inner berm and bankfull is the back of the bench.

Figure 2c. South Fork Mitchell River, Surry County, C4/E4 stream type. Bankfull is rarely the top of a point bar. However, in cases where there is an excessive upstream sediment supply, a point bar will build to bankfull as shown in this photograph. The inner berm is the lower bench.

Figure 2d. Hominy Creek, Wilson County, E5 stream type. Bankfull is the break in slope near the top of the bank. Notice the deposition on the floodplain. The inner berm is the lower bench inside the channel.

purpose for developing regional curves is to aid in identifying bankfull stage and dimension in un-gaged watersheds and to help estimate the bankfull dimension and discharge for natural channel designs. The bankfull cross sectional area vs drainage area regional curve for North Carolina rural piedmont is shown in Figure 3.

Details about the development of regional curves and additional data for the rural piedmont of North Carolina are discussed by Harman et al., (1999). Additional curves for North Carolina physiographic regions will be posted on the web at the following address as they are completed: **http://www.bae.ncsu.edu/bae/programs/extension/wqg/sri.**

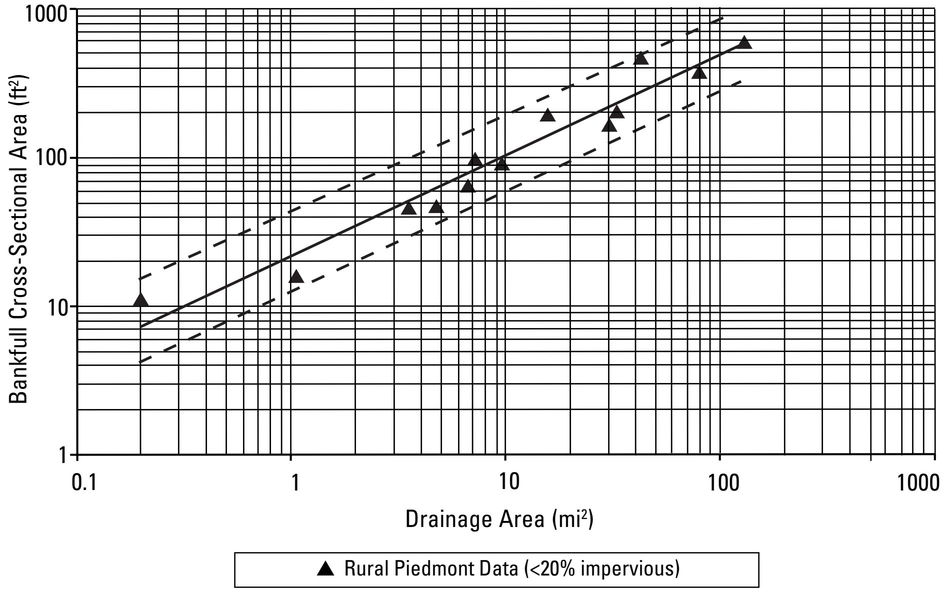


Figure 3. North Carolina rural piedmont curve.

Finding and Verifying Bankfull Stage in the Field

The following steps should be taken for identifying and verifying the bankfull stage in the field **on an un-gaged stream**.

1. Using a USGS quad sheet or similar map, determine the drainage area in miles squared for the watershed/stream section of interest.

2. Calculate the percent of impervious cover for the watershed of interest.

3. Using the indicators listed above, walk upstream and downstream for a distance of at least 20 times the bankfull width and flag the bankfull indicators.

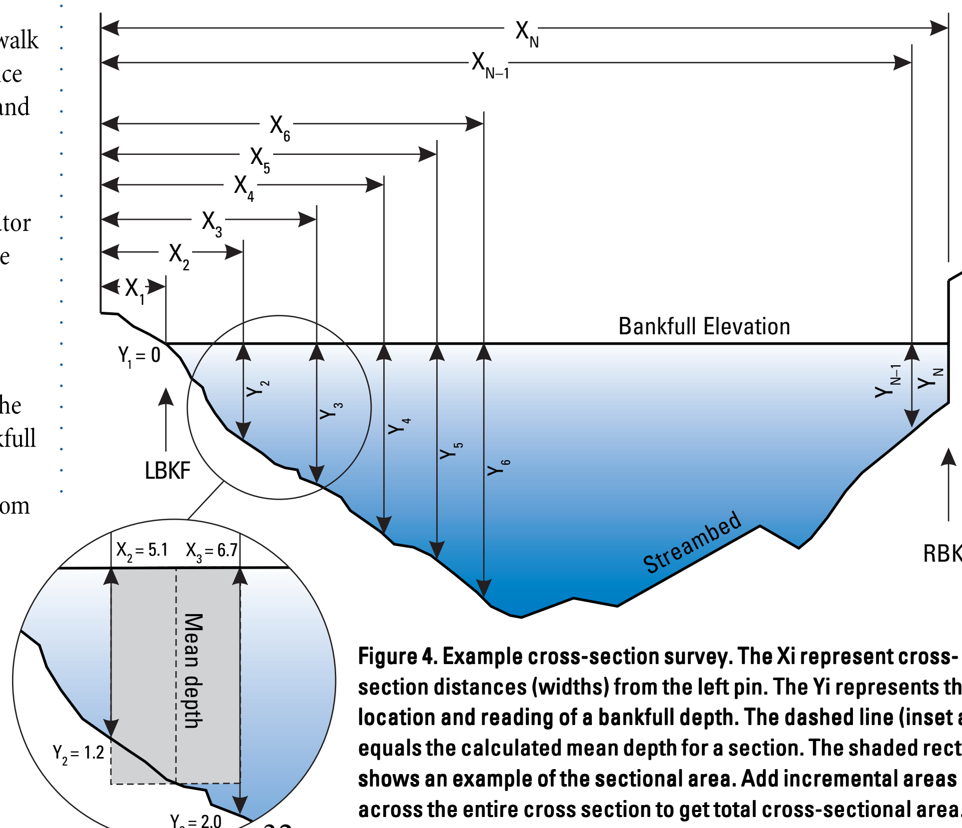
4. Use a survey rod to measure the difference between the bankfull indicator and the current water surface along the study reach. The variability of this difference should not be more than 6 inches.

5. At a riffle or run, pull a tape from the left bankfull indicator to the right bankfull indicator (cross section). Measure the depth to the channel bed/bottom (Yi), from a level line at bankfull or use a survey instrument, at several stations (Xi) along the cross section. Be sure to choose points that correspond to breaks in slope. Spacing between points should not be more than ¼ the width of the channel. An example is provided in Figure 4. Calculate the cross sectional area (A_{bkf}) as follows:

$$A_{bkf} = \Sigma (X_{i+1} - X_i) [(Y_i + Y_{i+1})/2]$$

where, X_i = cross section distances (widths) to successive vertical depths measured from the left bankfull station and Y_i = the vertical depth. The bankfull width (W_{bkf}) is measured as $X_{right\ bkf} - X_{left\ bkf}$.

6. For your watershed area and percent impervious cover, compare the field estimated bankfull cross sectional area to the area on the regional curve for that stream's hydrophysiographic region. If it is



Incremental area between X_2 and X_3

$= (X_3 - X_2) [(Y_2 + Y_3)/2]$

$= (6.7 - 5.1) [(1.2 + 2.0)/2]$

$= 2.56 \text{ ft}^2$

Figure 4. Example cross-section survey. The Xi represent cross-section distances (widths) from the left pin. The Yi represents the location and reading of a bankfull depth. The dashed line (inset at left) equals the calculated mean depth for a section. The shaded rectangle shows an example of the sectional area. Add incremental areas across the entire cross section to get total cross-sectional area.

close to the regression line (between the upper and lower 95 percent confidence limits, dashed lines on Figure 3) **AND** the feature is consistent for 20 bankfull widths, then this feature is (most likely) the bankfull stage.

If the measured bankfull cross sectional area falls outside of the 95 percent confidence limit, the following steps should be taken.

1. Recheck calculations.

2. If the point is below the lower 95 percent confidence limit, make sure that the feature is not the inner berm. Typically, the inner berm has roughly half the cross sectional area as bankfull. Look for other features above the inner berm, such as an upper scour line or break in slope that are consistent for a longer distance upstream and downstream of the cross section.

3. If the point is low, be sure there is not an upstream impoundment.

4. If the point is above the rural curve but below the urban curve, it may be part of a separate relationship for suburban development.

5. Visit a nearby gage station and check the return interval for BKF. It should be between 1 and 2 years.

6. Finally, know your watershed! Factors such as stream type, impervious cover, topography, channel materials, sediment transport, and bank vegetaion all contribute to the size of a bankfull channel.

Conclusion

Successfully identifying bankfull stage is the crux to any stream restoration design. With practice and experience, bankfull can be identified correctly and consistently in stable and moderately unstable streams. Regional curves should be used as an aid in verifying which morphological feature is or is not bankfull. When possible, gage stations near the project site should be surveyed and compared to the regional curve. If a gage station is surveyed, the bankfull stage should be carried through the gage plate to obtain a bankfull discharge from the stage/discharge relationship. Using the bankfull discharge and Log Pearson Type III flood frequency distribution, a return interval or exceedence probability can be obtained. The return interval should be between 1 and 2 years.

If regional curves are used for natural channel design, other methods such as Manning's equation or HEC 2/ HEC RAS should be used to estimate the bankfull discharge for comparison. If a sediment/ discharge relationship and flow duration curve is available for the project, then the effective discharge should be used for the design. In all cases, professional judgment is required to make the final design decisions. Therefore, it is imperative that the designer understands the cause and effect relationships governing the morphology of the channel.

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Prepared by

William A. Harman
Extension Specialist, Biological and Agricultural Engineering

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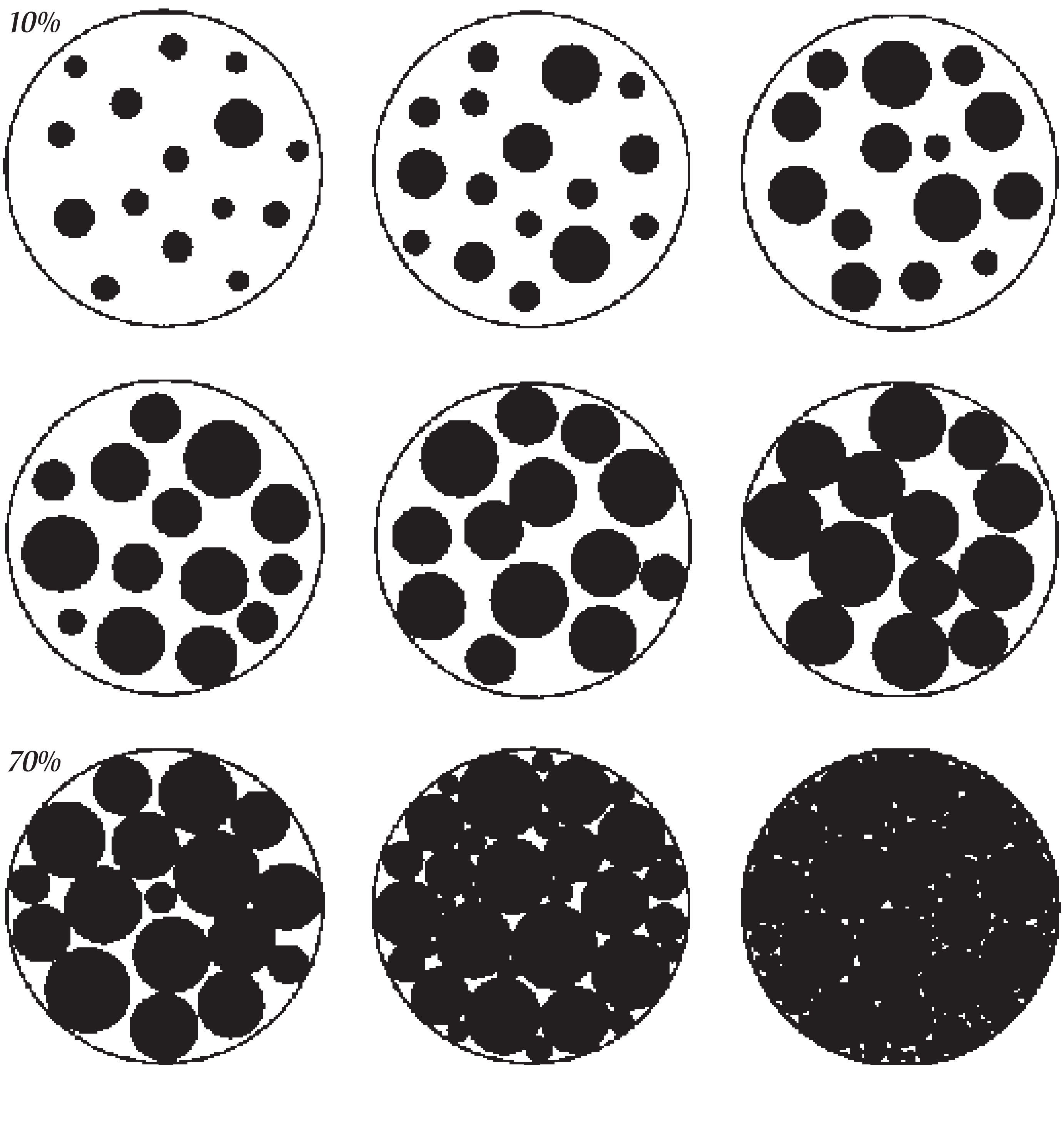
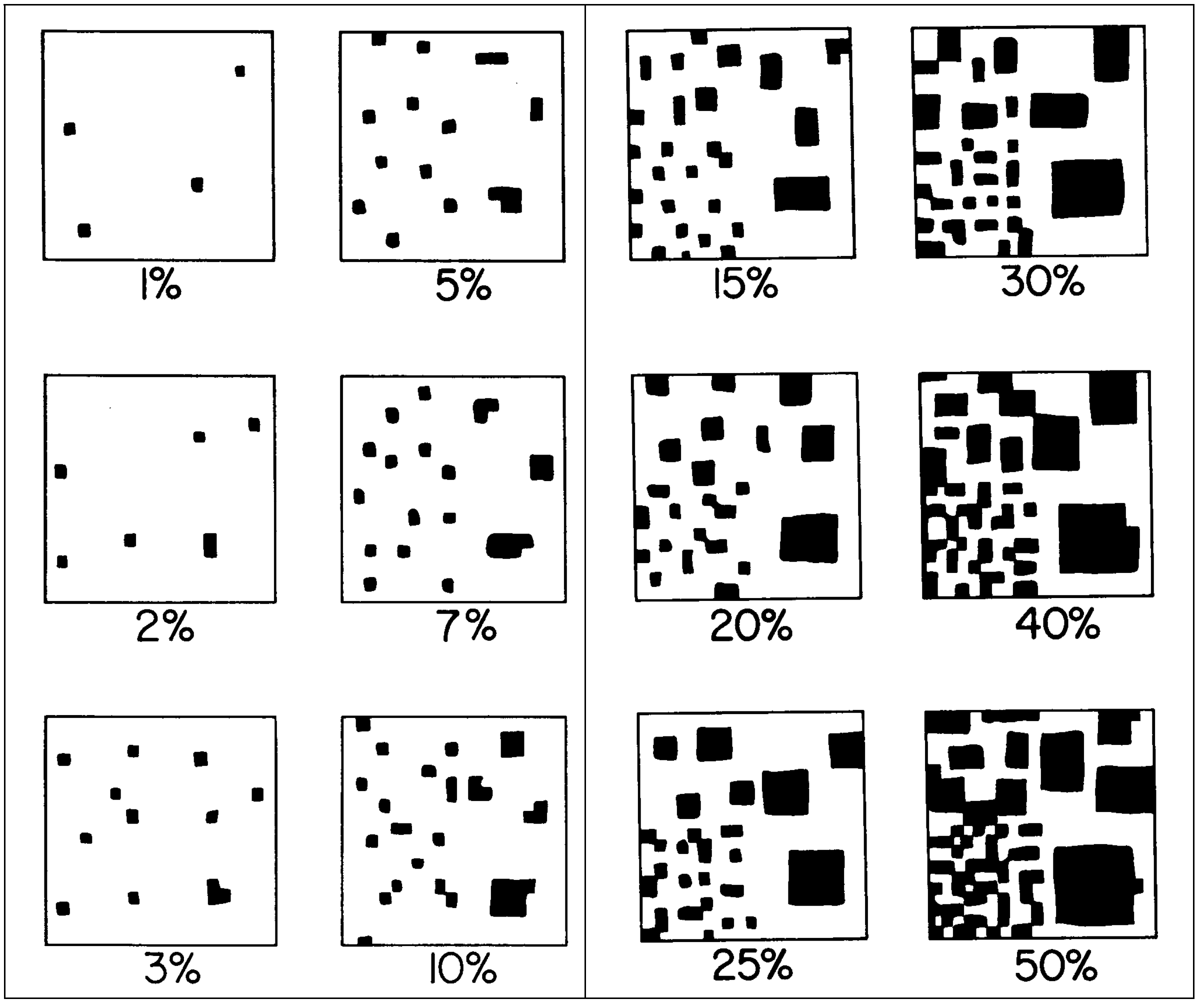
APPENDIX 3

VISUAL ESTIMATES OF PERCENTAGE COVER

Use these reference figures to help estimate the percentage of canopy cover and the percentage of low vegetation cover. We suggest you laminate this copy so it will last longer in the field.



APPENDIX 4



VISUAL ESTIMATE OF PERCENT INSTREAM HABAITAT/AVAILABLE COVER

(Each fourth of any one square has the same amount of black)