Appendix A: Wetland and Stream Restoration Techniques

The following is a summary of some of the wetland and stream restoration techniques developed by Thomas R. Biebighauser, who has built over 2,600-wetlands across North America since 1979.

Wetlands

Wetlands would be built to contain shallow, open water to provide habitat for a diversity of native animals and plants. Each wetland would be designed to contain features that would increase the likelihood of their use by rare species of bats, frogs, toads, and turtles. The wetlands would appear and function as natural ecosystems requiring little, or no maintenance.

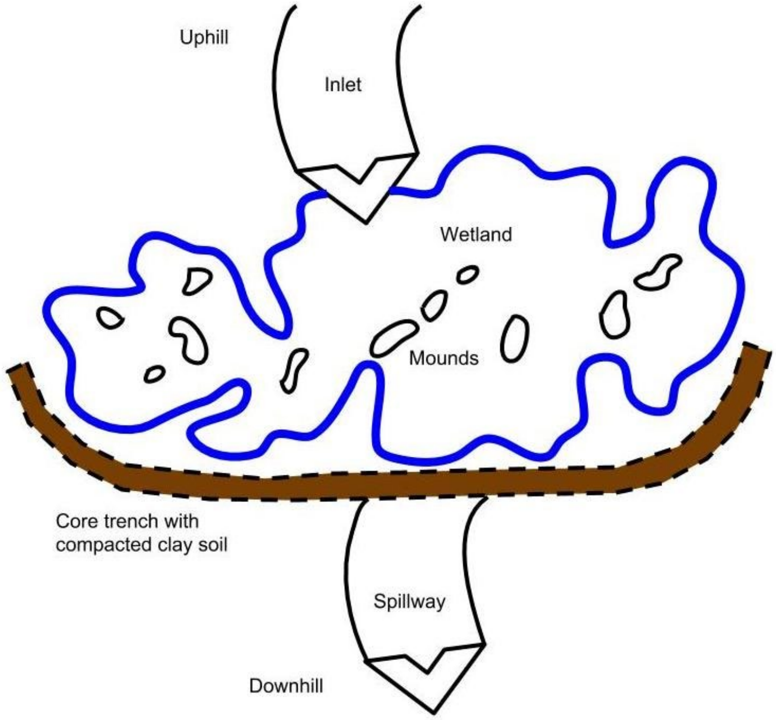
These criteria would guide wetland construction:

1. No dams would be built. Dams require maintenance and restrict aquatic organism passage.
2. No perennial, intermittent, or ephemeral drainages would be blocked or diverted.
3. Inlet and outlets (spillways) would be protected from erosion using plants and rock
4. The wetlands would be supplied with water naturally, without the use of pipes, pumps, water control structures, or diversions.
5. Wetland would be built to be deepest in the center, with gradual slopes, depressions, pits, and mounds.
6. A core trench would be dug along the lower two-thirds perimeter of each wetland being built. The core trench would be based on an impermeable layer of rock or clay. The core trench would be filled with soil that is high in clay, with each layer being compacted.
7. Native plants species would be used to vegetate exposed soils.
8. Nonnative plant species would be controlled.
9. The wetlands would be built so that they do not impact archeological resources.
10. The wetlands would be built so that they do not impact rare species.

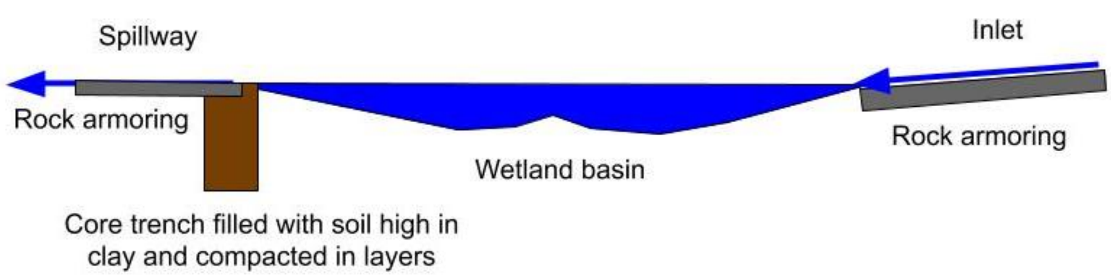
Wetland Construction Photos:

One may view wetlands that have been built using these techniques by viewing photo albums posted by the author on the web:

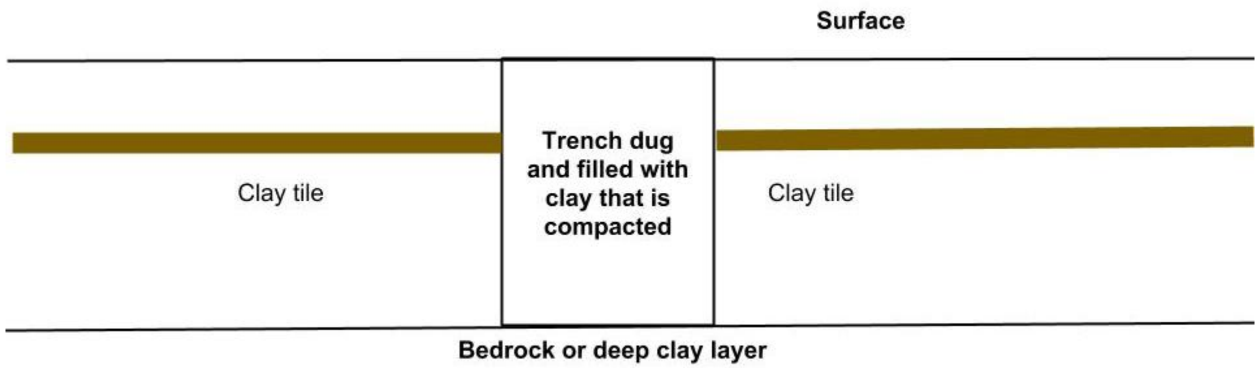
https://www.wetlandrestorationandtraining.com/?page_id=427



Key features of a wetland to be restored (typical plan view)

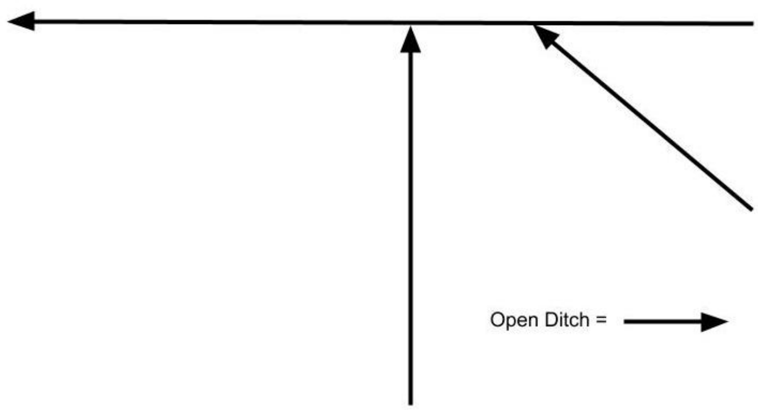


Key features of a wetland to be restored (typical profile view)

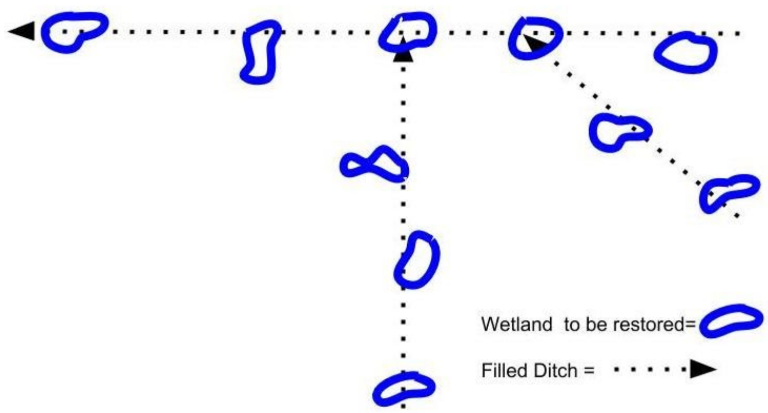


This drawing shows how a trench filled with soil that is high in clay and compacted may be used to block water flowing in a buried drainage structure, or buried permeable layers of sand or rock (profile view)

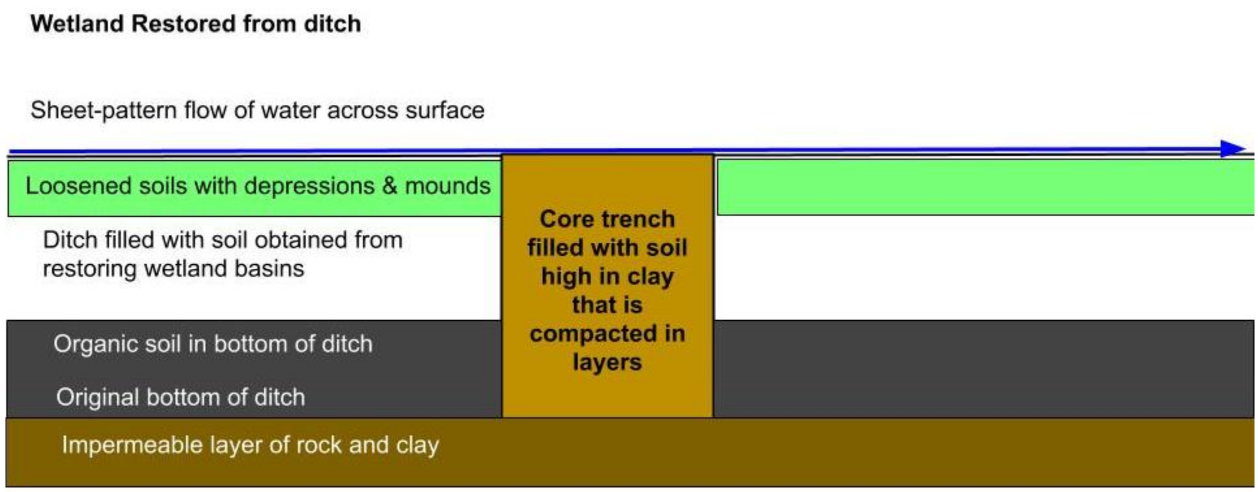
Ditch filling: Ditches would be filled with soil of similar soil texture and compaction rates as what is generally present on either side of the ditch being filled. The soil used to fill ditches would be obtained in part from soil present along the edge of the ditches. Additional soil would be obtained by building wetland depressions along the length of the ditch. The ditches would be filled to return a sheet-pattern of flow of water over the surface of the ground. Water would be prevented from flowing in the bottom of filled ditches by digging trenches across the 100-year floodplain of the ditch at periodic intervals, and filling these trenches with soil that is high in clay that is compacted in layers averaging 15cm.



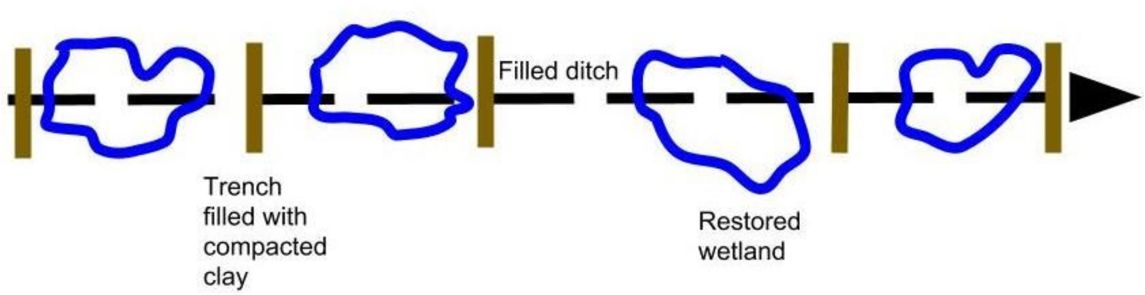
Functioning ditches-typical plan view



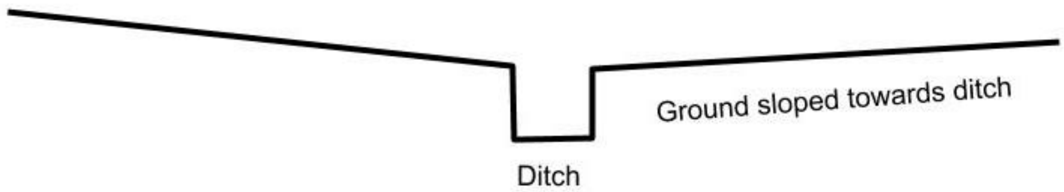
Filled ditches-typical plan view



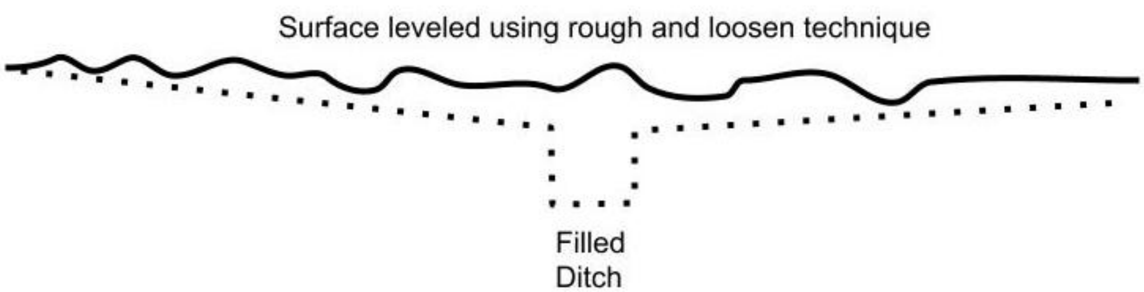
This drawing shows how a ditch and subsurface flow of water in a filled ditch may be blocked



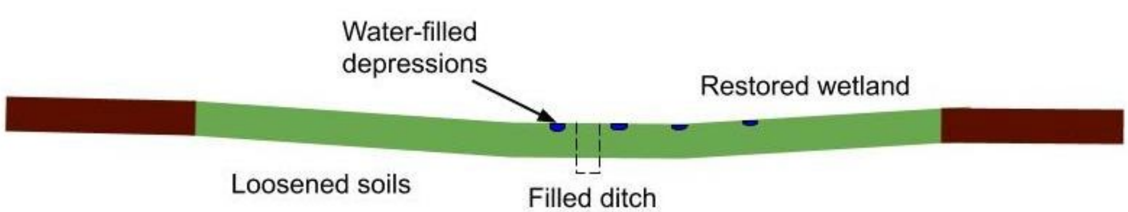
Trenches are filled with soil that is high in clay and compacted to control water flowing in a filled ditch (profile view)



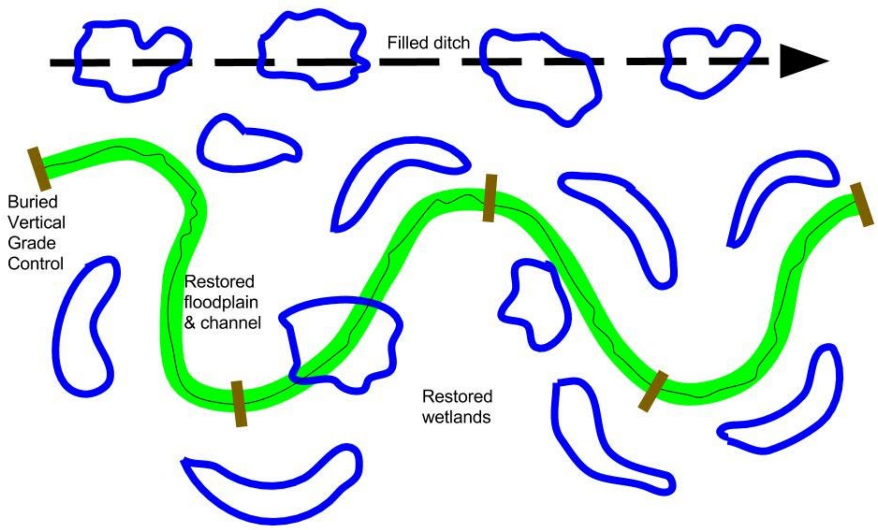
Functioning ditch with ground surfaces sloped towards the ditch-typical profile view



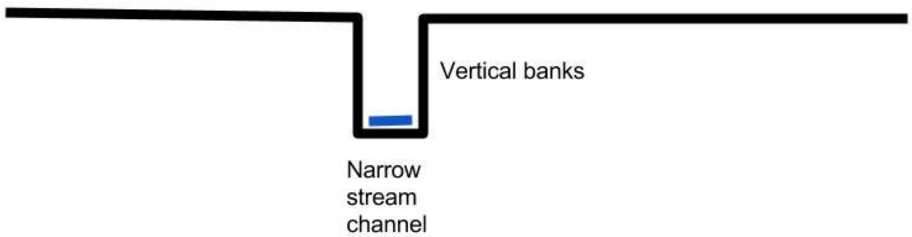
Filled ditch with surface leveled to provide a sheet flow of water-typical profile view



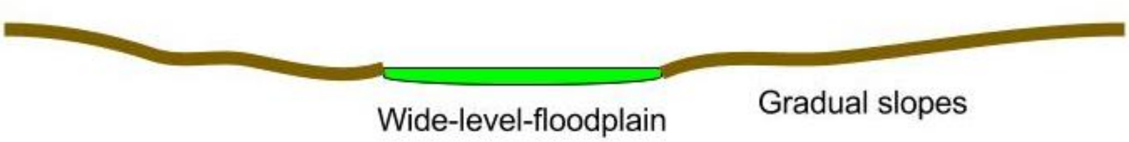
Filled ditch and restored floodplain typical front profile view



Floodplain after restoration (Plan View)



Channeled stream and floodplain before restoration (profile view)



Stream channel and floodplain after restoration (profile view)

Head-cuts would be controlled as part of the project.

Head-cuts form when:

- A ditch is dug through a wetland or series of wetlands
- Livestock make a path in a valley where there was no stream channel
- Someone drives through a wetland and leaves ruts behind
- Gravel is removed that lowers the base elevation of a stream
- A pond is dug in a stream channel or a drainage
- A dam is breached or removed
- There are high shear stresses in a spillway, stream, or ditch
- A culvert is installed at an elevation lower than the bottom of a channel in an existing ditch or stream
- The elevation of a culvert is lowered when it is replaced

What a head-cut does:

- Moves up hill, following a drainage, stream, or ditch
- Forms a deep ditch where there was no ditch or channel
- Makes an existing ditch or channel deeper and wider
- Removes standing water
- Lowers the elevation of groundwater
- Destroys wetlands on floodplains by drying them
- Destroys range and farmland by forming gullies and deep canyons
- Causes great erosion

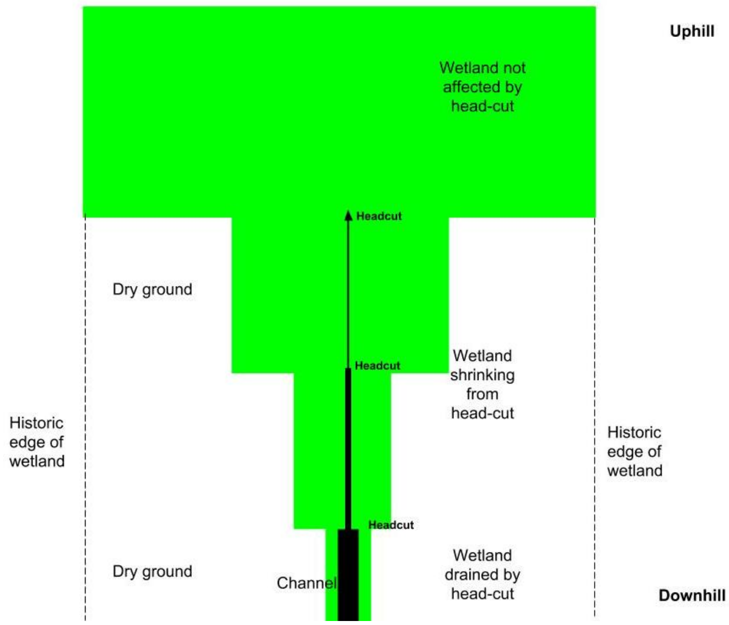
Head-cut characteristics:

- There can be multiple head-cuts advancing up a stream or ditch at one time
- Each head-cut causes a deepening and widening of the stream channel or ditch
- A head-cut stops advancing and digging deeper and when it hits bedrock
- A head-cut stops getting wider when shear-stresses are reduced
- Head-cuts cause channels to form where there was no channel

Head-cuts cause the drainage of wetlands of all different types.

A head-cut is like a zipper that drains a wetland as it moves uphill.

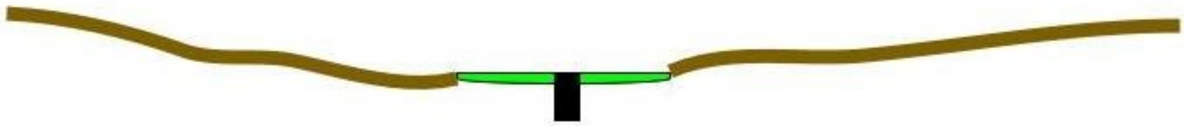
One cannot "slow" water by adding rock or logs to eroding stream channels or ditches. The flowing water is simply deflected, causing greater erosion.



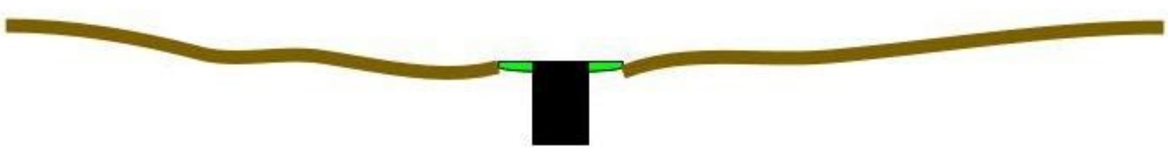
How a head-cut drains a wetland (Plan View)

Front x-section views of a drainage before and after a head-cut forms:

No head-cuts are present on this floodplain



Head-cuts are forming a channel on this floodplain that is draining the wetland



Head-cuts have formed a deep and wide channel that have drained the wetland

Head-cut Control

Head-cuts may be controlled by reducing water depth and steepness of slope.

Reduce boundary shear stress across the floodplain of the stream, ditch, or gulley to less than 1lb/ft^2. Boundary shear stress = (62.4lbs-*unit weight of water*) x (Average maximum depth of water in channel *feet*) x (Percent slope)

If possible, dry the valley containing head-cuts by diverting the flow of water. Only do this if the diversion would not cause other problems. Fill the ditch or gulley with soil and compact this soil. Shape the valley to have a wide floodplain with gradual slopes, both across the width and along the length of the valley.

Where the stream channel/ditch/gulley cannot be filled, place gradual slopes on the steep and eroding banks to reduce shear stress and provide floodwater with access to the floodplain.

Where the ditch or gully can be filled, fill the ditch with soil and compact this soil. Restore a wide floodplain with gradual slopes in the valley, and over the filled ditch. Armor the bed of a stream or ditch with rock embedded into the ground to prevent head-cuts from forming when the slope of the stream or ditch exceeds 1-percent.

Look for permanent vertical grade control at the upper and lower ends of the project area. Install buried vertical grade control structures where water enters and leaves the project area where these are not present.

The elevation of the bottom of the vertical grade control structure you are installing is equal to the elevation of the top of the nearest permanent vertical grade control structure located downstream. This applies when using rock or logs.

Install buried vertical grade control along the length of the project area where the valley slope is steeper than 1-percent, and there is a regular flow of water.

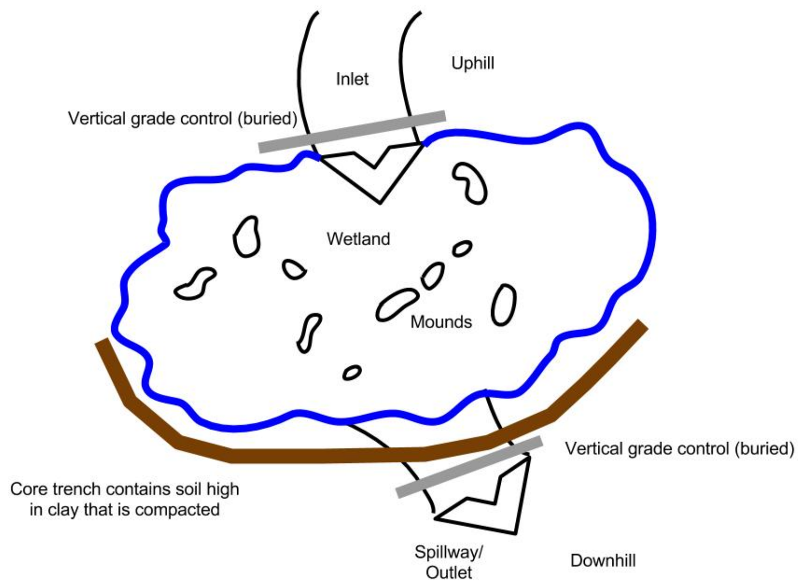
Buried vertical grade control structures should be made from rock, where possible.

Where possible, mine the rock needed to build the vertical grade control structures on site. Logs may be used to control head-cuts under certain circumstances.

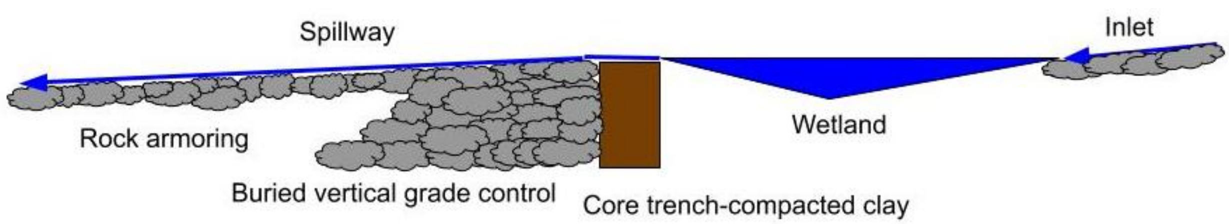
Use the rough and loosen technique over the 100-year floodplain, and on land above the 100-year floodplain, to allow water to soak into the ground, controlling erosion and promoting the growth of plants. The rough and loosen technique is not likely to control erosion in the channel of a stream or ditch with a perennial flow.

Rock for Vertical Grade Control

A buried vertical grade control structure made from rock can prevent a head-cut, located downstream, from advancing into the wetland, and draining the wetland. Use where the wetland interrupts a ditch or stream and where head-cuts occur downstream of the wetland being built. A buried vertical grade control structure may also be placed at the inlet of the wetland to prevent head-cuts from forming, whose soil can fill the wetland.

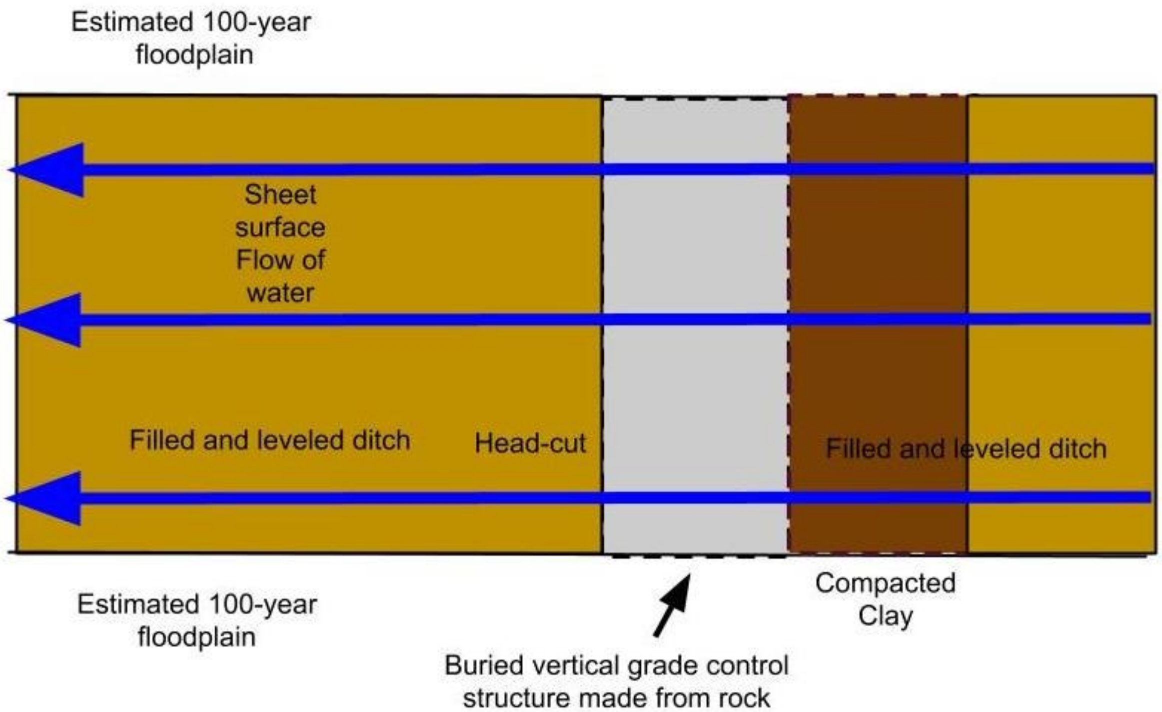


Typical plan view of wetland to be restored

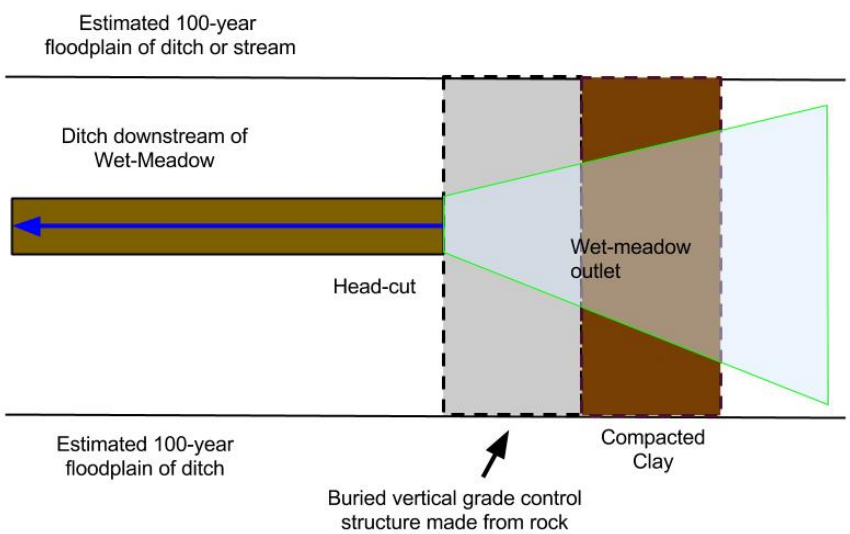


Typical profile view of wetland to be restored

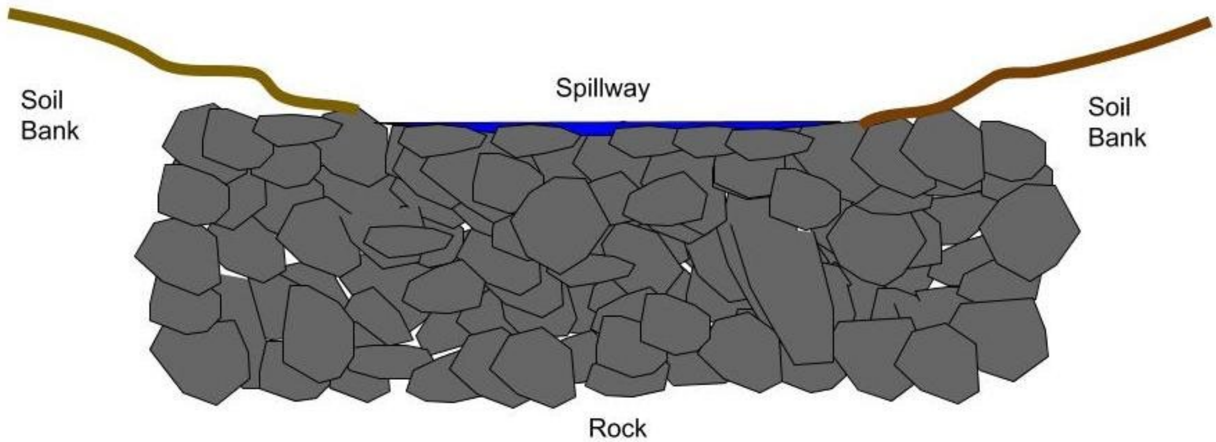
Rock from 30-70cm (football size) in diameter is generally used to build the buried vertical grade control structure. The rock may be mixed with soil, and compacted so that water flows over the top, like a stream riffle. The rock should be angular and not round. Avoid using gabion baskets to hold the rock as the wire would eventually rust and the structure may fail.



(Plan View)



(Plan View)



(Front profile view)

The buried vertical grade control structure extends across the 100-year floodplain, perpendicular to the stream. It's best to extend the structure beyond the elevation of the 100-year floodplain so that if beaver build a dam across the valley at the same location, head-cuts will not form where water flows around the ends of the beaver dam.

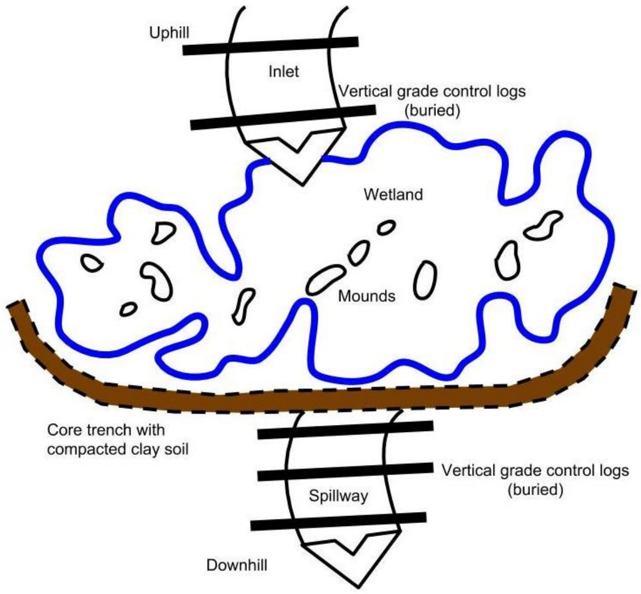
The bottom elevation of the buried vertical grade control structure will generally match the top elevation of the nearest permanent vertical grade control found downstream of the one being built.

The floodplain will be shaped so that when beaver build dams, canals, burrows, and lodges, restored areas will not be damaged.

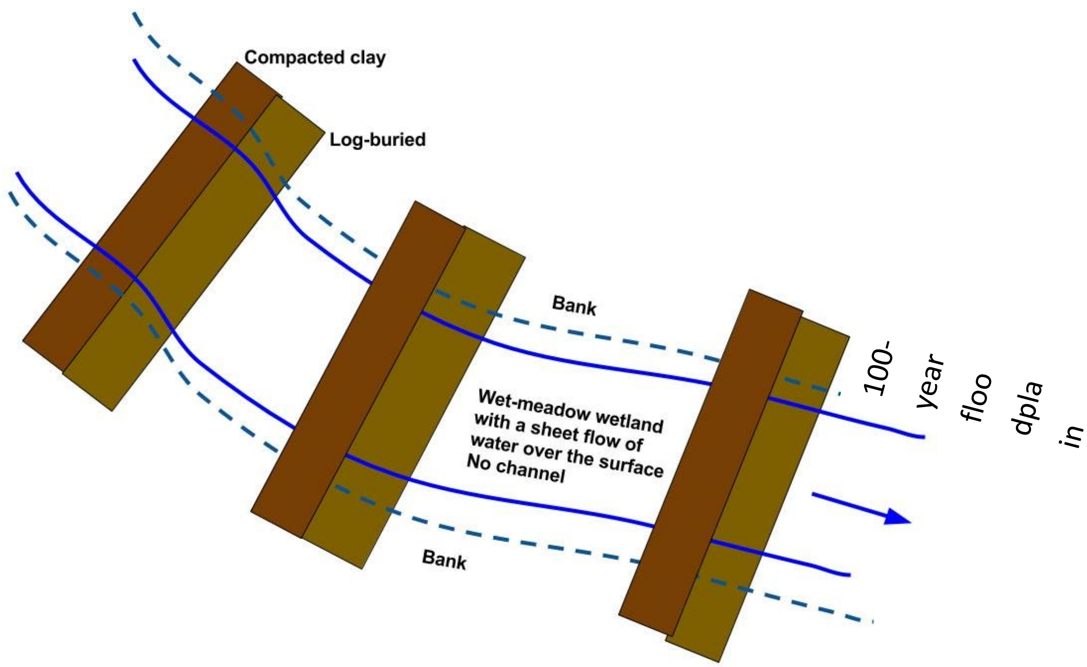
Mineral soil will be used to shape gradual, sloping banks over the edges of the rock used to build the buried vertical grade control structure.

Logs for Vertical Grade Control

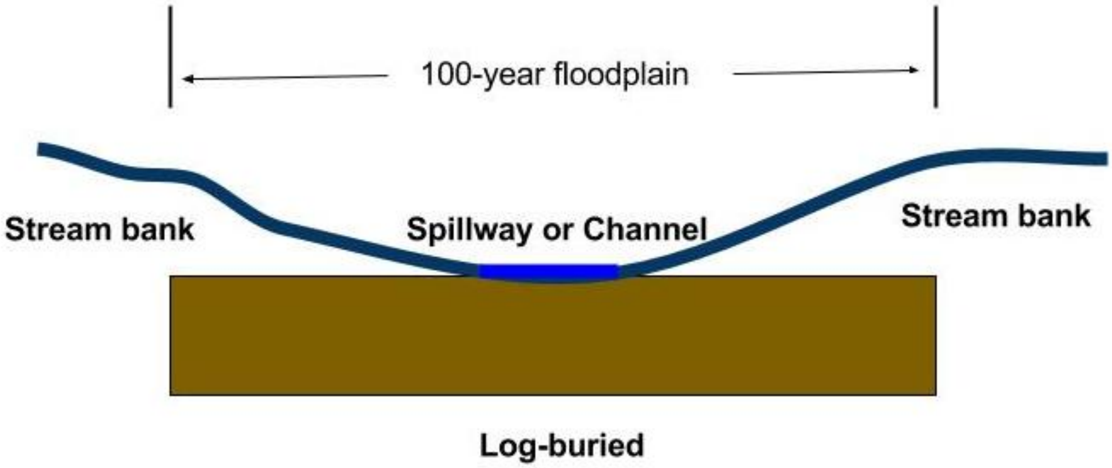
Logs may be used to build vertical grade control structures under certain circumstances. The soils surrounding the logs must remain saturated all year, or the logs will rot. The texture of soil should be high in clay so the soil may be compacted around the log, and the slope should be no greater than 6-percent. The logs should be straight, and at least 30cm in diameter. Logs are not stacked or water may flow between them, and the structure would fail.



Drawing showing where logs are buried to provide vertical grade control that prevents head-cuts from forming (Plan View)



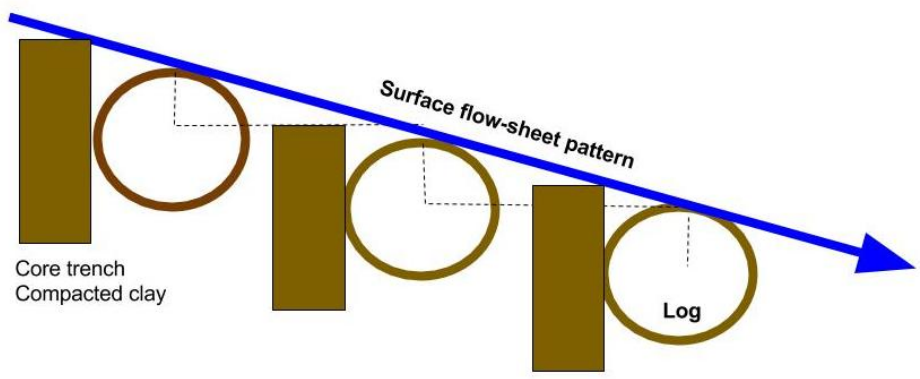
Drawing showing where logs are buried to provide vertical grade control that prevents head-cuts from forming in a restored wetland spillway or wet-meadow wetland (Plan View)



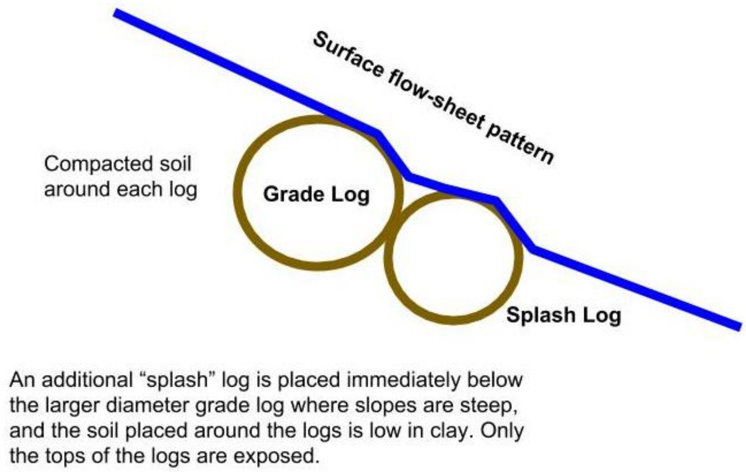
Drawing showing where a log is buried to provide vertical grade control that prevents head-cuts from forming in a restored wetland spillway or wet-meadow wetland (Front Profile View).

The logs used should be cut from live trees. They should be long enough to span the 100-year floodplain of the ditch or stream. Compact the soil around each log. Shape gradual banks over the ends of each log.

Side profile view

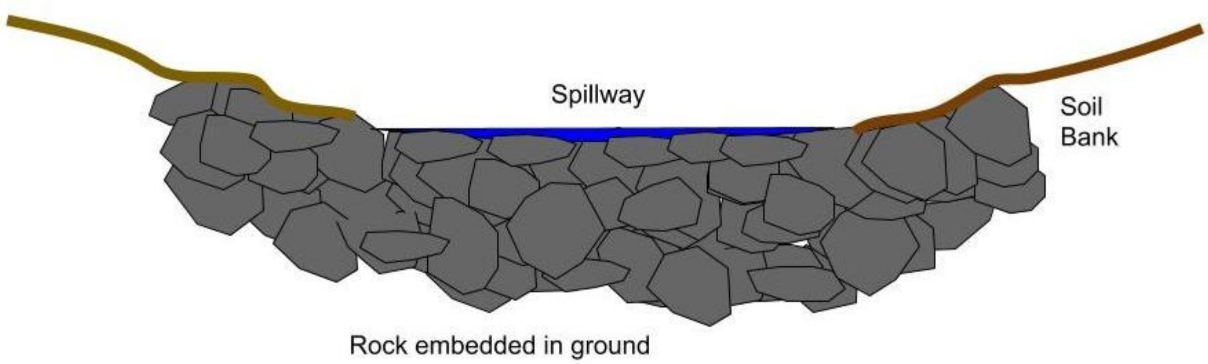


There should be no more than a 4-inch (10 cm) change in elevation between the tops of adjacent logs. The top of each log must be level so water may flow evenly over the surface of the log.

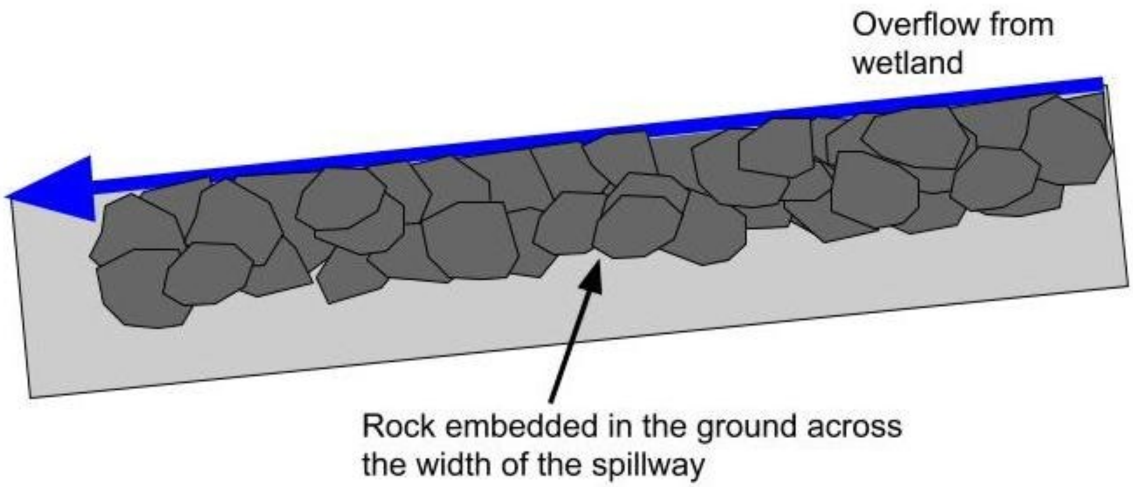


It may be necessary to place a large number of logs next to each other where there is a strong flow over steep ground. Use rock, instead of logs, where slopes are steep, and the soil does not remain saturated.

Spillways: Water would be managed where it flows out from constructed wetlands so it won't cause erosion. Naturally appearing and functioning spillways would be established for each wetland being restored. The spillway would generally be located along the natural lower edge of the wetland being restored. The spillway would be designed to have boundary shear stress of less than 2lbs/ft^2. Water would flow over the spillway in a sheet-like pattern, down a gradual slope no steeper than 1-percent. Rock will be used to armor spillways to prevent erosion where shear stresses exceed 2lbs/ft^2.



Rock armored spillway front profile view



Rock armored spillway profile view

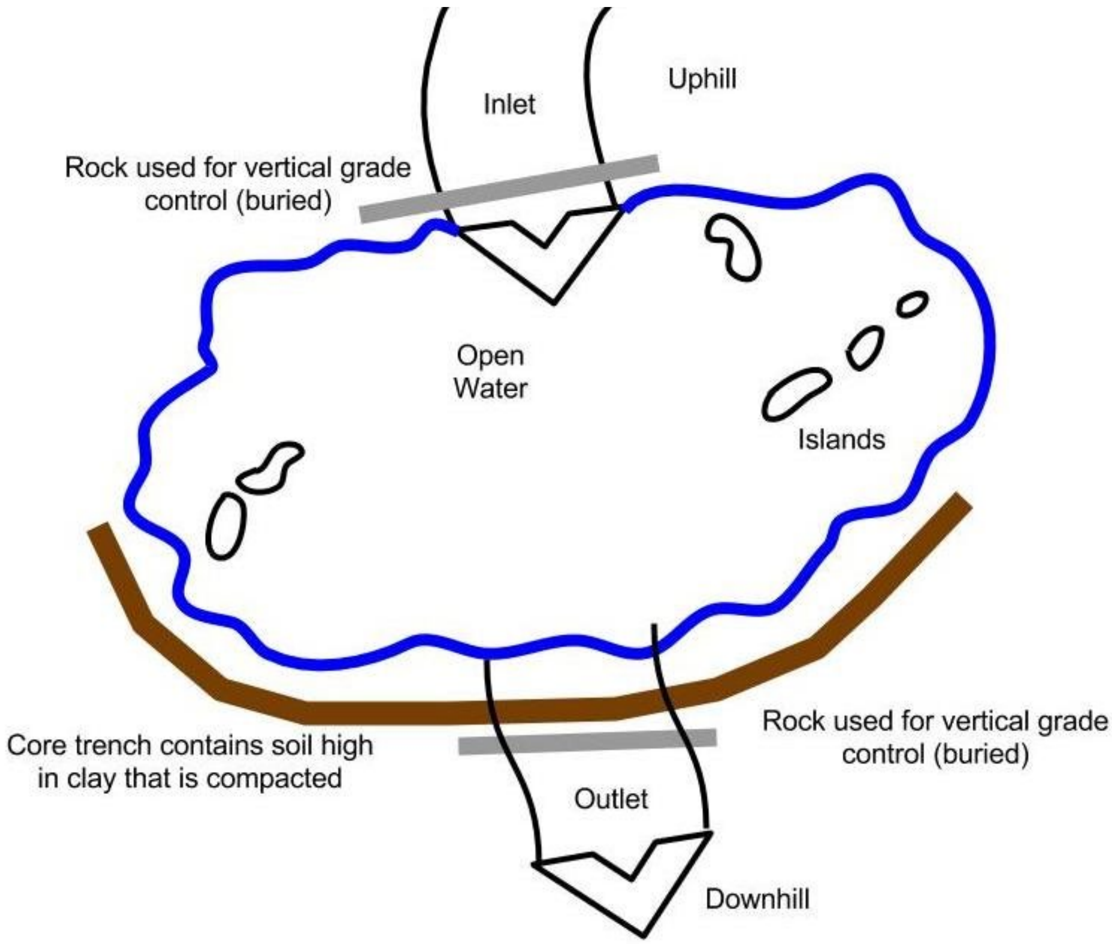
Inlets: Water would be managed where it flows into constructed wetlands so it won't cause erosion. Naturally appearing and functioning inlets would be established for each wetland being restored. The inlet would be designed to have boundary shear stress of less than 2lbs/ft². Water would flow into the wetland in a sheet-like pattern, down a gradual slope no steeper than 1-percent. Rock will be used to armor inlets to prevent erosion where shear stresses exceed 2lbs/ft².

Fill removal: Soil used to fill in wetlands would be removed. Fill is generally identified by digging test holes with the project area to identify historic buried organic layers. The soil removed from filled wetlands would generally be used to fill ditches that were dug to drain the wetland. The soil may be used to form uplands near the wetland being restored. Soils that are compacted within and around the wetlands being restored would be loosened to a depth of 1.0-meter using the rough and loosen technique prior to seeding and planting.

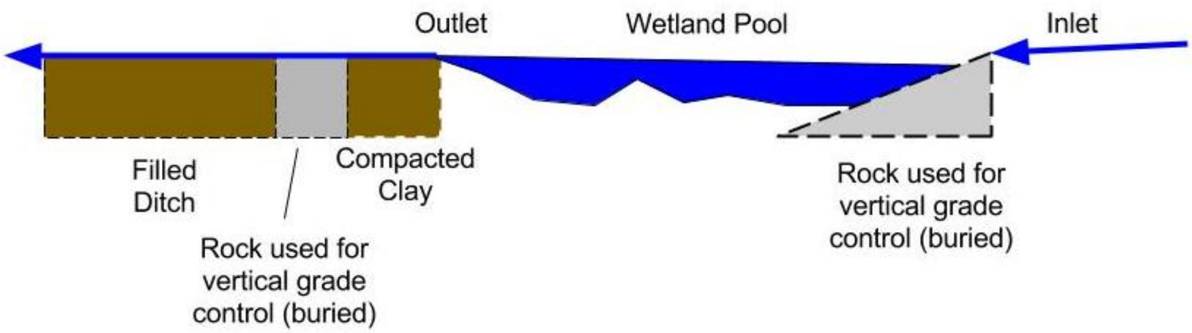
Landscape contouring: Areas where soil would be removed would also be shaped into naturally appearing and functioning shallow wetland basins where possible. These shallow depressions would inject precipitation and snowmelt into the ground, replenishing groundwater, and supporting wetland vegetation.

Perennial emergent wetlands, and seasonal wetlands would be restored. Seasonal wetlands, also called vernal ponds or ephemeral wetlands, are some of the rarest habitats in North America. The ephemeral wetlands would become wet meadow wetlands during the dry season. The ephemeral wetlands can be expected to support breeding populations of frogs, toads, salamanders, dragonflies, damselflies, fairy shrimp, tadpole shrimp, and other invertebrates. Sandhill Cranes would also make use of the ephemeral and wet-meadow wetlands.

The ephemeral wetlands would be built so that they dry in late summer and fall. This would prevent colonization by the nonnative American bullfrog or by nonnative fish. The wetlands can be expected to contain water for varying lengths of time, so that in wet or dry years, some would provide suitable conditions for successful breeding by amphibians and invertebrates.



Emergent wetlands, ephemeral wetlands, and wet-meadow wetlands would be made by shaping shallow basins (Typical plan view)



Emergent wetlands, ephemeral wetlands, and wet-meadow wetlands may be made by removing and shaping shallow depressions (Typical profile view)

Sheet flow: The ground surrounding the wetlands to be restored would be contoured to restore natural, sheet-pattern-flows of water over the land. The sheet flow of water can be expected to restore and maintain additional wet-meadow wetlands.

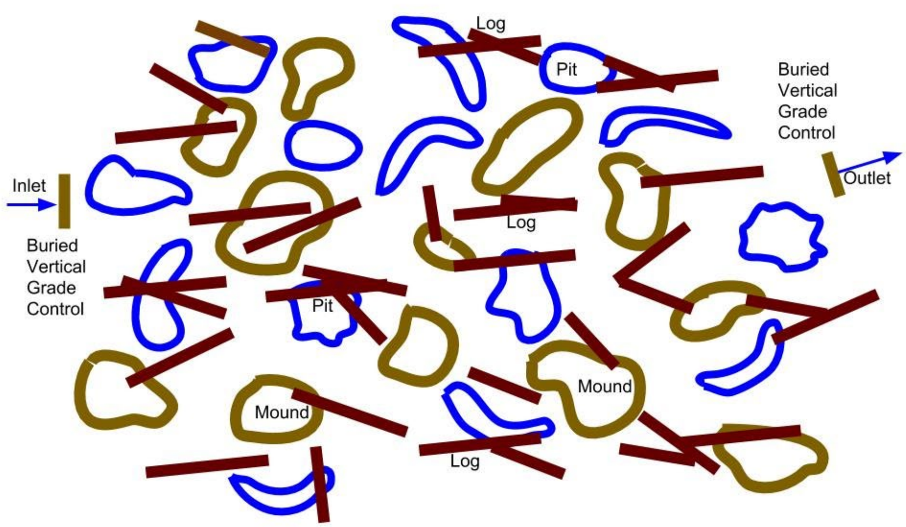
Swamp Restoration

Swamps containing natural pit and mound topography may be restored.

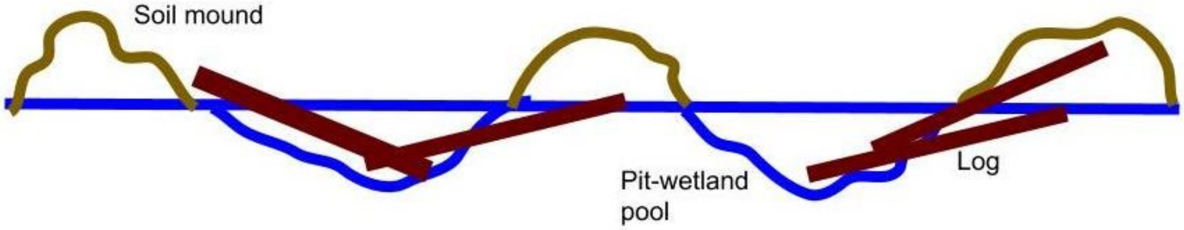
Natural swamps contain small pools of water, patches of sedges, and saturated soils.

A natural braided flow of water would be restored in swamps. There would be no defined stream channel with bed and banks.

Pit and mound topography along with large woody debris like what is show here would be restored. The pits will fill with runoff and allow the water to soak into the ground. The small pools of water would provide breeding habitat for amphibians.



Swamp restoration (Plan View)



Swamp restoration-profile view

Soil loosening: Compacted soils would be loosened using the bucket of an excavator to a depth of 100cm. Care will be taken to maintain the topsoil layer on the surface and not bury it below the surface of the ground. All tracks left by heavy equipment and vehicles will be removed and soils loosened prior to seeding and planting.

A series of naturally appearing shallow pits and mounds would be restored over the restored wetland area to support a diversity of plants and animals. The loosened soils would not erode and can be expected to provide habitat for burrowing mammals.

Here the excavator uses the *rough and loosen* technique to loosen compacted soils on a wetland restoration project. The loosened soils are seeded and planted to native species, and mulched using wheat straw to control erosion and maintain moisture for developing native plants.

Large woody debris: Large diameter logs, branches, and root masses would be placed in and around the restored wetlands to improve habitat for a diversity of plant and animal species. Branches of various diameters and lengths would be placed in the wetlands to provide egg attachment sites for amphibians, and improved habitat for invertebrates, and plants.

The logs placed in this emergent wetland provide loafing sites for waterfowl.

Large diameter logs would be placed in the restored wetlands to resemble trees naturally falling over. This photo shows one of many dead trees placed in wetlands restored at Meadow Creek in January 2016.

Planting and seeding: Desirable native plants that may be disturbed during restoration would be saved as part of construction and replanted in the restored wetlands the same day. Large clumps of native plants and their roots would be removed and saved using an excavator.

Species of wetland plants that are native to the region would be seeded and planted to restore a diversity in the restored wetlands. Seeds from native wetland plants growing near the worksites would be collected and sown by hand on areas of exposed soil. Other seeds and plants would be purchased. The species planted and seeded would favor flowering species used by pollinators, including the monarch butterfly.

Nonnative plants would be removed and/or buried as part of the wetland restoration project. Exposed soils would be mulched using the straw from native plants if it's available, otherwise, wheat or oat straw would be used. Straw would be spread by hand on exposed soils in the restored wetland to control erosion, and to suppress nonnative plants. A straw blower would not be used because the rubber tires would cause unwanted compaction of the ground. Straw rarely contains weeds or nonnative plant species. Commercial hay would not be used. Hay is cut grass that often contains weeds and nonnative plants. However, hay that is cut from native species provides ideal mulch and would be used if it's available. Portions of the wetland that are restored would be seeded, planted, and mulched the same day they are completed.

The clumps of sedges shown in this photo were saved and replanted as part of wetland restoration at Meadow Creek. The restored wetland is 4-months old in this photo.

The design prepared for this restoration project shows the approximate locations of where the above described techniques would be used. The actual application and placement of each technique on the ground would be finalized during implementation of the project.

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