3.2.2 Stream Morphology and Classification

This section provides more technical information for the curious about the relationship between stream ***form*** (or ***morphology***) and physical stream ***function*** (i.e., flood behavior, sediment transport).

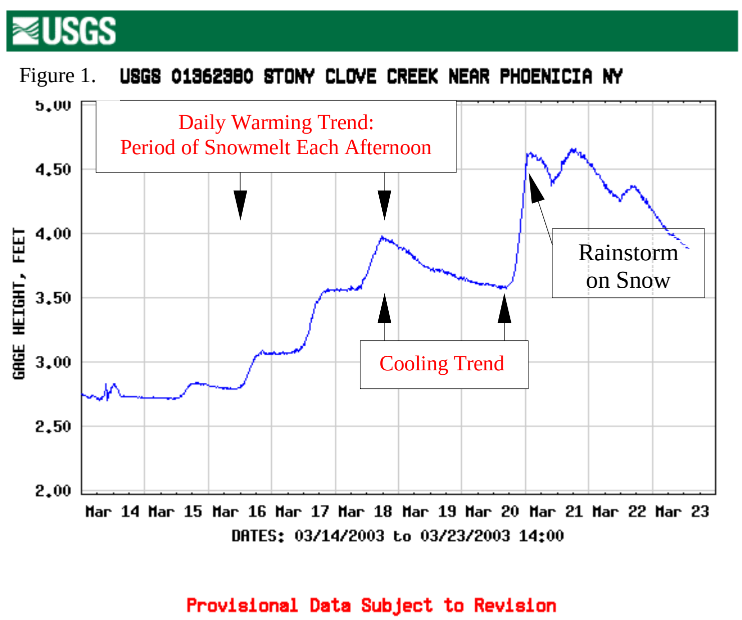
The last section described how a stream's form --slope and depth-- determine its function --how much potential force the stream has to move the silt, sand, gravel, cobble and boulders that make up its *bedload*. We focused on slope and depth because they are often changed --intentionally or unintentionally-- by stream managers. There are, however, many characteristics that come together to influence how a stream "makes itself", and whether it is stable or unstable in a given valley. These characteristics[2] include:

Stream flow (Q)

Usually represented as cubic feet or cubic meters per second, streamflow is also called stream ***discharge***. Stream flow changes from hour to hour, from day to day, from season to season, and from year to year.

The typical pattern of streamflow over the course of a year is called the streamflow regime.

Some streamflows play a more significant role than others in determining the shape of the stream. As described in Section 3.1.4, the "*bankfull flow*" is considered most responsible for defining the stream form, and for this reason, bankfull flow is also sometimes called the *channel-forming flow*. This flow typically recurs every 1-2 years. It may seem surprising that very large floods aren't more important in forming the channel, but while they may induce catastrophic changes in a stream—severely eroding banks and washing countless trees into the channel—these major floods are more rare, occurring on the average every decade or so. The flows that have the most effect on channel shape are those that come more frequently, but which are still powerful enough to mobilize the gravel and cobble on the streambed: the smaller, bankfull flows.



The height of the water in the channel is called the ***stage***. When a stream overtops its banks, it's

[2] Each characteristic is followed, in parentheses, by the variable used to represent it in formulae.

in ***floodstage***. ***Bankfull stage*** –when the stream is just about to top its banks-- is used as a benchmark for measuring stream dimensions for classifying different stream types (see ***Rosgen Classification System***, below).

Slope (S)

We already mentioned slope as one of the two main determinants of a stream's potential force for erosion of the streambed and banks. The slope of a stream usually refers to the average slope of the water surface when the stream is running at bankfull flow.

Channel average depth (d)

Depth is the other primary determinant of potential force, and is measured from the streambed to the water's surface. Again, this will depend on the level of the streamflow. When used to compare one stream reach to another in ***stream classification systems*** (see below), the average depth of the stream during a bankfull flow is used.

Channel width (w)

Together with average depth, the ***width*** of the channel determines the ***cross-sectional area*** (Area = width x depth). If a roadway encroaches on a stream, its width is reduced. To pass the same sized flood, it's going to have to be deeper, that is, floodstage is increased.

Channel roughness (n)

So far we've only talked about what gives the water its potential force to erode the streambed and banks. There are also characteristics of the stream that slow the water down, or resist the flow. One of these is the channel ***roughness***: it's harder for the stream to flow through a section of stream filled with boulders than through a stream with a silt-bottomed bed, and no obstructions. Water flows more slowly across a floodplain filled with trees and dense brush than it does across a smooth, newly mown lawn or parking lot, and so is less likely to cause erosion. This is also sometimes referred to as ***bed*** or ***channel roughness***.

Sinuosity (k)

A different kind of roughness that slows water down has to do with whether the channel runs straight, or curves. When the flow of a stream is slowed as it moves around a bend in the stream, we say that the flow is encountering ***form roughness***. The curviness of a stream is called its ***sinuosity***, and is measured as the stream length divided by the valley length. That is, if a stream runs completely straight down a mile long valley, both the valley and the stream are the same length, or 1 mile / 1 mile = a sinuosity of 1. If the stream snakes, or ***meanders***, down the same valley, it might be two miles long, or 2 miles / 1 mile = a sinuosity of 2.

As a rule of thumb, we find that, in natural channels, the lower the slope, the more sinuous the stream.

Radius of curvature (Rc)

Radius of curvature is another measure the “curviness” of the stream, but at a single curve, and is measured as in this illustration:

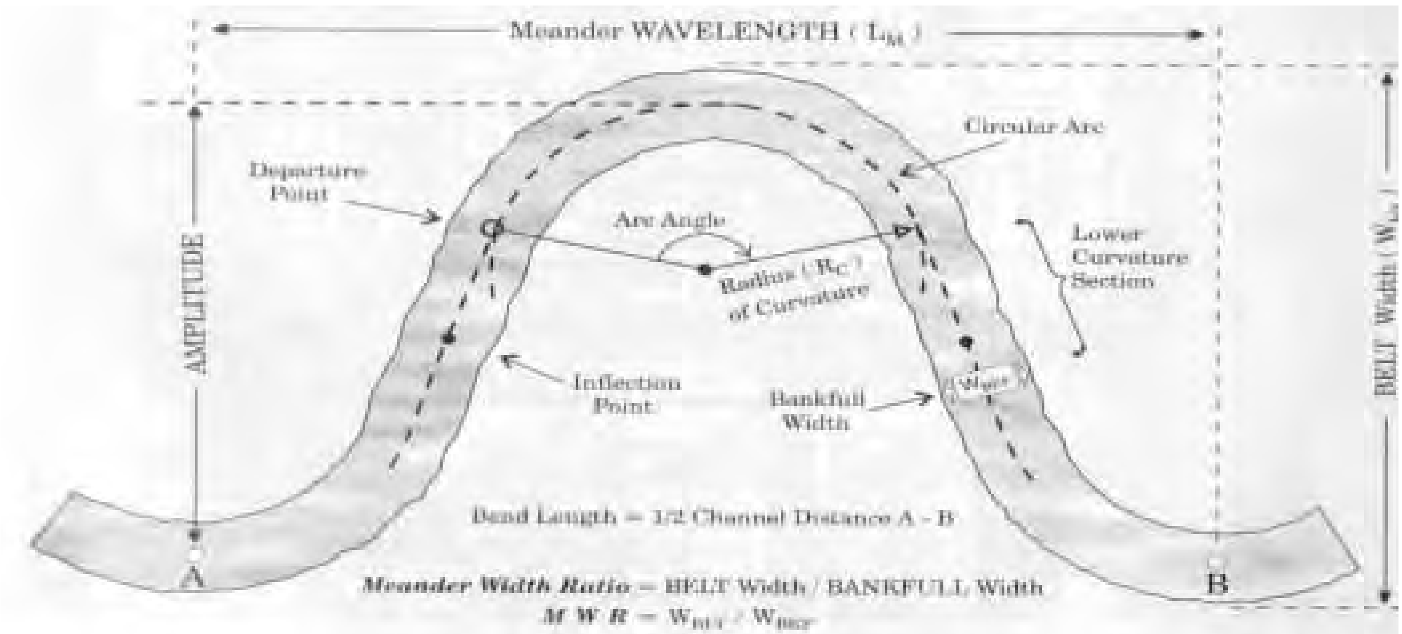


Figure 2. Adapted from The Reference Reach Field Book, D. Rosgen.

Sediment size (D50)

Table 1. Size ranges of selected categories of stream sediment, in millimeters.

Name	Size
Silts	< 0.062mm
Sands	0.064mm - 2mm
Gravels	2mm - 64mm
Cobbles	64mm – 256 mm
Boulders	256mm – 48mm

It takes more force for a stream to move the material on the bed of the stream if it is made up of large cobbles than if it is sand or silt; the smaller the particles, the more easily they will be moved. To classify or assess a reach of stream, about 100-300 particles are randomly selected and measured (see photo at left), and the median size particle gives the ***D50*** of the reach: meaning that 50% of the particles in the stream are smaller, and 50% are larger.

Bed and Bank Cohesiveness

Due to the glacial history of the region, soils in the Catskills are extremely variable from place to place, and some soil types hold together better than others, or are more ***cohesive***. Some streambeds have their gravel and cobble locked together in a form that resists movement by streamflow, and others “unzip” easily. The roots of trees and shrubs can reach deep into the soil of a streambank, and the web of fine root fibers can add a tremendous amount of cohesiveness to the soil.

The “balance” that streams develop over time when they aren’t disturbed is the balance between the erosive forces of floodwaters, and the strength of the bed and banks to resist that erosive power. This balance develops because streams will erode away their banks until, eventually, the lengthening of their meanders reduces the slope, or the stream is widened and depth is decreased sufficiently, such that the cohesiveness of the soil and vegetation together just equal the erosive potential of the floodwaters.

If the vegetation on the streambank is changed, the soil cohesiveness will change, and that balance point will change. Likewise, if a streambank gradually migrates into a less cohesive soil type, it can suddenly begin eroding very quickly.

Sediment discharge (Qs)

When silts and sands, gravels, cobbles or even boulders have been moved by the streamflow, we call them ***sediment***. ***Sediment discharge*** is the amount of sediment moving past a particular point over some interval of time, and is usually measured in tons per year. ***Bedload*** is sediment that moves along the bottom of the channel, while ***washload*** is sediment that is suspended up in the water.

Measuring sediment discharge is one way to determine if a stream is stable or not. If the amount of sediment coming into a reach of stream doesn’t roughly equal the amount leaving the reach in the same time period, the form of the reach will have to change.

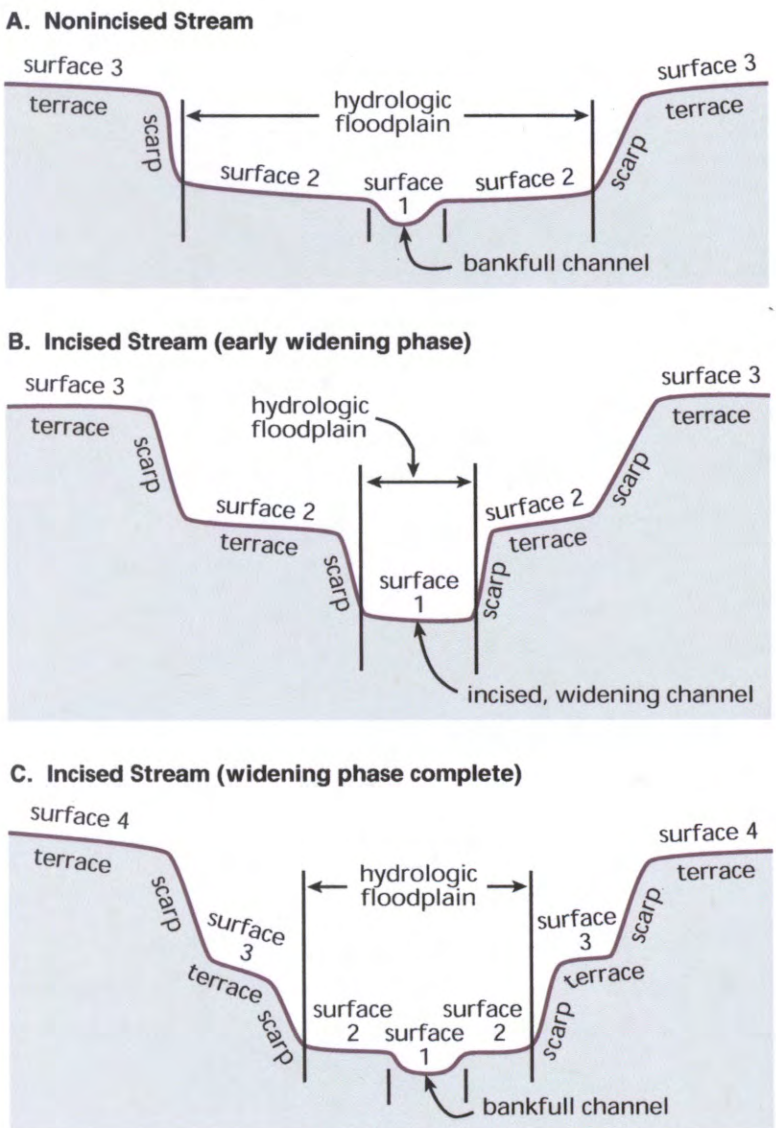


Fig. 1.24 – Terraces in (A) nonincised and (B and C) incised streams. Terraces are abandoned floodplains, formed through the interplay of incising and floodplain widening.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).

Figure 3. Stream evolution model, Montgomery and Buffington, NRCS, 1998.

Entrenchment

When a reach of stream is straightened or narrowed, it may cut down into its bed, so flood flows can't spill out into the floodplain. When this happens, we say the reach is ***entrenched***. Entrenchment can be moderate or extreme. When even large floods are confined to the narrow channel of the stream, they can become very deep, and therefore very erosive. The result may be that the stream cuts down even further into the bed, or the banks may erode away on both sides, widening the channel. Eventually, the channel may widen enough to allow a new floodplain to develop inside the entrenched banks (Figure 3.). This is one way streams evolve over time.

One method of measuring entrenchment was developed by hydrologist Dave Rosgen. His ***entrenchment ratio*** compares the stream's width at bankfull flow with its width at twice the maximum depth at bankfull flow (Figure 4.).

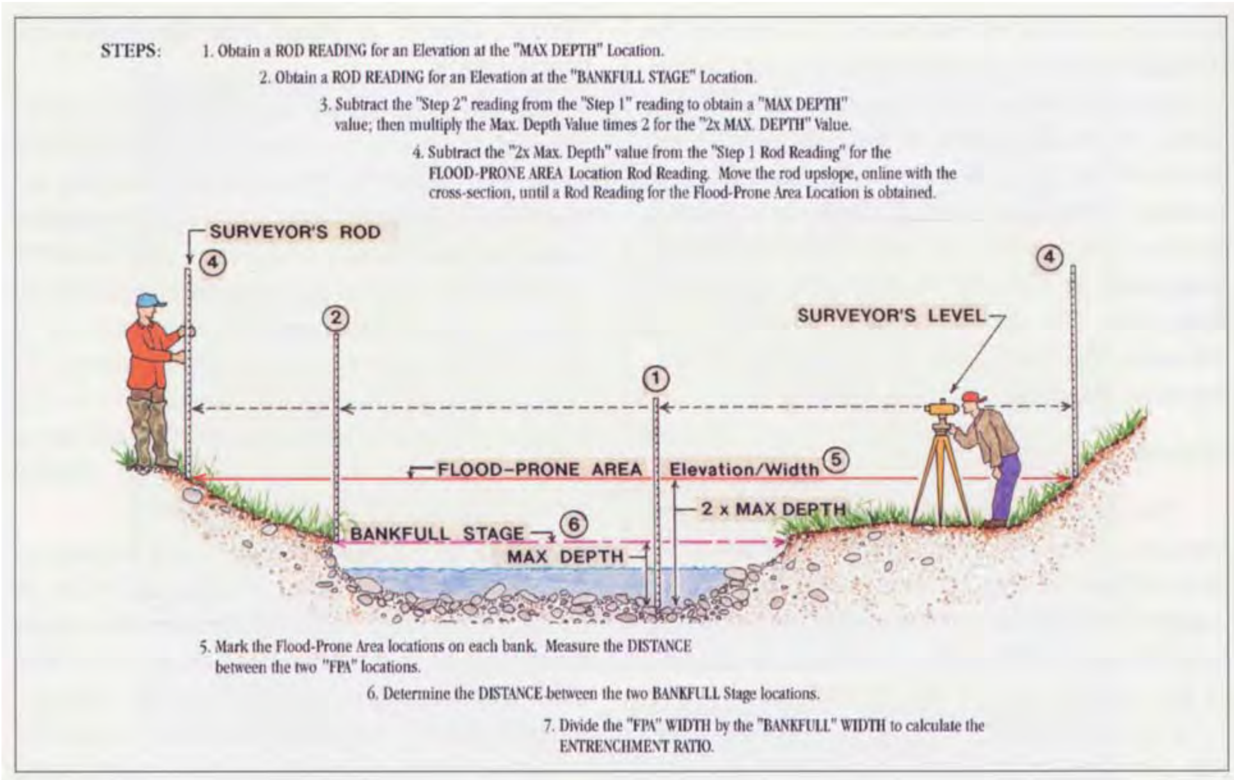


Figure 4. Measurement of entrenchment ratio, from Rosgen, 1996.

Applying the Science of Stream Form and Function to Stream Management

By carefully measuring all these characteristics of stream form, stream managers can get a fairly good idea about the relative stability of a stream, reach by reach, over its whole length. Throughout this Plan you will find references to these different characteristics. By understanding the relationship between the stream's form and its function, managers can prioritize severely unstable stream reaches for treatment, and can apply different management strategies appropriately, and more cost effectively. Analysis of stream morphology can also make for more successful design of stream restoration projects; designers identify and survey stable stream reaches and then use their form characteristics as a design template for restoration projects.

Classifying Streams by their Form

One useful tool for stream managers, also developed by Dave Rosgen, is a system for classification of different stream reaches on the basis of their form. Rosgen's system gives letter and number designations to different stream types, depending on their combination of five characteristics:

1) Entrenchment ratio
2) Ratio of width to depth
3) Slope
4) Sinuosity
5) Sediment size (D_{50})

Different combinations of these characteristics result in a great number of different stream types, from A1 through G6 (see Figure 5. read letter designation across the top, number down the left side). These letter/number designations provide a sort of shorthand for summing up the form of a stream reach.

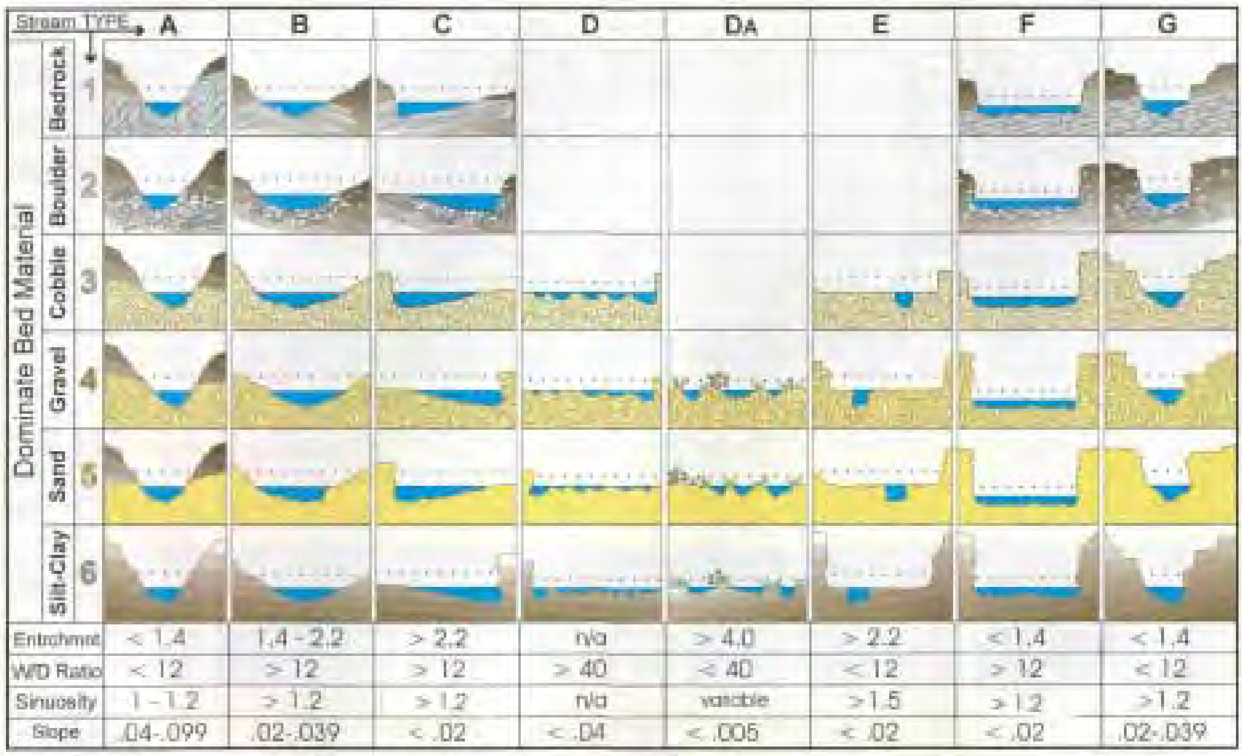


Figure 5. Stream Types, from Rosgen 1996.

So, for example, a B3 stream type has a cobble dominated bed, has a moderate amount of accessible floodplain, is more than 12 times as wide as it is deep, is moderately sinuous, and drops between 2 and 4 feet for every 100 feet of stream length. How does a B3 differ from an F3? An F3 is more entrenched, meaning that it can't spill out onto it's floodplain during storm flows, and it's also less steep, dropping less than 2 feet for every 100 feet of stream length. How is a B3 different from a G3? Not only is the G3 more entrenched, like the F3, but also has a smaller width-to-depth ratio than a B3.

As we have discussed above, each of these different forms functions a little differently from the next, especially with regard to the stream's ability to transport its sediment effectively. By classifying the different stream types in a watershed, then, different management strategies can be applied appropriately to different sections of stream. Rosgen (1994) has created a table (see Table 2) which suggests how the different stream forms can be interpreted with regard to a number of management issues. In the following sections, the Broadstreet Hollow Creek will be described in terms of these Rosgen stream types.

Stream type	Sensitivity to disturbance[a]	Recovery potential[b]	Sediment supply[c]	Streambank erosion potential	Vegetation controlling influence[d]
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	very high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate
D6	high	poor	high	high	moderate
Da4	moderate	good	very low	low	very high
DA5	moderate	good	low	low	very high
DA6	moderate	good	very low	very low	very high
E3	high	good	low	moderate	very high
E4	very high	good	moderate	high	very high
E5	very high	good	moderate	high	very high
E6	very high	good	low	moderate	very high
F1	low	fair	low	moderate	low
F2	low	fair	moderate	moderate	low
F3	moderate	poor	very high	very high	moderate
F4	extreme	poor	very high	very high	moderate
F5	very high	poor	very high	very high	moderate
F6	very high	fair	high	very high	moderate
G1	low	good	low	low	low
G2	moderate	fair	moderate	moderate	low
G3	very high	poor	very high	very high	high
G4	extreme	very poor	very high	very high	high
G5	extreme	very poor	very high	very high	high
G6	very high	poor	high	high	high

a Includes increases in streamflow magnitude and timing and/or sediment increases.
b Assumes natural recovery once cause of instability is corrected.
c Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
d Vegetation that influences width/depth ratio-stability.

Table 2. Management Interpretations of Rosgen Stream Types (Rosgen 1996)

References:

FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US gov't). Stream incision image: http://www.usda.gov/stream_restoration/Images/scrhimage/chap1/fig1-24.jpg . GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3.

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