ELSEVIER

Catena 27 (1996) 295–299

CATENA

Discussion

An examination of the Rosgen classification of natural rivers

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Received 2 March 1995; accepted 6 May 1996

In the June 1994 issue of *Catena*, D.L. Rosgen presented a paper entitled "Classification of Natural Rivers," which represents an updated version of an earlier scheme (Rosgen, 1985). A primary objective of this classification system is to provide the mechanism with which to "[p]redict a river's behavior from its appearance" (Rosgen, 1994, p. 170). Thus, Rosgen has extended his classification beyond its use as a communications tool and into the realm of predicting fluvial process. If such an extrapolation is to be pursued, it must be demonstrated that the criteria upon which the classification is based have geomorphic significance. We will argue in the following paragraphs that the Rosgen Classification, as it has come to be known, fails this critical test. Moreover, the use of the Rosgen Classification to adequately predict geomorphic response(s) to system perturbations runs contrary to much of the geomorphic literature published during the past several decades, as will be shown below.

We note first that any in depth evaluation of Rosgen (1994) is complicated by an incomplete data set and a diffuse presentation that makes it difficult to determine exactly what the author is attempting to demonstrate. Especially problematic are (1) the use of undefined terms (e.g., channel stability, stream potential, streambank erosion potential, vegetation controlling influence, and recovery potential), (2) the inconsistent use of terminology (e.g., channel pattern), (3) the lack of data points on figures and graphs, and (4) a failure to communicate how various analyses were carried out. For example, in the discussion pertaining to the relationships between stream type and hydraulic geometry (p. 189), Rosgen states that he "assembled stream dimensions, slopes, and hydraulic data for six different stream types having the same discharge and channel materials." He goes on to present a series of graphs that are intended to illustrate the relationships between discharge and mean depth, mean velocity, stream width, and cross sectional area (Rosgen, 1994, Fig. 11, p. 190) for various stream types in his classification. Presumably, the intent is to illustrate that each stream type exhibits a unique hydraulic

PII S0341-8162(96)00017-3

geometry. Unfortunately, the reader has no idea of what streams Rosgen is referring to or the spread of data about the lines plotted on Fig. 11. Moreover, there is little, if any discussion of how these lines were derived. This in itself is not a trivial issue. If each line is the product of data collected at a single cross section on one river of a given type (as one of the authors of this discussion believes), its universal extrapolation to other fluvial systems is questionable. If however, each line is the product of data collected from multiple cross sections of a given stream type (as the other author believes), the hydraulic geometry relations should be compared on the basis of discharges of similar frequency (i.e., it becomes similar to the downstream analysis of Leopold and Maddock, 1953). However, Rosgen never mentions discharge frequency in the text or within the figure caption. Thus, at best the reader is confused; at worst the analysis is completely erroneous.

Another example can be taken from Fig. 13 (p. 192) and its associated text. Here, Rosgen (1994) asserts that by knowing stream type one can predict the critical dimensionless shear stress values (τ_{ci}^*) along a given reach where

$$\tau_{ci}^* = 0.0834(d_i/d_{50})^{-0.872}$$

In the above equation, d_i/d_{50} is the ratio of the surface particle diameter coarser than the ith % to the median subsurface particle diameter. Unfortunately, Rosgen has not defined d_i, and we do not know if Fig. 13 is based on a d_i value equivalent to the 50th percentile, the 84th percentile, or some other value. Also lacking is an explanation of the relation between stream type and critical dimensionless shear stress. This relation is not obvious; for instance, B4 streams have higher values than B3 when in fact the bed material is smaller in B4 channels. Is this is function of subpavement characteristics? If so, how does the Rosgen Classification, which is based on bed surface material properties, account for subpavement affects?

Notwithstanding the difficulties in understanding the meaning of the text, we turn our attention to the logic surrounding the criteria on which the classification is based. In this aspect, we find a serious problem in that apples and oranges are used repeatedly to support his conclusions. Examples are too numerous to spell out in this limited space, but for a specific case, we encourage you to examine Fig. 2 (Rosgen, 1994, p. 175) and the excellent paper by Grant et al. (1990) on which it is based. You will find that the relationships between bed morphology and bed slope were constructed by Grant et al. using data collected from steep, boulder-bed, mountain channels. The extrapolation of bed morphology–slope relations to other channel forms (e.g., Rosgen type C, D, E, F, and G channels) or geologic settings was never demonstrated by Grant et al., nor did they ever intend to make such an extrapolation. Yet Rosgen (1994, p. 175) plotted all stream types on Fig. 2 (from Grant et al., 1990) and used, in error, these data to concluded that, "[b]ed morphology can be predicted from stream type."

In most cases, Rosgen (1994) has not attempted to explain the geomorphic significance of the boundary values that separate one stream type from another. For instance, entrenchment ratio is defined by Rosgen as the ratio of the width of the flood-prone area to the width of the bankfull channel, where the flood-prone area is measured at an elevation of twice the maximum bankfull depth (p. 181). Yet, many stream reaches never experience stages equivalent to twice the maximum bankfull depth. In fact, many arid-climate rivers do not rise above bankfull, but instead tend to adjust their channel cross-sectional dimensions and position during flood (see for example, Kresan, 1988). Thus, we doubt that stream type boundaries as defined by the entrenchment ratio have any geomorphic significance. Similarly, we fail to see the process significance between a channel with a sinuosity of 1.2 versus 1.4. Or, for that matter, any of the parameter boundaries put forth in the Rosgen Classification.

Perhaps the most significant shortcoming of the paper is its attempt to utilize the classification system to assess a stream reaches' sensitivity to disturbance, recovery potential, sediment supply, streambank erosion potential, and vegetation controlling influence. Again, none of these parameters, presented in Table 3 (Rosgen, 1994, p. 194), are defined, and they can easily be taken to have more than one meaning. For example, does the recovery potential refer to a channel's ability to reach a new equilibrium condition following a threshold crossing event, or does it mean the capacity to return to the morphology exhibited prior to the occurrence of an infrequent, high-magnitude flood event?

Regardless of the difficulties surrounding its underlying premises, it is clear that the classification *cannot* be utilized for the management purposes put forth in Table 3 for the following reasons:

(1) *Rosgen stream types are not linked to the current equilibrium state of the channel.* The magnitude of channel adjustment to changing water and sediment discharge depends on the current equilibrium state of the system (Black, 1971, p. 76). However, Rosgen's stream classification tells us little, if anything, about the equilibrium state of a river. A reach categorized as a Rosgen C3 stream type, for instance, may or may not be in an equilibrium state. The point is that a reach which Table 3 (p. 194) suggests has a low or moderate sensitivity to disturbance may in reality be extremely susceptible to future changes in water and sediment discharge if it is currently in a state of disequilibrium, or tending toward a state of disequilibrium;

(2) *Our current understanding of fluvial systems does not allow for the prediction of the type or magnitude of geomorphic response to a given perturbation.* Perhaps the ultimate goal of fluvial geomorphology, from an applied perspective, is to predict the response(s) of river systems to changes in the controlling factors (e.g., climate, tectonics, and land-use). Unfortunately, we are not close to achieving this goal and, perhaps, the best we can currently hope for is to predict the variety of possible responses (Schumm, 1969, Schumm, 1977; Ritter et al., 1995). In fact, we now know that any given reach may respond differently, at different times, to an event of similar magnitude (Newson, 1980; Kochel, 1980, 1988; Beven, 1981; Kochel et al., 1987; Schumm et al., 1987). Ironically, this point is illustrated by Rosgen. The response of an E4 channel differs between Figs. 8 and 9 (pp. 185, 186) though the E4 channel in both is perturbed by presumably the same stream bank instability. In Fig. 8, the channel ultimately evolves into a D4 braided channel; whereas in Fig. 9, the E4 channel returns to its pre-existing condition (note that no references documenting these types of responses were provided). If such dramatically different responses are associated with a single stream type, how can the classification system be used to predict fluvial behavior?

In addition to the above, it should be remembered that geomorphic systems are palimpsest. That is, the type of geomorphic adjustment that occurs in response to a perturbation is dependent on that system's past geomorphic history, a factor that is not (and, possibly cannot be) incorporated into the Rosgen Classification. It is, therefore, improbable that a specific stream type, as defined by Rosgen (1994), can be associated with a particular form or magnitude of geomorphic adjustment; and

(3) *The Rosgen classification does not consider climatic or hydrologic regime.* According to Table 3 in Rosgen (1994) a stream type should exhibit a similar sensitivity to disturbance and recovery potential, regardless of the climatic or hydrologic regime in which they are located. He also states (p. 180) that "the classification can be applied to ephemeral as well as perennial channels with little modification." However, it has been repeatedly shown that the effect of major floods on channel and floodplain configuration is dependent on the environmental setting (Costa, 1974; Gupta and Fox, 1974; Baker, 1977; Moss and Kochel, 1978; Kochel, 1988). Moreover, it has been demonstrated that the recovery time, defined as the time needed for a river to recover its equilibrium form after a major flow event has disrupted its configuration, varies greatly between climatic zones (Wolman and Gerson, 1978). In humid climates, the recover time is generally short (1–20 years), whereas in semiarid to arid regions it tends to be much longer. Thus, the recovery potential, however it is defined, is likely to vary significantly for any given stream type.

We wish to stress that we have no major problem with using the Rosgen classification as a communications tool. But as we have said above, the process significance of the defined stream types and their use in a predictive sense is questionable. Unfortunately, earlier versions of Rosgen (1994) have been utilized in evaluation guides for riparian areas (USDA, 1992), and U.S. Forest Service management plans (e.g., USDA, 1984) with the purpose of defining fluvial behavior. Moreover, many federal agencies in the U.S. are now examining the use of the Rosgen (1994) classification in the development of stream restoration programs. We understand the desire to obtain a painless "cookbook" method of predicting fluvial process that can be used in management programs as the Rosgen Classification attempts. Nevertheless, we strongly suggest that the utilization of such tools that are not based on criterion having geomorphic significance is of little value. It may be argued that their application as a surrogate for detailed fluvial investigations could even be worse than useless if they lead to counterproductive management schemes that are accepted as being indicative of reality.

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