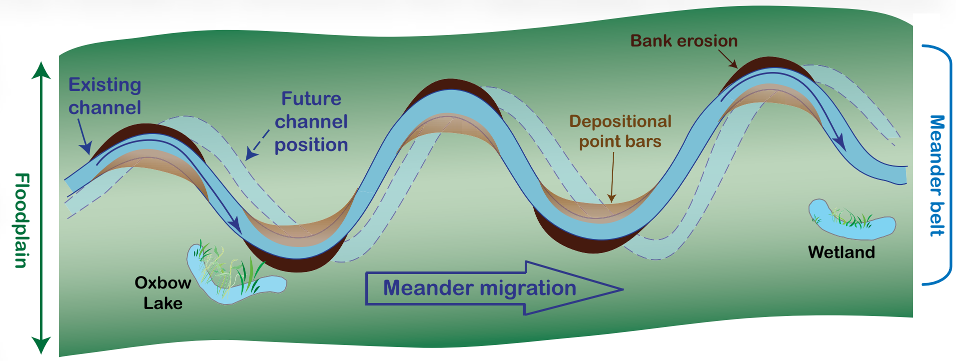
# Resource Sheet 1: Streambank Erosion and Restoration

## Why is my streambank eroding?

In order to determine why a streambank is eroding and to develop a restoration approach, it is necessary to understand stream behavior. All streams are dynamic, gradually changing shape as they erode, transport, and deposit sediment. A natural stream will have slowly eroding banks, developing sandbars, migrating meanders, and channels reshaped by flood flows. They are in a state of *dynamic equilibrium*, where the stream is able to maintain a stable shape (dimension, pattern, and profile) over time without excessive erosion or sedimentation even as natural changes or artificial changes occur in the watershed (see informational sheet Understanding Our Streams and Rivers). A stream system maintains this dynamic equilibrium when its natural flexibility and a functional connection to the floodplain are preserved (see figure).




A natural, healthy stream channel meanders from bend to bend within a *meander belt*. This meandering (seen here from above) is known as the stream's *pattern*.

Many streams are artificially confined; consequently, they cannot adjust or regain their equilibrium within their meander belt or floodplain after a disturbance. Streams are increasingly confined by agriculture, infrastructure, and development in the floodplain. When ditches and levees, roads, bridges and culverts, rock revetments, and other structures are placed in the floodplain, the state of dynamic equilibrium is interrupted. Confined streams can no longer self-mend, which results in instability where bed and bank erosion is a common consequence.

*Land use change and channelization*: The floodplain and stream corridor are impinged by agricultural fields. The meanders are disconnected after straightening by channelization.

## Common causes of stream instability

### Land use changes

Land use activities throughout the watershed lead to stream instability by changing the watershed's *hydrology*. Land use changes force a stream to adjust to changes in *discharge*, water *velocities*, or *sediment load*. For example, both urban storm drains and agricultural tile funnel rainfall quickly and directly into streams. These practices dramatically increase the peak discharge and water velocity of a stream. Additionally, this direct flow is low-sediment or "sediment-hungry" runoff and is very erosive. Another land use change that impacts hydrology is draining wetlands. By removing natural water storage, streams are further burdened with water that is no longer retained on the landscape. Consequently, affected streams are unstable, usually degraded and incised, and must eventually adjust their shape to accommodate the flashy discharge events with un-naturally high peak flows.

### Vegetation changes

Streambank instability, erosion, and bank failure also result from a lack or loss of natural vegetation along streambanks. Deep, dense-rooting, and flood-tolerant native plants strengthen and stabilize the banks and slow floodwaters. (See additional benefits explained in Resource Sheet #2.) The loss or degradation of natural riparian vegetation can be caused by livestock overgrazing, row crops without vegetative buffers, herbicide applications, deforestation, or development. Once streambanks are degraded the potential for accelerated erosion is greatly increased because the banks are weak and unstable. Common practices of repairing banks with riprap are expensive, less stable, and lack the biological benefits of a vegetated bank.

**Definitions:**
***aggradation***: *rising streambed, sedimentation*
***degradation***: *lowering streambed, erosion*
***discharge***: *volume of water carried by a stream per unit time*
***headcut***: *downcutting of streambed in upstream direction*
***hydrology***: *movement of water through the hydrologic cycle*
***nickpoint***: *sudden change in the slope of the streambed*
***sediment load***: *amount of sediment carried by a stream*
***slumping***: *block(s) of bank slips down*
***velocity***: *speed of flow*

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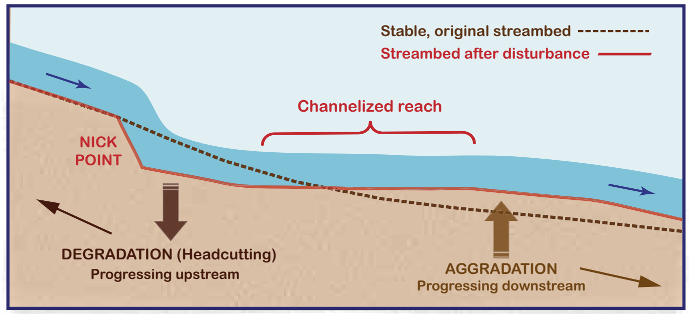
### In-channel changes

In-channel alterations of stream shape directly disrupt stream balance resulting in *aggradation* and *degradation*. For instance, ditching or channelizing a stream replaces a long, sinuous stream reach with a short, straight, smooth channel. Such a change steepens the slope and removes roughness from the streambed. The sudden increase in speed and erosive energy of the streamflow will degrade the streambed within the straightened reach. Upstream the channel will begin to incise at the *nickpoint*. This forms an active *headcut* that migrates upstream (referred to as headcutting). Over time, the streambed continues to deepen and the entire stream reach becomes incised and disconnected from its floodplain.




*In-channel changes*: As shown in this side view, channelizing a stream may cause headcutting upstream and aggradation downstream.

The effects of channelization are widespread and impact the entire stream network. A headcut can initiate headcuts in the tributaries. This leads to excessive erosion and instability upstream into the basin. As excessive sediment is released into the stream system, the instability will extend downstream as the newly eroded sediment aggrades in flatter valley reaches.

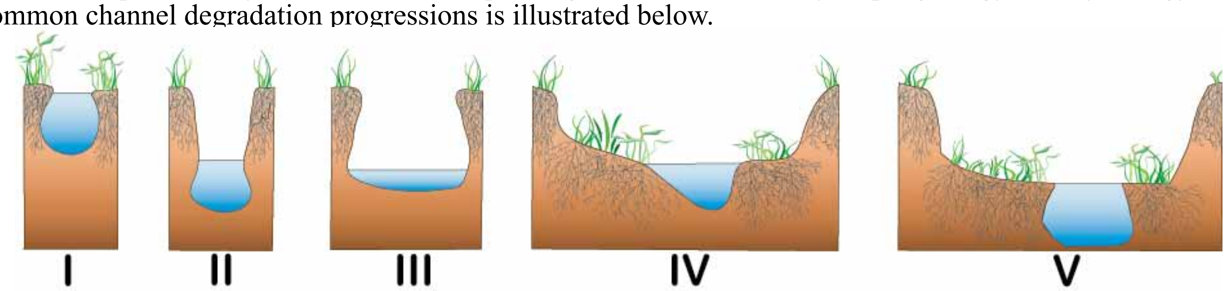
In-channel structures such as dams, bridges, and culverts interrupt the natural stream shape by creating unnatural reservoirs or passageways. For instance, culverts are commonly too small, set improperly, and do not emulate the natural channel pattern. Stream instability is the result as demonstrated by flooding upstream and erosion downstream of these structures.

*Headcut & nickpoint:* An active headcut degrades the bed of an Illinois stream.

### Stream responses to disturbances

A disturbance such as ditching, development, or deforestation that changes the hydrology, stream shape, or riparian vegetation causes a stream to lose its equilibrium. When a stream is in disequilibrium, the stream channel actively adjusts toward a more stable form by going through transitional phases. Channel evolution can progress through many phases, where each phase could persist for years to centuries depending on stream and valley slope, geology, and hydrology. One of the more common channel degradation progressions is illustrated below.

**Channel evolution**




**I.** A properly shaped stream in **equilibrium** and connected to its floodplain prior to disturbance.
**II. Channel incision** from ditching or by a headcut originating in a channelized reach due to increased slope and flow.
**III. Channel widening** as the channel begins to meander again.
**IV.** A more properly shaped stream as it evolves to re-establish equilibrium and rebuild a new floodplain.
**V.** A new, properly shaped channel in equilibrium with a lowered floodplain.

The first section below describes an undisturbed stream in equilibrium. The next three sections describe common responses to stream instability after a disturbance. These responses vary greatly in extent and duration depending on the disturbance and the channel's recovery potential.

### Equilibrium

A stream in equilibrium (Stage I in Channel evolution figure above) can transport water and sediment and dissipate the water's energy while maintaining its shape over time without excessive degradation or aggradation. A stream channel in equilibrium has these shape features:

- Pattern: a sinuous pattern that increases the stream's length, thereby decreasing its gradient and stream flows
- Profile: an alternation between riffles that help control stream gradient and pools that absorb the water's energy
- Dimension: the proper width and depth to effectively transport water and sediment supplied by the watershed

Furthermore, the channel is connected to the floodplain during high flows, the riparian zone is well vegetated, and the channel is not confined throughout the meander belt. As a result, channel movement (meander migration) and streambed and streambank erosion are minimal.

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### Channel incision

When a channel is incising (Stage II in Channel evolution figure), the streambed is actively eroding, downcutting, or degrading in response to disturbances such as:

- changes in the watershed (urban stormwater drains, ditching, tiling, draining wetlands) that introduce higher volumes of water or low-sediment ("sediment hungry") runoff,
- erosion by low-sediment water flowing over a dam or out of a reservoir,
- improperly sized or placed bridges or culverts that constrict flow and effectively act as dams,
- increased streamflow velocities because of disturbances such as channelization or urbanization, or
- a headcut that originated downstream.

An incised channel is disconnected from its floodplain. During high flows, the channel must transport the total volume of water because it cannot access the floodplain that, under natural conditions, could store and slow down the floodwaters. The banks of an incised channel are actively eroding (see Channel widening, below). Consequently, excessive erosion of the streambed and streambanks occurs and often results in long-term instability. As degradation continues, streambank heights and angles increase, which further reduces bank stability resulting in weak banks prone to failure and *slumping*.

### Channel widening

Channel widening is lateral erosion of the streambanks (Stage III in Channel evolution figure). It can be caused by one or more of the following: channel incision; scour below culverts, bridges, or dams; flood flows in incised channels; weakened banks; increased streamflows due to watershed changes; aggradation; or construction of over-wide channels.

Channel widening occurs in an incised or scoured stream reach that attempts to find a new equilibrium by reforming and amplifying meanders to decrease the slope of the streambed and stream velocities. Also during this process, developing point bars establish a new floodplain that corresponds to the channel's new, lower streambed elevation. (For more detail, refer to the MN DNR website for the brochure, "The Shape of Healthy Rivers.")

## Restoration philosophy

**Incision** is a common stream channel condition in Minnesota due to the prevalence of activities such as ditching and draining wetlands. It is also a systemic problem that results in stream instabilities throughout the watershed. During this response stage the channel will continue to unwind (degrade) until a new equilibrium is established. To reach equilibrium, the channel will go through successional stages that erode the banks to develop meanders, rebuild a new floodplain, and develop a properly sized channel that can effectively transport water and sediment. This process can be advanced artificially by constructing a properly shaped channel with a new lowered floodplain. Another method involves installing riffles and rock weirs that incrementally elevate the streambed to reconnect the channel to the original floodplain. These structures, unlike check dams, maintain sediment transport and are submerged during a bankfull event.

**Widening** is a successional stage following incision or aggradation when the channel is in disequilibrium. Restoration approaches depend on the cause, the extent of incision or aggradation, and future impacts. A restoration design could include the following:

- address upstream impacts by restoring upstream reaches (e.g. replace improperly placed culverts),
- restoring riparian vegetation,
- installing woody material and structures to add roughness, narrow the channel, and protect the banks,
- reshaping cutbanks with a bankfull bench,
- installing tree or rootwad revetments,
- excavating a properly shaped channel, or
- excavating a new floodplain.

**Aggradation** in Minnesota most commonly occurs downstream of channelized reaches. To re-establish equilibrium, an aggraded stream reach must develop a properly shaped channel (sinuous, deep, and narrow) through the aggraded sediment, which becomes the new floodplain. A restoration approach would be similar to that described above for an over-wide channel and similarly would depend on the cause, the extent of aggradation, recovery potential, and future circumstances.

(left) *Incision*: Extreme field erosion and an active headcut resulting from unbuffered runoff. (right) *Aggradation*: Downstream of the headcut, the flow of water slowed where the terrain flattened and deposited sediment, forming a delta.

### Channel aggradation

Channel aggradation is the raising of the streambed elevation as sediment is deposited from upstream erosion along the flatter valley reaches, making the channel too shallow or over-wide. An aggraded stream reach will continue to fill and widen because the channel dimensions are out of balance with the amount of sediment that needs to be transported by the stream. More sediment settles out, further aggrading the stream bed. The channel becomes increasingly shallow, water extends laterally and erodes the banks, and stream flows more readily cause flooding.

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## What are the steps to address streambank erosion?

Extreme streambank erosion indicates an unstable, unhealthy stream. The instability stems from a change in the stream's shape, flow, or connectivity (see info sheet Understanding Our Streams and Rivers). These changes can be direct (ditching, dredging, straightening, dams) or the results of land use changes within the watershed (degradation of natural riparian vegetation, urbanization, logging, agriculture). Explained below are the recommended steps for restoring an eroding streambank with naturally designed approaches.

### Identify the underlying cause

The first step is to determine the cause of stream instability. Are there disturbances in or along the stream; or are there destabilizing activities in the watershed? Individual landowners may not be able to control activities in a watershed that affect a stream, but landowners and citizens can have a voice in promoting and advocating natural channel design. In any situation, restoration and protection of natural riparian zones is a positive step for landowners to take to prevent or reduce streambank erosion and promote good stewardship of the watershed.

### Additional adverse impacts to stream health

Channel incision, widening, and aggradation not only affect stream **shape** and **flow** but also degrade the other components of stream health:

- **Biology.** Loss and degradation of aquatic and riparian habitat (e.g. sedimentation in riffles and pools, degraded riparian vegetation).
- **Water quality.** Higher turbidity and nutrient concentrations from erosion and land inputs. Warmer water temperatures in aggraded reaches and in reservoirs.
- **Connectivity.** Disconnection from floodplain habitat (lateral) in incised streams. Disconnection from upstream and downstream reaches (longitudinal) due to dams and culverts. Increased flood risk in aggraded streams.

### Adopt a natural design approach

Below is a list of recommended designs and approaches that can be used in combination to stabilize the soils in a streambank, protect the banks and floodplain, accelerate recovery, and ultimately restore stream stability. The keys to a successful bank stabilization project are:

- Allow the stream to maintain its dynamic equilibrium by not confining the channel.
- Design streambank structures to temporarily protect the banks while they stabilize.
- Consider future watershed conditions in a project design to assess how the stream will need to adjust with time.

The structures and materials listed in the box below are explained in more detail in following resource sheets.

### Natural design approaches

**Landscape scale**
- Preserve and re-establish natural riparian and floodplain vegetation buffers
- Re-establish and protect the floodplain with compatible land use practices

**Streambank stabilization and protection** *(Resouce Sheet #2)*
- Vegetation: seed or plant native, deep-rooting vegetation on banks
- Biodegradable erosion-control blankets or hydroseeding
- Brush mattresses
- Biologs, wattles, or fiber rolls
- Tree revetments
- Toe wood-sod mat

**In-stream bank protection**
- Root wad revetments
- Bankfull bench
- J-hooks and rock vanes

**Grade control** (to decrease slope and reconnect channel to floodplain)
- Riffles and rock weirs

**Large-scale restoration**
- Re-meander straightened reach
- Remove or modify dams or improperly place culverts
- Excavate properly shaped channel
- Excavate new floodplain
- Reestablish and protect a functional floodplain with compatible land use practices
- Promote best management practices for runoff including: wetland restoration; minimum tillage; grassed waterways on agricultural land; and rain gardens and pervious pavement in urban areas

*These approaches are described in following resource sheets in this **Understanding Our Streams** series (in development).*

### Consult with a professional and determine what permits you need

Contact a representative of the Stream Habitat Program from DNR Ecological Resources, your Area Hydrologist from DNR Waters, or your local soil and water conservation district to discuss what you can do on your streambank and within the watershed to minimize or correct streambank erosion. Before attempting any stabilization project, obtain the applicable permits from the DNR or other agencies. The permits you need can be identified when you contact your DNR Area Hydrologist and representatives from other agencies.

### Contact Information

DNR Ecological Resources in St. Paul:
500 Lafayette Road, Box 25, St. Paul, MN 55155, (651) 259-5900
Stream Habitat Program website:
http://mndnr.gov/eco/streamhab
DNR Waters in St. Paul: 500 Lafayette Road, Box 32, St. Paul, MN 55155, (651) 259-5700
DNR Waters website:
http://mndnr.gov/waters