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FACT SHEET

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Stream Classification

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Why Classify a Stream?

Stream systems have been classified according to their relative position within a stream network in order to help us understand, discuss, and explore similarities and differences between them. Many stream order classification systems have been developed, but no single system has been universally accepted. One of the earliest methods developed, and arguably the most commonly used method today, was developed by Strahler in 1952[1]. In this system, the smallest headwater tributaries are called first-order streams. Where two first-order streams meet, a second-order stream is created; where two second-order streams meet, a third-order stream is created; and so on (Figure 1).

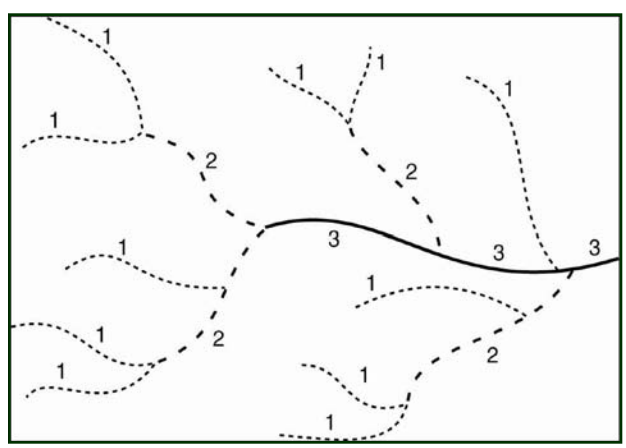

Figure 1. Strahler Stream Order Classification Method[1]

Stream order is an important characteristic of stream systems because it can be related to drainage area and stream size. An example of how drainage area and stream size are related to stream order for the State of Ohio is presented in Table 1[2]. More than 75% of the streams in Ohio are first- or second-order streams, which are considered small headwater streams less than 5 mi[2]. Many of the headwater streams in the Midwest region of the United States are constructed agricultural ditches or are natural streams that have been straightened and deepened to facilitate the removal of excess water from agricultural fields (Figure 2).

Figure 2. A typical modified headwater stream in the midwestern United States.

Table 1. Relationships between stream order, drainage area, and total stream length for the State of Ohio.

Stream Order	Drainage Area (sq. mi.)	Total Length (miles)	Miles (%)	Cumulative %
1	0.2 - 1	67,530	51.5	51.5
2	1 - 4.7	33,138	25.3	76.8
3	4.7 - 23	15,963	12.2	89
4	23 - 109	7,803	6	95
5	109 - 518	3,810	2.9	97.9
6	518 – 2,460	1,861	1.4	99.3
7	2,460 – 11,700	908	0.7	100

Stream order also is important because it can be related to the expected ecological function of a stream system. The River Continuum Concept (RCC)[3] and the Flood Pulse Concept (FPC)[4] were developed for lotic ecosystems and were based upon the idea that there are predictable changes in geomorphology and hydrology, forming a template for adaptation of biological communities[5], as you move downstream through the system.

Stream Classification Methods

Streams also can be classified by describing the morphology of the channel. Examples of this approach include identifying a stream by the average size of bed material (sand-bed, gravel-bed, bedrock) or by physical setting and land use (mountain stream, meadow stream, urban channel, etc.). One of the earliest morphology-based classifications was the Leopold and Wolman[6] approach of identifying rivers according to their pattern: braided, meandering, or straight. Schumm's[7] classification of streams into erosion, transport, and deposition reaches is helpful in beginning to understand the sediment transport behavior of a stream. These approaches are useful in conveying an image of the channel, topography, and/or the adjacent land use, but they provide a limited amount of information about the stream system. Rosgen[8, 9], Whiting and Bradley[10], Montgomery and Buffington[11], Simon[12], Nanson and Croke[13] and numerous other geomorphologists, geographers, and engineers have developed more comprehensive approaches.

Regardless of the method used, the primary objective for having a stream classification system based on stream morphology is to provide a common ground for understanding stream condition and potential in vastly different settings and influences. More specifically, as suggested by the Rosgen classification objectives[8] this includes:

- providing a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines and interested parties.
- predicting stream behavior from appearance.
- developing specific hydraulic and sediment relationships for a given stream type and its state.
- providing a mechanism to extrapolate site-specific data to stream reaches with similar attributes.
- identifying if the stream is in dynamic equilibrium and/or in a transitional (stable or unstable) stage.
- providing a context for evaluating stream health.

It is important to remember that a classification system is only one component to the management of a stream, the development of an engineering design, or the restoration of aquatic habitat. It does not directly provide a design solution. In presenting any methods in this fact sheet, we are not proposing they be used in design or that a basic understanding of the method be a substitute for the extensive interdisciplinary knowledge needed to make informed decisions.

Rosgen Classification Method

Most of the methods mentioned previously have seen limited application with the exception of the Rosgen Stream Classification Method[8, 9]. This is arguably the most widely used method in the United States; therefore, we will briefly discuss details of the method, how it applies to Ohio and Midwestern streams, and what do when a stream does not seem to fit any category of the method. The basic tenet of the Rosgen classification approach is as follows:

Natural stream stability is achieved by allowing the river to develop a stable dimension, pattern, and profile such that, over time, channel features are maintained and the stream system neither aggrades nor degrades. For a stream to be stable, it must be able to consistently transport its sediment load, both in size and type, associated with local deposition and scour. Channel instability occurs when the scouring process leads to degradation, or excessive sediment deposition results in aggradation.[8]

This classification approach is divided into the following four hierarchical levels:

- Level I: Geomorphic characterization that integrates topography, landform, and valley morphology. At a broad scale the dimension, pattern, and profile are used to delineate stream types.
- Level II: Morphological descriptions based on field-determined reference reach information.
- Level III: Stream "state" or condition as it relates to its stability, response potential, and function.
- Level IV: Validation at which measurements are made to verify process relationships.

Level II of the Rosgen classification approach is summarized in Table 2. Streams are classified into types (A–G) based on the following seven channel attributes: (1) mean bankfull depth; (2) maximum bankfull depth; (3) bankfull width; (4) flood-prone area width; (5) channel sinuosity; (6) mean channel slope or water surface slope; and (7) median channel material size.

Table 2. Rosgen's Level II stream classification system.

Stream Property	Stream Types*							
	A	B	C	D	D_A	E	F	G
Entrenchment Ratio, ER	<1.4	1.4-2.2	>2.2	na	>4.0	>2.2	<1.4	<1.4
Width to Depth Ratio, W/D	<12	>12	>12	>40	<40	<12	>12	<12
Sinuosity	1-1.2	>1.2	>1.2	na	variable	>1.5	>1.2	>1.2
Bed Slope, S (%)	4-10	2-4	<2	<4	<0.5	<2	<2	2-4

***Add after the stream type a number that corresponds to the mean bed material type where: Bedrock: 1; Boulders: 2; Cobble: 3; Gravel: 4; Sand: 5; Silt-Clay: 6. For example: A Rosgen Type C4 stream has a gravel-bed.**

Rosgen Type A Stream

Type A streams are typically steep, entrenched, and confined channels. They can be thought of as "mountain streams". They range from A1 bedrock channels associated with faults, scarps, folds, and joints to A6 channels that are incised in cohesive soils. Type A streams have a step-pool or cascading bed form with boulder-, bedrock-, cobble- and, to some extent, gravel-bed channels (Figure 3). Bedrock- and boulder-bed channels are high-energy streams with a limited sediment supply whereas cobble- and gravel-bed channels are high energy with high sediment supply. Erosion, instability, mass wasting, and debris flow become more dominant processes as the bed material becomes finer (A3 to A5).

Figure 3. Rosgen Type A: W/D < 12; Sinuosity > 1–1.2; ER < 1.4; S 4–10%

Rosgen Type B Stream

Type B streams are typically moderately entrenched and less steep than Type A streams. They can be thought of as "babbling brooks" that are found in narrow valleys of rolling hill landforms (Figure 4). The channel bed consists of a series of rapids and cascades with irregular scour pools. The bed and banks are relatively stable, and they are sediment-supply limited systems. If available, large woody debris is an important component to in-stream fish habitat in these systems.

Figure 4. Rosgen Type B: W/D > 12; Sinuosity > 1.2; ER > 1.4–2.2; S 2–4%

Rosgen Type C Stream

Type C streams are slightly entrenched, meandering systems characterized by well-developed floodplains (Figure 5). They have a riffle-pool bed form and are typically wider than they are deep. These streams are stable and usually are sediment supply and transport limited. However, if they have gravel or finer bed and bank materials they are susceptible to scour, erosion, and meander migration. As the bed and bank materials become finer, a larger percentage of the sediment load will be suspended or wash load. Type C channels might occur up to bed slopes of 2 percent; however, valley wall confinement and the lack of a wide floodplain usually will force a Type A or B stream at steeper slopes.

Figure 5. Rosgen Type C: W/D > 12; Sinuosity > 1.2; ER > 2.2; S < 2%

Rosgen Type D Stream

Type D streams are multiple-channel, or braided, systems that typically do not have a boulder or bedrock channel bed; however, there are cases where localized bedrock control (such as a bedrock outcrop) results in the formation of a short braided reach. Braided channels (Figure 6) can occur across a wide range of morphological and topographic conditions. Alluvial fans in broad alluvial valleys, U-shaped glacial valleys, glacial outwash valleys, low relief alluvial valleys, and deltas are all common locations for Type D streams. With the exception of Type DA streams (wetland, marsh, or delta systems), these systems have high sediment supply and transport capability, so they typically have high sediment yields.

Figure 6. Rosgen Type D: W/D > 40; Sinuosity > 1.2; ER n/a; S < 2%

Rosgen Type E Stream

Type E streams have a low width-to-depth ratio and exhibit a wide range of sinuosity (Figure 7). They are found in a variety of landforms. (Many meadow streams are Type E streams.) Generally they are very stable, in part because they have well developed floodplains with dense (often grassy) vegetation that helps to stabilize the near vertical banks.

Figure 7. Rosgen Type E: W/D < 12; Sinuosity > 1.5; ER > 2.2; S < 2%

Rosgen Type F Stream

Type F streams are meandering, entrenched, and highly incised systems in low gradient landforms. In these systems, top-of-bank elevation is much higher than bankfull elevation (Figure 8). Boulder and bedrock F channels are usually stable while gravel and sand-bed F channels can have high bank erosion rates and are often a failed or failing type C channel. In Ohio, Type F streams will not be in dynamic equilibrium.

Figure 8. Rosgen Type F: W/D > 12; Sinuosity > 1.2; ER < 1.4; S < 2%

Rosgen Type G Stream

Type G streams are deeply entrenched systems similar to Type A streams, except that they occur at bed slopes of 2 to 4 percent (Figure 9). Boulder and bedrock systems are usually stable. Cobble, gravel, and sand-bed G channels are unstable, often deeply incised, have high bank erosion rates, and are often a failed or failing Type B or E channel. Typically, the G3 to G6 types have characteristics of a gully. In

Ohio, Type G streams usually will not be in dynamic equilibrium.

Application to Ohio and the Midwest: Locations and Anomalies

Closer examination of the Rosgen classification approach will reveal that for each stream class, there are some streams that have properties that fall outside of one or more of the expected values for that class. The stream properties in Table 2 should be considered as *expected mean values* for each stream class. It is common for any stream to not exactly fit the requirements specified in the Rosgen Method, especially in the predominantly low gradient Midwest. Few streams from the Midwest were used in the development of the method, so we should not be surprised to find streams with properties larger or smaller than the "expected" values.

Although short reaches of Type B systems can be found throughout Ohio, only a small percentage of the streams will be classified as Type A, B, or D. This is because of an older, low gradient landscape that does not produce much bed load. The steep A and B types usually are associated with bedrock control or are too small to have much stream power in spite of their steep slopes. Most of these will be first-order headwater streams, generally found in rolling hill and mountainous areas. Only 5% of the named stream miles in Ohio have an average slope in the Type A range; only 3% are in the Type B range[14]. Type C and E streams are the most common systems in Ohio and many of the other midwestern states. Typically, E streams are first- or second-order headwater streams, but they also are the standard for southeast Ohio, where sand load is high (Figure 10).

Type C channels found in the virtually flat, lake plain soils areas of the Midwest exhibit a wide range of bed slopes with cohesive fine-grained (silt and clay) banks and beds. Type C streams in low gradient watersheds sometimes have a lower than expected sinuosity particularly in urban areas or settings where they have been modified. Many Ohio streams have the characteristics of a Type C except are classified as a Type E because of a low width-to-depth ratio. Additionally, misclassification of streams can occur as a result of difficulty in determining bankfull conditions in unstable or modified systems that are constantly changing, or as a result of incorrect interpretation and analysis of bed and bank sediment sizes.

Figure 9. Rosgen Type G: W/D < 12; Sinuosity > 1.2; ER < 1.4; S < 2–4%

Figure 10. A first-order E stream in a suburban development in Ohio.

Rivers with stream orders of four or larger commonly will be Type C streams that sometimes might have some Type F problem reaches. Type F streams can be found in just about any setting and often occur due to human change (such as urbanization) in the land use; the removal of stabilizing vegetation on the banks and in the floodplain; or a modification to the channel such as straightening and/or a hydraulic control structure (road crossing, weir, or a log jam). Type G streams can also be found in a variety of settings. Constructed agricultural ditches best fit a G classification, but in most midwestern states, they will have bed slopes that are a fraction of specified slopes for this stream type. This makes Tye Gc the most common channel type in Ohio, but we must keep in mind that the classification system was designed for natural, not modified, streams. Floodplain benches typically form in the bottom of these ditches when constructed with adequate width and a small inset E channel is formed (Figure 11).

Overall, the Rosgen Stream Classification Method works well for midwestern streams. Almost any channel can fit into it and be classified, even if some landscapes are not described as well as they are typified by outliers. For example, there is not much useful description of Type Gc channels, but they do exist in the method. The method is useful in Ohio and has an ability to focus attention to the most important physical attributes of our streams: entrenchment ratios, width-to-depth ratios, and bed material classification. However, others might suggest a process-based classification, which gives insight to the balance of stream power and sediment supply, in order to quantitatively predict the future geomorphic condition of a stream rather than a form-based classification that qualitatively predicts relative condition[15].

Figure 11. A modified channel that has formed an inset Type E channel at the bankfull elevation.

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References

[1]Strahler, A. N. (1952). Hypsometric (area-altitude) analysis of erosional topography. *Geological Society American Bulletin, 63,* 1117–1142.

[2]Ward, A. D., & Trimble, S. T. (2004). *Environmental hydrology* (2nd ed.). Boca Raton: CRC Press.

[3]Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, K. W., & Cushing, C. E. (1980). The river continuum concept. *Can. J. Fish. Aquat. Sci., 37,* 130–137.

[4]Junk, W. J., Bayley, P. B., & Sparks, R. E. (1989). The flood pulse concept in river-floodplain systems. *Can. Spec. Publ. Fish. Aquat. Sci., 106,* 110–127.

[5]Giller, P. S., & Malmqvist, B. (1998). *The biology of streams and rivers.* Oxford: Oxford UP.

[6]Leopold, L. B., & Wolman, M. G. (1957). River channel patterns: Braided, meandering, and straight. *United States Geological Survey Professional Paper 282-B,* 39–84.

[7]Schumm, S. (1977). *The fluvial system*. New York: J. Willey.

[8]Rosgen, D. L. (1994). A classification of natural rivers. *Catena, 22,* 169–199.

[9]Rosgen, D. L., & Silvey, H. L. (1996). *Applied river morphology*. Pagosa Springs, CO: Wildland Hydrology Books.

[10]Whiting, P. J., & Bradley, J. B. (1993). A process-based classification system for headwater streams. *Earth Surface Processes and Landforms, 18*(77), 603–612.

[11]Montgomery D. R., & Buffington, J. M. (1997). Channel-reach morphology in mountain drainage basins. *GSA Bulletin, 109*(5), 596–611.

[12]Simon, A. (1989). The discharge of sediment in channelized alluvial streams. *Journal of the American Water Resources Association, 25*(6), 1177.

[13]Nanson, G. C., & Croke, J. C. (1992). A genetic classification of floodplains. *Geomorphology, 4,* 459–486.

[14]Ohio DNR. (2001). *Gazetteer of Ohio Streams* (2nd ed.). (Water inventory report 29.) Columbus, OH: Division of Water.

[15]Simon, A., Doyle, M., Kondolf, M., Shields, F. D., Jr., Rhoads, B., & McPhillips, M. (2007). Critical evaluation of how the Rosgen Classification and Associated "natural channel design" Methods fail to integrate and quantify fluvial processes and channel response. *J. AWRA*, *43*(5), 1117–1131.