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DISCUSSION

"The Role of Observer Variation in Determining Rosgen Stream Types in Northeastern Oregon Mountain Streams"

by B. Roper, J. Buffington, E. Archer, C. Moyer, and M. Ward[1]

David L. Rosgen[2]

The concept of testing the stream classification procedure with field data collected by a group of independent field crews is encouraged by this author and can be beneficial. However, regardless of which classification system is being tested, the protocols and procedures specific to the classification system must be followed. This discussion demonstrates that the Rosgen classification system was not applied properly in the Roper *et al*. study as nonstandard protocols and inconsistent measurements were used among the various crews. Field data derived from operational protocols that are inconsistent amongst observer groups will inevitably produce conflicting results. Variability and inconsistency in the application of the Rosgen classification system does not support the conclusion that the classification itself is flawed.

Roper *et al*., however, do correctly call for expert training to produce field competent practitioners and correctly state the need for accurate bankfull elevation determinations necessary to apply the Rosgen stream classification system and to accurately assess stream type and condition. Nevertheless, this discussion addresses the implication in Roper *et al*. that the Rosgen system provides "little mechanistic insight regarding channel processes and response potential to either natural or anthropogenic disturbance" (p. 418). This conclusion, unfortunately, was reached by Roper *et al*. from a biased selection of literature rather than a full literature review and consistently applied field research.

THE ROSGEN CLASSIFICATION SYSTEM

The Rosgen classification system includes four levels in the hierarchical assessment of channel morphology (Rosgen, 1994, 1996b). It appears that the authors refer to the "Rosgen classification system" as only the Level II stream classification, largely overlooking Level I, Level III, and Level IV. Level I involves a geomorphic characterization and identifies valley types, which integrate structural controls, fluvial process, depositional history, climate, and broad life zones. Level I also rapidly classifies streams at a broad-level on the basis of valley landforms and observable channel dimensions to deliver one of eight stream type letter designations (A, B, C, D, DA, E, F, and G), including channel pattern (multiple-thread versus single-thread channels), entrenchment ratio, width-to-depth ratio, sinuosity, and slope. The Roper *et al*. authors on page 418 incorrectly stated and left out both stream slope and channel pattern as delineative criteria in the initial eight broad groupings of stream types (depicted in Figure 1 in Rosgen, 1994, p. 174).

Level II is the morphological description and classifies stream types within certain valley types with field measurements from specific channel reaches and fluvial features. The delineative criteria to classify stream types include single versus multiple-thread channel patterns, entrenchment ratio, width-to-depth ratio, sinuosity, slope, and channel materials (the numerals 1–6 reflect bedrock to clay, respectively). Sub-categories of slope are also utilized along a slope continuum where the combined morphological variables are consistent for a stream type. However, for a particular stream reach that is steeper or flatter than the normal range of that type, a small letter subscript is used to best reflect actual variables (Rosgen, 1994, p. 181). The subscript letter "a" represents a slope range > 0.04, "b" = 0.02–0.04, "c" < 0.02, and "c-" < 0.001. The various categories and threshold ranges were obtained by field data from hundreds of rivers using frequency distributions from each major stream type grouping over a 30 year period. The categories were used to establish the interrelations of morphological data rather than set "artificial boundaries" as stated by Roper *et al*. The questioning of the suitability of the parameter ranges as stated on page 424 are described by the frequency distribution from measured data sets of over 800 rivers as summarized in Chapter 5 in Rosgen (1996b).

Level III assesses stream condition to predict river stability (e.g., aggradation, degradation, sediment supply, streambank erosion, and channel enlargement) by including time-trend aerial photo analysis, detailed field measurements, sediment competence and sediment capacity prediction, and hydraulic analysis. Level IV involves the validation of all components of Levels I–III, including classification and process measurements. Validation procedures include annual dimension, pattern, profile, and sediment resurveys; annual streambank erosion studies; sediment competence validation; hydraulic relations using gaging stations or current meter measurements; and direct measurements of bedload and suspended sediment for the accurate estimate of sediment transport capacity.

The Roper *et al*. (2008) article states that the Rosgen system provides "little mechanistic insight regarding channel processes and response potential to either natural or anthropogenic disturbance." The recently published *River Stability Field Guide* (Rosgen, 2008b) and *Watershed Assessment of River Stability and Sediment Supply (WARSSS)* (Rosgen, 2006b) give great detail on process measurement and validation procedures to counter the Roper *et al*. statement. Also, the Weminuche Creek example displayed in Rosgen (2008a, Tables 2 and 3) refers to stream type changes from actual field measurements in relation to form and process variables and the consequence of stream channel adjustment of the physical variables due to imposed, anthropogenic influences (spraying willows along the riparian corridor).

Furthermore, the authors seriously question whether the Rosgen classification system meets three of the four listed objectives (p. 418): 1) To predict a river's behavior from its appearance, 2) To allow development of specific hydraulic geometry and sediment relations for different channel types, and 3) To permit extrapolation of site-specific data to reaches of similar character. These objectives can be met through the four levels of the hierarchical assessment.

In regards to the first objective, the Catena paper (Rosgen, 1994, Table 3) includes the recovery potential as one of many predictions listed in that table by stream type. The recovery potential is listed as *good* for gravel-bed C4 and E4 stream types, *poor* for F4 stream types, and *very poor* for A4 and G4 stream types. Following 20 years of observation, Newman and Swanson (2008) indicated that more attributes of C and E stream types improved, while A, F, and G stream types did not show any significant improvement. These findings agree with the prediction of channel response by stream type in the early publications of Rosgen (1994, 1996b).

The second objective has been validated by the example of a sediment rating curve stratified by stream type for Colorado bedload data that minimizes the variance from the general relation (Rosgen, 1996b, Figure 8-5; Rosgen, 2006b, Figures 2-25 and 2-26). Hydraulic relations by stream type are also shown in Rosgen (1994, Figures 11–13; 2008a, Figures 2 and 3) where the variance is also minimized by stream type stratification.

Referring to the third objective, "to provide a mechanism to extrapolate site-specific data collected on a given stream reach to those of similar character," for the purpose of natural channel design, extrapolation of 43 stream variables is required. These variables, often expressed as dimensionless relations, represent the dimension, pattern, and profile from reference reach data of similar stream types in appropriate valley types (representing similar boundary conditions/controlling variables) (Rosgen, 2007). Regime equations used for river restoration were also greatly improved with stratification by stream type (Hey, 2006). These hydraulic geometry relations (regime equations) used for river restoration were improved by the stratification of stream types, which met both the second and third objectives of the classification system described in the Catena paper (Rosgen, 1994).

Also, the use of dimensionless relations using the bankfull condition for the normalization parameter allows for extrapolation of hydraulic, sedimentological, and morphological relations by stream type (to adjust for scale). These extrapolations have been put into practice for numerous successful river restoration projects (National Research Council, 1992; Rosgen, 1998). Contrary to the inferences made by Roper *et al*., the aforementioned examples and references demonstrate successful applications of the first three objectives in the Rosgen classification system (Rosgen, 1994, 1996b).

Unfortunately, Roper *et al*.'s literature review is one-sided to support their inference that the objectives in the Rosgen classification system can not be met. The authors appear to use the literature to only support their primary conclusions even when the literature supports the Rosgen classification system. For example, Roper *et al*. cite the Savery *et al*. (2001) article to support their claim that the Rosgen system is still used by many state and federal agencies despite the many criticisms of the system. However, Roper *et al*. fail to state Savery *et al*.'s primary conclusion that "the Rosgen classification system can be used to classify streams within the Chequamegon-Nicolet National Forest" (p. 653). "Using the Rosgen stream classification key and continuum limits, it was possible to classify 89 percent of the CNNF stream reaches sampled" (p. 653). Since the Savery *et al*. evaluation, over 600 stream reaches have been successfully classified with the Rosgen system on these National Forests in Wisconsin.

It also seems biased that Roper *et al*. only report and cite the critical, adverse views while ignoring the responses to Kondolf (1995), Miller and Ritter (1996), Juracek and Fitzpatrick (2003), Kondolf *et al*. (2003), and Smith and Prestegaard (2005). Formal responses are readily available in Rosgen (1996a, 2003, 2006a), including the most recent discussion pertaining to the inaccuracies and unfounded claims in the Simon *et al*. (2007) article (Rosgen, 2008a).

In regard to the fourth objective of the Rosgen classification system (to provide a consistent and reproducible frame of reference of communication), Roper *et al*. conclude that the system "appears to do little to improve communication among practitioners…" (p. 425). The following sections will discuss the inaccuracies of their study to address this conclusion.

INNACCURACIES OF THE ROPER *et al*. (2008) STUDY

The aim of the paper was "to determine whether measurements made by different observers yield consistent classification of Rosgen stream types…" (p. 418). Consistent classification is unlikely when "each group used their own protocols to evaluate the five attributes necessary to classify Rosgen (1994) stream types (Table 2). Two of the groups, AREMP and PIBO, had identical operational definitions for these stream attributes, but differed in training, survey instruments, and locations within a reach where attributes were evaluated" (p. 419). To properly apply the stream classification system and "determine whether measurements made by different observers yield consistent classification of Rosgen stream types," the field crews need to: 1) have similar training by individuals competent in applying the Rosgen stream classification; 2) use identical protocols (operational definitions); 3) use comparable field instruments; 4) take measurements for comparison within the same identified reach location on the same bed features (i.e., riffles, pools, etc.); and 5) be calibrated in field bankfull determination and have locally validated regional bankfull discharge curves. Unfortunately, the field crews in the Roper *et al*. study did not meet these standard requirements to help prevent user error.

Observer Training

Roper *et al*. acknowledge that source of training may be a factor for the inconsistent classification results and state: "While requiring similar training and protocols would increase consistency, this step alone **may not** be enough to ensure similar identification of Rosgen stream type" (p. 422). On the contrary, I argue that similar training and protocols would ensure similar classification results. By persisting with the view that "consistent protocols and training ***may be*** desirable" (p. 422), rather than **absolutely essential**, it ensures that no meaningful conclusions about the classification system can be drawn from the study based simply on inappropriate differences in protocols and insufficient training.

The authors reference the Whitacre *et al*. (2007) study, comparing the precision of channel attribute measurements, to imply that the Roper *et al*. study crews were adequately trained and had better protocols "than the vast majority of federal and state personnel used to conduct stream survey" (p. 422). There is nearly a one to one correlation between the length of crew training (Whitacre *et al*., TABLE 7, p. 934) and the number of crew hits for high precision (Whitacre *et al*., TABLE 8, p. 935). Crew training in the Whitacre *et al*. study ranged from 3 to 10 days; they conclude: "while the field measurement of stream attributes has continued to be refined, the results of this study suggest that differences within and among USFS and USEPA **protocols** affect means and measurement precision for many commonly evaluated attributes." Also, Whitacre *et al*. state: "Many crews had difficulty in distinguishing bankfull width on particular streams, perhaps resulting from a lack of training in a variety of stream types" (p. 934). With the conclusions drawn from the Whitacre *et al*. study and from my personal experience in field survey methods training, it is obvious that protocol differences of measured field variables will directly affect stream classification results.

Inaccurate Protocols for the Rosgen Classification System

The three stream attribute protocols used in the Roper *et al*. (2008) article include: Aquatic Riparian Effectiveness Monitoring Program (AREMP) (Reeves *et al*., 2004); PacFish-InFish Biological Opinion Monitoring Program (PIBO) (Kershner *et al*., 2004); and the Upper Columbia Monitoring Program (UC) (Hillman, 2004). These protocols listed in TABLE 2 (p. 420) significantly differ from the Rosgen protocol with respect to measurement of entrenchment ratio and width/depth ratio.

For example, the UC protocol measured entrenchment ratio at three equally spaced transects. Entrenchment ratio, as described in the field methods section in Rosgen (1996b), is the ratio of the width of the flood-prone area to the surface width of the bankfull channel. “To measure the width of the flood-prone area, select the elevation that corresponds to twice the maximum bankfull channel depth as determined by the vertical distance between bankfull stage and the thalweg of a riffle” (p. 5-19). As the UC group measured entrenchment ratio at evenly spaced transects, it is very likely that their values were derived from non-riffle locations. Consider the implications of taking maximum bankfull depth measurements in a pool or a run cross-section versus maximum depth values from a riffle cross-section; inevitably entrenchment ratio values will be different (assuming each group selected the same/correct bankfull stage). Taking measurements in non-riffle locations may explain some of the variability in entrenchment ratio in FIGURE 3 in the Roper *et al*. article.

Another confounding problem is that the AREMP and UC protocols measured width-to-depth ratio (bankfull channel width to mean bankfull depth) at 11 equally spaced transects (TABLE 2, p. 420). As explained in Rosgen, “…the best locations for determining bankfull channel dimensions are at the riffle or “cross-over” reach of “C,” “E,” and “F” stream types; within the middle of the “rapid” reach for “B” stream types; and the narrow width of the transition reach as it extends from the “step” into the head of the pool for “Aa+,” “A,” and “G” stream types” (1996b, p. 5-9); Figure 5-4 and Figure 5-5 in Rosgen (1996b) depict the most representative, appropriate locations to determine bankfull channel dimensions. It is very possible that the AREMP and UC groups **did not** measure width-to-depth ratio values at the appropriate bed feature location required by the Rosgen classification protocols.

Furthermore, not only did the UC protocol average width values at 11 equally spaced transects (which may or may not include pool widths, riffle widths, etc.), but they defined and measured the “mean bankfull depth” as the average depth of thalweg – a maximum depth measurement. To have meaningful comparisons between crews using mean bankfull depth variables, it is essential for each crew to use the same protocol for measurement and analysis. If not, one would observe unacceptable variability among crews.

The West Fork Lick Creek case is one example where these inconsistent protocols may explain why one AREMP crew’s data did not fit the classification with an entrenchment ratio of 1.85 and a width-to-depth ratio of 6.2 (p. 420). As the AREMP crews measured width-to-depth ratios at equally spaced transects, it is possible that they included non-riffle data, which would lead to low width-to-depth ratios. While these values are unusual in combination, it appears that the data did not fit the classification because of the **misapplication** of the system rather than the classification system itself. Another indicator that this is a plausible explanation is that the average width-to-depth ratio for all crews is 15.6 (TABLE 1, p. 419), which is probably much closer to the actual value.

Bankfull Discharge

The authors are correct that bankfull measurements based on identifying the bankfull elevation from field indicators may be subjective and difficult; this is precisely why it is essential to use consistent definitions, calibrate the bankfull discharge at USGS gages and develop regional curves. FIGURE 3 in the Roper *et al*. article depicts the variation of entrenchment ratio values between groups for each river and indicates that crews were not consistent in determining the stage of bankfull discharge, which "is the single most important parameter used in Level II classification" (Rosgen, 1996b, p. 5-7). As further stated in Rosgen, "Correct and reliable interpretations of the interrelationships between dimension, pattern, profile, and streamflow depend upon the correct field identification of bankfull stage and the related discharge" (1996b, p. 5-7). "A common error in the Level II classification process is the failure of field observers to calibrate the elevations of appropriate field indicators of bankfull stage to known streamflows. Such calibration is essential until one gains sufficient field experience in a given locale to be sure of the proper interpretation of those indicator features representing the stage or elevation of the bankfull discharge" (Rosgen, 1996b, p. 5-9). The field procedure to calibrate field-identified bankfull stage with known streamflows and return periods is included in Rosgen (1996b, 2006b, 2008b) and USEPA (2006).

The data from the bankfull calibration at gage sites is also used to develop regional curves relating the bankfull discharge, cross-sectional area, and bankfull dimensions to drainage area. The observations of similar geomorphic features are then used at ungaged sites to obtain the bankfull values from a measure of drainage area. If obvious geomorphic surfaces that are indicators of the bankfull stage are not observed, especially in the case of actively incising channels (G stream types), then regional curves (locally calibrated) are used to make the determination of the bankfull discharge and corresponding stage. It is desirable to use more than one indicator for the bankfull stage; thus, supportive evidence of the bankfull stage is often used to help in the delineation. Regional curves are discussed in detail in Dunne and Leopold (1978) and Leopold (1994, p. 92).

In the Roper *et al*. study, it appears that the inconsistency even among crews within monitoring groups who have the same protocols (where AREMP crews classified 42% of the streams differently, PIBO crews classified 30% differently, and UC crews classified 50% differently) can be attributed to incorrectly identifying bankfull in the field and not first calibrating bankfull at gage site locations or not using regional curves. Failure to calibrate bankfull is misuse of the Rosgen classification system. The authors acknowledge that their "findings suggest that measurement of bankfull channel geometry and classification parameters derived from it may be a primary source for observer differences" (p. 423). Again, developing/using regional curves would have ensured the correct designation of bankfull stage and would have improved consistency in bankfull measurements among crews.

Another possible reason in the Roper *et al*. study for the variability in bankfull measurements may be because many observers underestimate the bankfull stage due to confusing depositional surfaces and the presence of perennial vegetation that often occur within the active channel. The inner-berm or depositional surfaces often occur within the active channel but below the bankfull stage, as described by Osterkamp and Hedman (1982). Unfortunately, in field practice, the bankfull stage determination is often left up to the observers to "use their best judgment." Because an individual's best judgment is based on experience and proper training, and if this is not subsequently provided for field crews, then bankfull determination at ungaged sites will be inconsistent. Field training of crews at USGS gages allows field observers to relate or "calibrate" geomorphic surfaces (incipient point of flooding) with known discharges and associated recurrence intervals.

Training on identifying the bankfull stage is available in several courses including training modules accessible through the USEPA stream web pages and in the online advice of many state agencies engaged in the measurement and evaluation of stream channels (e.g., USEPA, 2008). As previously stated, Roper *et al*. (2008) used their FIGURE 5 to misclassify a B channel as an A channel. Given the training tools available today, that should not occur. The Forest Service Stream Team web page can direct users to three training sets that show how to identify bankfull stage in the United States (USDA Forest Service, 2008).

Roper et al. Case Examples

If the values in TABLE 1 (p. 419) were accurate field-validated values, all of these respective streams would classify as follows: Big (C4), Bridge (B4c), Camus (B3c), Crane (C4), Crawfish (B3a), Indian (B4a), Myrtle (B4a), Potamus (B3), Tinker (C4b), Trail (C4), West Fork Lick (B4), and Whiskey (B4a) (note that in field practice, values would not be averaged across crews). Based on these data, it simply is not possible to classify the sites any differently. Nonunique solutions did not occur and no adjustments to the classification key were required to classify each stream. However, without knowing the actual, field-validated values of each river and having the raw data for each crew for each river, it is difficult to determine and assess why the inconsistencies in classification occurred in TABLE 3 (p. 421).

Furthermore, the Roper *et al*. authors state: "The fact that this study constantly needed to incorporate the expected variation of classification parameters to ensure consistent identification of stream type indicates two potential problems for application of Rosgen's approach" (p. 424). Their unnecessary emphasis that the "continuum of physical variables" was applied is primarily driven by the inaccuracies of some of the survey crew protocols and inaccuracies of their own application of crew data. Applying the continuum (where values of entrenchment and sinuosity ratios can vary by +/- 0.2 units and values for width-to-depth ratio can vary by +/- 2.0 units) does not mean that streams fall between channel types; it means that the observed values are at the tail end of the distribution for that parameter (Rosgen, 1996b). Roper *et al*.'s evaluation of survey crew data placed 40% of the Northeast Oregon streams into the Rosgen continuum "grey zone" implying that "fuzzy" classification boundaries are a problem. This result in the Roper *et al.* study is most likely caused by inappropriate survey protocols – not the recognition of a physical river continuum in the Rosgen classification system.

Roper *et al*. also use West Fork Lick Creek to demonstrate that the Rosgen classification system can result in nonunique solutions (i.e., more than one channel type possible) because it could classify as either an F or a B stream type (p. 425). They state that "…some type of rule set is required to decide between nonunique solutions that result from Rosgen's allowed variation of classification parameters. Visual assessment of the reach morphology is likely the best way to decide between nonunique solutions." Here, the authors largely ignore the Level I geomorphic characterization that serves to "provide for the initial integration of basin characteristics, valley types, and landforms with stream system morphology" (Rosgen, 1996b, p. 4-3). A Level I classification, including an assessment of valley type, is necessary before completing the Level II stream classification (Rosgen, 1994, 1996b). Consideration of the geomorphic context is a key factor as particular stream types are associated with certain valley types. For example, "F stream types are deeply incised in valleys of relatively low elevational relief…The "F" stream types occur in low relief valley type III, and in valley types IV, V, VI, VIII, IX, and X" (Rosgen, 1996b, p. 4-41). However, "the "B" stream types exist primarily on moderately steep to gently sloped terrain, with the predominant landform seen as a narrow and moderately sloping basin…"B" stream types are usually found within valley types II, III, and VI" (Rosgen, 1996b, p. 4-6). It is likely that West Fork Lick Creek is within a colluvial valley type II where a B stream type (not an F stream type) would typically. The summary information for this site also indicates a B, not an F, stream type. The entrenchment ratio (1.69), width-to-depth ratio (15.6), sinuosity (1.28), slope (0.0330), and D_{50} particle size (26) all yield a B4 stream type.

The Roper *et al*. claim that streams were often assigned a stream type that did not fit the visual appearance of the evaluated stream is also inaccurate (pp. 424-425). For example, Roper *et al*. classified Crawfish Creek as a Rosgen stream type A; contrary to their classification, it is evident from the photograph (FIGURE 5 p. 425) of Crawfish Creek that its visual appearance and supporting morphological data (TABLE 1) justify a B3a stream type classification. Roper *et al*. also stated that Crawfish Creek was misclassified five of eight times when it actually was correctly classified as a B3/4a five of eight times (TABLE 3). Furthermore, the "a" notation in the B3a classification denotes that the stream type has a steep slope between 0.04–0.099, similar to the slope of A stream types. B3a stream types are typically step/pool stream types. In common usage, "step/pool" channels cover a wide range of stream types including Aa+, A, B and G as shown in Figure 1 (Rosgen, 1994, 1996b as modified from Grant *et al*., 1990). Using the relations shown in Figure 1, the bed feature description can be "rapids-dominated" for B stream types or step-pool bed features for the Ba stream type. Although steeper than the B stream type, the Ba stream type still has the dominant morphological characteristics of the B stream type (Rosgen, 1996b, p. 4-24). This slope classification and the associated bed features of Grant *et al*. (1990) agree closely with the major slope breaks of the Rosgen stream types, which indicate that these slope delineation breaks are more than an "artificial boundary" as inferred by Roper *et al*.

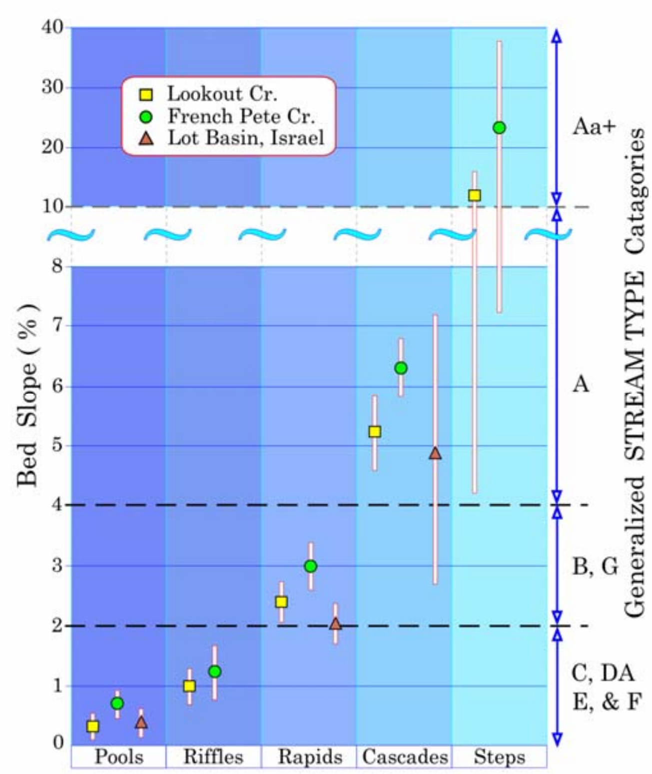

FIGURE 1. Relationship of Bed Slope to Bed Forms (from Grant *et al*., 1990) for Various Stream Types (Rosgen, 1994, 1996b).

DISCUSSION AND SUMMARY

Overall, this discussion paper demonstrates that the conclusion by Roper *et al*. that the Rosgen classification system "appears to do little to improve communication among practitioners"… is incorrect. The variability to consistently classify streams in the Roper *et al*. study is due to the **misapplication** of the Rosgen classification.

Regardless of which classification field practitioners use, it is imperative that data is collected in a consistent and comparative manner so that many users across disciplines can share and interpret stream data for future use to enhance our understanding of river systems. In order to enhance the comparability, consistency, and applicability of data from field-based protocols, the following suggestions need to be considered:

1. Be familiar with the original spatial context, regional setting, and purpose of the protocol.
2. Receive expert and career long training in the identification of bankfull stage and indicators of geomorphic processes.
3. Calibrate your interpretations at USGS streamgages.

The authors and others are encouraged to perform unbiased formal tests of the classification system by those who have had appropriate experience and training in Rosgen stream classification.

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