STREAMBANK EROSION FACTORS, MECHANISMS, AND CAUSES

Streambank Erosion Factors

The Wisconsin Department of Natural Resources (WDNR), for permitting purposes, adapted Dave Rosgen's Bank Erosion Hazard Index (BEHI) procedure to rate the potential severity of streambank erosion. The following seven factors are used in the BEPI (Bank Erosion Potential Index), adapted from Rosgen, David L. "A Practical Method of Computing Streambank Erosion Rate."

1. Bank Materials
2. Hydraulic Influence of Structures
3. Maximum bank height divided by the OHWM (bankfull) height
4. Bank Slope
5. Stratification/Bank Layering
6. Bank Vegetation
7. Thalweg Location

The worksheet can be found in WDNR Administrative Code NR-328, Subchapter III, "Shore Erosion Control Structures on Rivers and Streams" (http://dnr.wi.gov/org/water/fhp/waterway/permits/BankErosionPotentialIndexWorksheet.pdf). The WDNR metrics and a description of each of the streambank erosion factors are defined in the worksheet. The higher the BEPI score, the higher potential for streambank erosion.

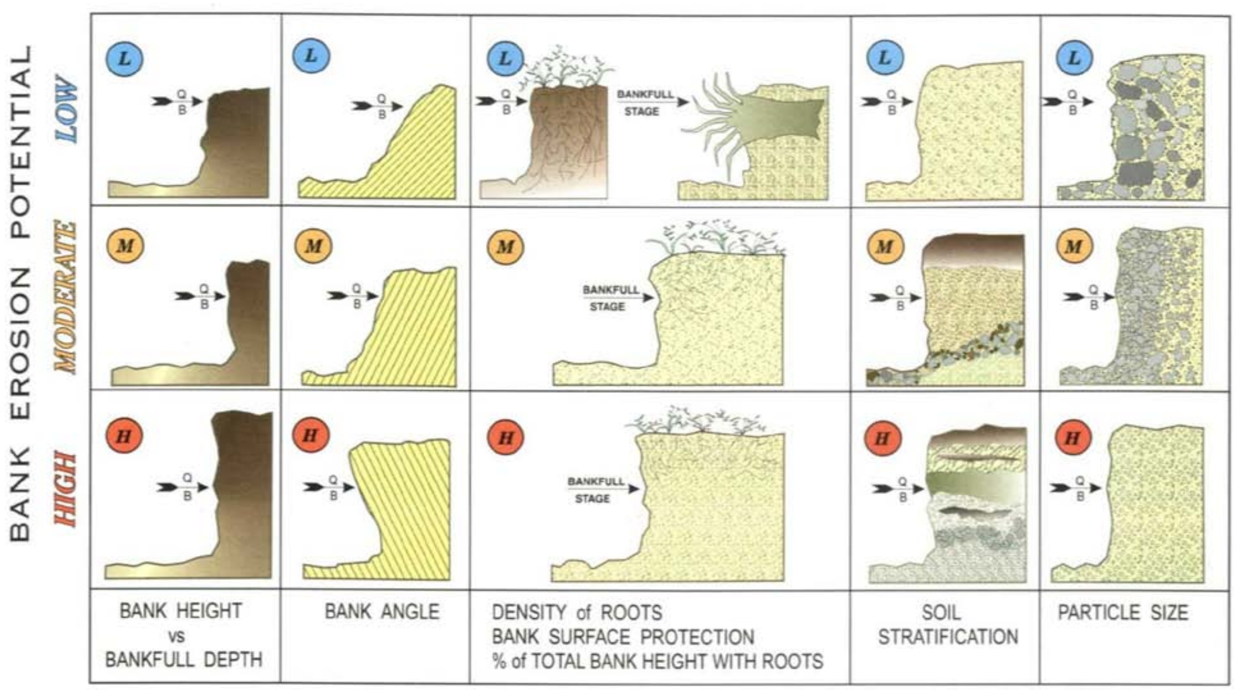


Figure 1: Streambank erodibility factors.

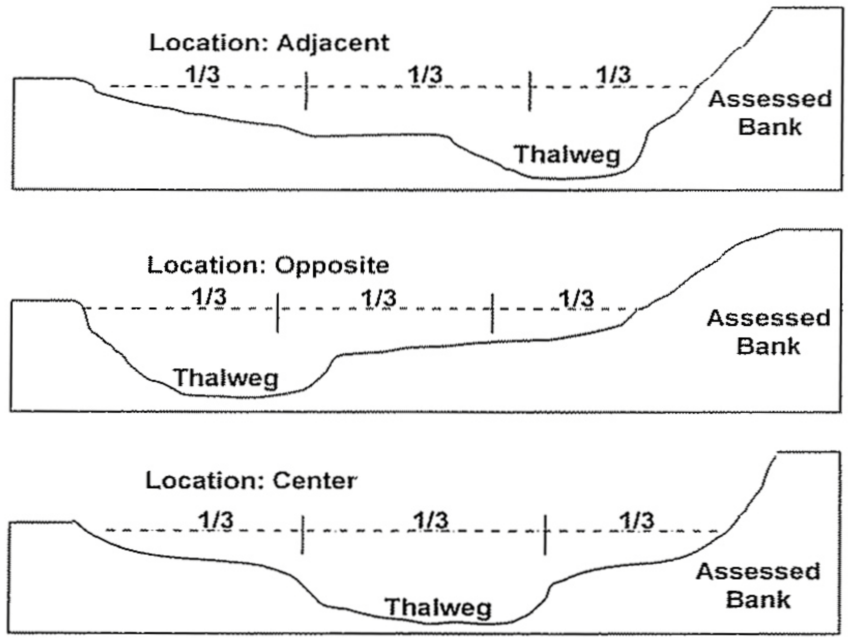


Figure 2: Thalweg location in relation to assessed bank

Following is more detailed information on bank materials.

Streambank Materials and Erosion

Streambank failure is closely related to the composition of the streambank material. Although these materials can be highly variable, they can be broadly divided into four categories.

Bedrock**.** Outcrops of bedrock are generally quite stable; however, they can cause erosion in the opposite bank if it is softer material.

Cohesionless Banks**.** Cohesionless soils are heterogeneous mixtures of silts, sands, and gravels. These soils have no electrical or chemical bonding between particles and are eroded particle by particle. Erosion of cohesionless soils is determined by gravitational forces, bank moisture, and particle characteristics. Factors influencing erosion also include seepage forces, piping, and fluctuations in shear stress.

Cohesive Banks**.** These banks generally contain large quantities of clay particles which create a higher level of bonding between the particles. Consequently, cohesive soils are more resistant to surface erosion because they are less permeable. This reduces the effects of seepage, piping, and frost heaving. However, because of low permeability, these soils are more susceptible to failure during rapid drawdown of water levels due to the increase in soil pore water pressures.

Stratified or Interbedded Banks**.** These banks are generally the most common bank type in fluvial systems because of the natural layering process. These soils consist of layers of materials of various textures, permeability, and cohesion. When cohesionless layers are interbedded with cohesive soils, the erosion potential is determined by the characteristics of the cohesionless soil. When the cohesionless soil is at the toe of the bank, it will generally control the erosion rate of the overlaying cohesive layer (Figure 3). When a cohesive soil is at the toe of the slope, it will generally protect any cohesionless layers above (although these layers will still be subject to surface erosion).

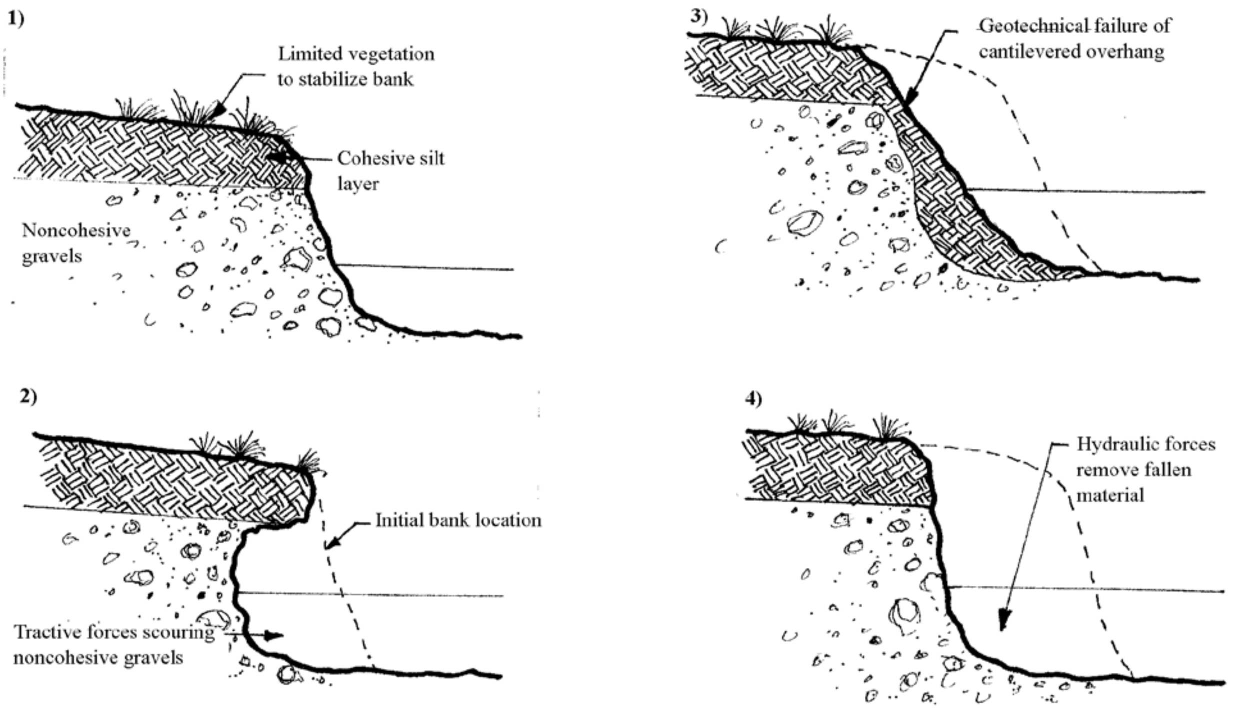


Figure 3: Stratified Streambanks and Combination Failures (*Adapted from Johnson and Stypula 1993*)

Streambank Failure Mechanisms

Bank failures in fluvial systems generally occur in one of three ways (Fischenich 1989): hydraulic forces remove erodible bed or bank material, geotechnical instabilities result in bank failures, or a combination of hydraulic and geotechnical forces cause failure. Fischenich (1989: pp 103) describes each failure mechanism and its characteristics as follows.

***Hydraulic Failures*.** Bank erosion occurs when flowing water exerts a tractive force that exceeds the critical shear stress for that particular streambank material. Hydraulic failure is generally characterized by a lack of vegetation, high boundary velocities, and no mass soil wasting at the toe of the slope.

***Geotechnical Failures*.** Geotechnical failures that are unrelated to hydraulic failures are usually a result of bank moisture problems. Moisture can affect the ability of the bank material to withstand stresses. Failures are often the result of the shear strength of the bank material being exceeded. Characteristics of geotechnical failures can vary, although mass wasting of soil at the toe of the bank is often one indicator.

***Combination*.** The most common failure is due to a combination of hydraulic and geotechnical forces (refer to Figure 1). For example, bed degradation due to hydraulic forces can lead to an oversteepening of the banks which can result in a geotechnical failure of mass wasting.

***Cause of Failures*.** Although bank failures result from three different mechanisms, the actual causes of erosion are complex and varied (Fischenich 1989). Successful protection projects need to address the causes of failure.

Erosion from hydraulic forces is usually connected to flow velocities and/or its direction (Fischenich 1989). Human actions are often responsible. Channelization and constrictions caused by bridges are examples that will change velocities. Changes in flow direction often result from an obstruction along or in the channel. Any unnatural destruction of bank vegetation promotes erosion by hydraulic forces. Geotechnical failures are usually the result of moisture conditions in the streambank which create forces that exceed bank resistance. Common examples of the causes include (Hagerty 1991; USACE 1981):

- Banks are destabilized by the piping of cohesionless soil from lenses (Figure 2).
- Capillary action temporarily decreases the angle of repose of the bank material to less than the existing bank slope.
- Liquefaction of fine-grained material causes fluid-like failures of the bank from pore pressure increase during rapid drawdown.
- Shrinking and swelling of clay soils during wetting and drying cycles causes tension cracks.
- Freezing and thawing of soil which weakens the shear strength.
- Subsurface moisture changes weaken the internal shear strength of the soil mass at the interface of different soil types.

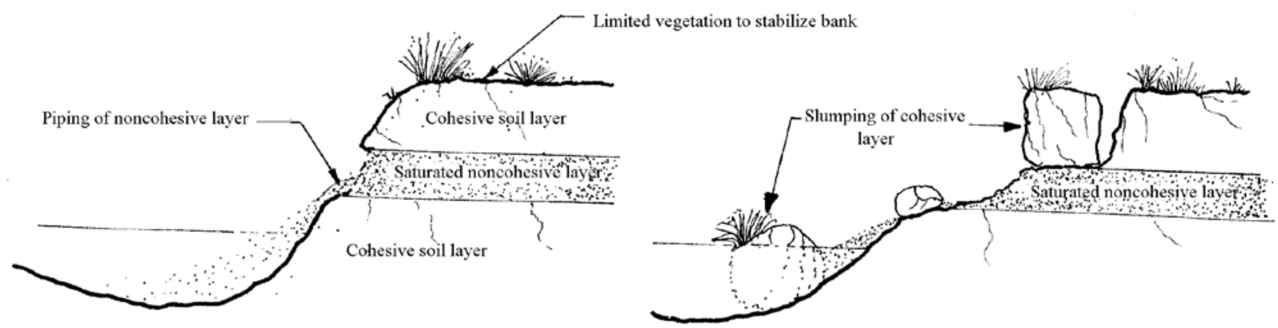


Figure 4: Bank Erosion Due to Piping (Adapted from Hagerty 1991).

<u>Streambank Erosion Mechanisms (Leopold, 1994)</u>

Streambank erosion mechanisms include the following:

- Shear caused by high velocity flow against banks
- Seepage forces
- Frost

The most widely known and generally accepted cause of bank erosion is shear stress on streambanks caused by fast moving water during peak flows. However, in many rivers, the shear stress is not important as an erosion mechanism because bank material is softened, granulated, crumbled, or slumped due to either seepage or frost.

The loose material becomes a pile of debris ready to be moved downstream during the next high flow. After a flood peak has passed, water drains through soil in the floodplain to the streambank, causing slumping or other erosion.

If it is during the winter, flow from the floodplain to the streambank is slow and provides a source of water to any ice crystals growing on the bank surface. As an ice crystal grows, a granule of bank sediment can be held at the tip of the crystal. When the crystal melts, the sediment falls to the base of the bank. As this process is repeated, sediment is accumulated at the base of the bank to be washed away in the next high flow.

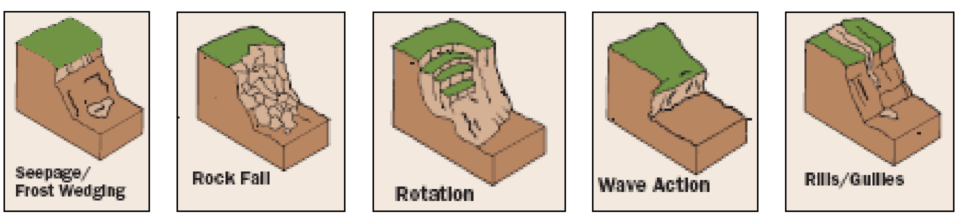
Investigations

For information on investigating a site to determine stability, see the Wisconsin supplement to EFH Chapter 16, "Stream Stability Problem Identification" and "Investigations""

Since bank failures are geotechnical or related to hydraulics, or both, an interdisciplinary team is crucial in identifying the causes of failure. Investigations should cover the list of items in the Wisconsin supplement to EFH Chapter 16, "Streambank Protection Design" and "Stream Channel Restoration Design." Some of the steps to assist in determining streambank failure mechanisms and causes include the following.

1. Identify the streambank erosion factors on page 1 at the site including streambank composition and stratification (bank materials and layering).
2. Assess possible streambank failure mechanisms by observing the site over a period of time.
3. Several cross sections should be taken to graphically show the channel in relation to the floodplain. This information will help reveal the type of degradation (i.e., lateral erosion or downcutting) and will provide baseline data for future monitoring. If a channel is actively downcutting, these sites are significantly more difficult to stabilize and should generally be avoided unless instream structural measures are planned. If the streambank is cutting laterally, appropriate bioengineering methods may be more successful.
4. A longitudinal profile survey should be completed to highlight convergence or divergence of the water surface and low bank profile, which would indicate instability. See Longitudinal Profile Instruction in Companion Document 8, Detailed Instructions for Reference Reaches.
5. Type of bed material and distribution should be determined. This will provide clues to the resistance of the material to erosive flows. Particle size distributions can be calculated by collecting and screening samples, or for the surface layer only, a pebble count of exposed particles can be sampled (Leopold, 1994).

Other Erosion Mechanisms



Frost Wedging is a process of physical weathering in which water freezes in a crack and exerts a force on the soil or rock causing further rupture. Frost action generally occurs on poorly drained soils, such as clay, and often results in the development of heaves or depressions.

Rockfall is a type of mass movement that involves the detachment and movement of a small block of rock from a bank face to its base. Normally occurs when the rock has well defined bedding planes that are exaggerated by freeze-thaw action or thermal expansion and contraction.

Rotational Slip is a downward mass movement of unconsolidated soil material that moves suddenly along a curvilinear plane. Groundwater exerts outward pressure on soil particles and causing a seep which creates a landslide. Additional causes include increased weight, toe erosion and saturated conditions. This process is also called a **slump** or a **slide**.

Wave action is the impact of waves hitting directly on exposed soil. Waves vary with wind speeds and duration, water depth, and the continuous length of water over which winds blow in one direction. Wave heights can be calculated when these properties are known. Choosing and designing a shoreline stabilization method requires knowing the maximum height of waves affecting the property. Waves can also be created by heavy boat traffic near shorelines.

Rill erosion is the removal of soil through the cutting of many small, but conspicuous, channels where runoff concentrates. Rill erosion is intermediate between sheet and gully erosion. The channels are shallow enough that they are easily obliterated by tillage; thus, after an eroded field has been cultivated, determining whether the soil losses resulted from sheet or rill erosion is generally impossible. Rilling is the most common process of rainfall erosion losses.

Gully erosion is the consequence of water that cuts down into the soil along the line of flow. Gullies form in exposed natural drainage-ways, in plow furrows, in animal trails, in vehicle ruts, between rows of crop plants, and below broken man-made terraces. In contrast to rills, they cannot be obliterated by ordinary tillage. Deep gullies cannot be crossed with common types of farm equipment. The total amount of soil eroded due to gullies is not necessarily as great as that removed from rilling.