Chapter 3. Wetland Restoration Practices

Healthy wetland ecosystems are resilient and self-sustaining, whereas degraded wetlands respond poorly to environmental stress. Wetland restoration strives to reestablish healthy conditions in degraded systems by implementing design practices that promote natural structures, composition, and processes.

Restoration practices can be divided into passive and active practices. Passive wetland restoration involves removing the source of wetland degradation without otherwise intervening. In some cases, this is all that is needed for successful restoration. Active wetland restoration involves physical onsite intervention and is appropriate when simply removing the source of degradation is not sufficient for recovery.

This chapter presents a selection of common restoration practices recognized by regulatory and conservation agencies in Vermont. These practices rely on straightforward, low risk methods and natural materials. Each section provides pre-construction planning and construction sequencing procedures for a particular restoration practice, along with clear details and specifications for implementation.

The chart below provides an estimated range of planning effort and cost for each primary practice on a scale of low, medium and high. In general, passive practices and revegetation require the least amount of planning effort and cost. Hydrologic manipulations, including ditch plugs and tile drain removal, involve the most pre-planning and expense. Practices can be used individually or in combination depending on the source and degree of impact, as well as the available physical and financial resources.

Cost/Planning Matrix

Depending on site conditions and desired outcomes, a wetland restoration project may only use one practice. In other cases, multiple practices may be employed at a single site. Combining practices can increase the time required for planning and implementation, but it can also lead to a more diverse and higher functioning wetland ecosystem. Strategically combining complementary practices (such as those that require excavating soil and depositing soil) can lead to significant cost savings.

Also included in this chapter are supplemental practices that may be appropriate components of a restoration plan, depending on the project. Supplementary practices include site stabilization procedures, woody material additions, beaver dam analogs, and conservation measures.

3.1 Passive Restoration

Wetland restoration projects vary in size, scope, and expense. There are many situations where taking a passive approach is all that is needed to restore a wetland. Passive restoration involves reducing or eliminating the sources of degradation and allowing the wetland time to recover naturally. This works when the restoration site still retains basic wetland characteristics and the source of degradation is an action that can be stopped (e.g. by removing grazing cattle, discontinuing mowing, etc.). Passive approaches are low cost and can often be implemented without a lot of pre-planning.

Passive Restoration

GOALS

Allow wetland condition to be restored by natural means

BENEFITS

Variable depending on the source of degradation: Improved water quality and improved biodiversity can be anticipated in most restoration projects

1. Identify degradation source
2. Demarcate project area limits
3. Remove source of degradation
4. Monitor for Success

DEFINITIONS

Hydrology: The distribution and movement of water both above and below the ground.

Passive Restoration Examples

Natural revegetation: Mowing in wetlands results in reduced biodiversity and overall wetland function. Fertilizer applied to mowed fields diminishes water quality. Establishing no-mow zones (signs and maps can be helpful here) and discontinuing fertilizer management provides an opportunity for native wetland vegetation to reestablish and for improved water quality.

Abandon Management: Ditches in wetlands often fill with sediment resulting in periodic maintenance through dredging. Discontinuing ditch maintenance can over time result in the natural filling of the ditch and reestablishment of wetland hydrology.

Exclusion of Livestock: Cows, horses, sheep and goats can all have negative impacts on pastured wetlands. Removing and fencing off livestock from wetland areas provides an opportunity for native wetland vegetation to reestablish as well as removes a water quality contaminant source.

Examples of agriculturally impacted wetlands

Passive restoration

Challenges & Solutions

- Future impacts: Passive restoration can be vulnerable to reversal, especially if a property is sold to a new owner. Permanent protection of a wetland restoration area is possible through conservation easements and/or deed restrictions, which protect the land for future generations.

- NNIS: Since there is a preponderance of non-native invasive species (NNIS) on the landscape in some areas, there is a high likelihood of infestation, especially on open soils. Monitor for invasives that may introduce themselves, and make sure to remove them ASAP to prevent colonization.

> ! Abandoned management practices cannot be reestablished without additional permitting

Complementary Practices:

3.2 Invasive Species Control & Management

Native plant species help create a healthy ecosystem. Non-native invasive species (NNIS) complete with native species, often dominating the landscape and choking out native species. NNIS species are pervasive in our environment and represent a threat to most wetland restoration projects. On sites without NNIS present, prevention of NNIS establishment (especially when the soil is disturbed) is critical to maintain biodiversity in the restoration area. In cases where NNIS are currently established, control efforts may be integral to restoration success.

Invasive Species Management

GOALS: Prevent introduction of NNIS to sites that do not currently have NNIS present and eradicate/ manage/control invasive species on sites that do currently have NNIS present

BENEFITS: Protect biodiversity; diversify wildlife habitat; improve and protect water quality

1. Collect Baseline Data
2. Develop NNIS Management Plan
3. Identify Disposal Location
4. Implement Control Measures
5. Monitor for Success

DEFINITIONS

Non-native invasive species (NNIS): Non-indigenous plants that threaten the diversity and survival of native species or the ecological stability of infested ecosystems.

Invasive Plants Common in Wetlands


Honeysuckles


Buckthorns


Japanese knotweed


Purple loosestrife


Multiflora rose


Common reed

Invasive Species Prevention
(The site does not have NNIS)

The key to prevention is frequent, ongoing monitoring and rapid response. Identify and remove NNIS before soil disturbance, and then at least once a year for at least 5 years, making sure to remove plants before they produce new seeds.

NNIS can become established from nearby populations via wildlife seed dispersal from rhizomes (underground stems), or from human introduction.

NNIS readily become established on areas of exposed soil.

Ask work crews to clean tools and boots and power-wash equipment before entering the restoration site.

Do not use soil from a location where NNIS are found if importing soil as part of the restoration.

Use certified weed-free straw to prevent accidental introduction of NNIS if using mulch for erosion prevention.

Invasive Species Resources

- Vermont Invasives Gallery
- Seek from iNaturalist
- Native Plant Trust GoBotany
- Vermont Agency of Natural Resources

Invasive Species Control
(The site has NNIS)

NNIS Baseline Mapping

- Identify the NNIS species on site and map distribution of each species.
- Describe the population including # of plants, density, and what % of the restoration area is covered by the plants.
- The baseline map will be used to gauge progress of the project.

NNIS Management Plan- ***this plan should include:***

- Realistic goals for management of NNIS.
- Priorities for management, if more than one NNIS species is present.
- Specific control methods that will be used for each NNIS species present. These methods vary depending on the species, its abundance, and the goals of the restoration.
- Description of disposal methods for NNIS plant material. Removed plant material needs to be dealt with properly so that it does not resprout, often requiring it to be burned or bagged and disposed of in the trash.
- Plan for monitoring the success of any control actions. Keep notes about each treatment and track your progress.
- Timeline for all control and monitoring activities. Treatment often involves more than one year, and should be planned for.

Left: Cut & drip NNIS treatment, Katie Kain, USFWS
Right: Cut stump application, Ryan Creehan, USFWS

NNIS Species

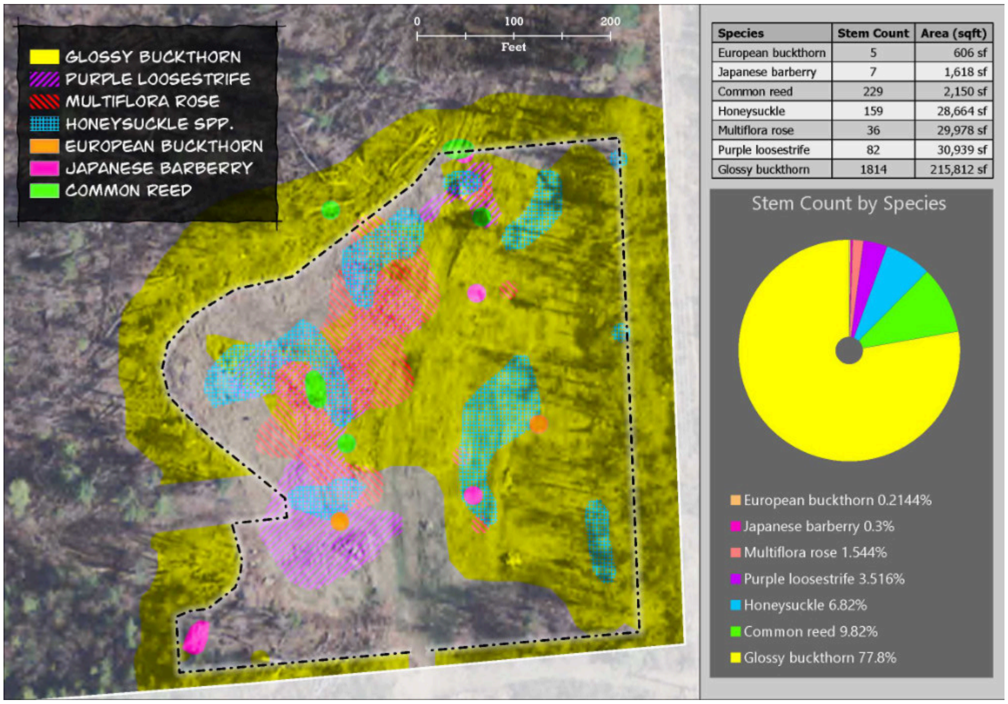
Group	Taxa	Common Name	NNIS List	Typical Habitat
Trees & Shrubs	*Frangula alnus*	Glossy buckthorn	Class B Noxious	Upland
	Rhamnus cathartica	Common buckthorn	Class B Noxious	Upland
	Lonicera spp.	Honeysuckle	Class B Noxious	Upland
	Berberis spp.	Barberry	Class B Noxious	Upland
	Rosa multiflora	Multiflora rose	Watch List	Upland
Grasses	*Phalaris arundinacea*	Reed canary grass	Watch List	Wetland
	Phragmites australis	Common reed	Class B Noxious	Wetland
Herbs	*Lythrum salicaria*	Purple loosestrife	Class B Noxious	Wetland
	Alliaria petiolata	Garlic mustard	Class B Noxious	Upland/Wetland
	Hesperis matronalis	Dame's-rocket	Watch List	Upland
	Pastinaca sativa	Wild "poison" parsnip	Watch List	Upland
	Anthriscus sylvestris	Wild chervil	Watch List	Upland
	Fallopia japonica	Japanese knotweed	Class B Noxious	Upland/Wetland
	Aegopodium podagraria	Goutweed	Class B Noxious	Upland/Wetland
Vines	*Celastrus scandens*	Asiatic bittersweet	Class B Noxious	Upland

NNIS Control Methods

Method	Description	Advantages	Disadvantages	Typical Species
Hand-pulling	Manually pulling plants	Can be effective on small populations of certain species	Can be difficult to remove below-ground parts. Not realistic for mature woody individuals.	Garlic mustard, dame's rocket, seedlings of woody species
Uprooting with hand tools	Uprooting plants with shovels or "weed-wrenches"	Removes below-ground parts to prevent re-establishment; effective on small infestations of certain species	Labor-intensive; not realistic for large infestations; not realistic for mature woody individuals.	Young woody species such as honeysuckle, buckthorns, barberry, and multiflora rose
Mechanical uprooting	Uprooting plants with heavy machinery such as tractors or excavators	Removes below-ground parts to prevent re-establishment; effective on mature woody individuals	Can be expensive; danger of creating disturbed soil for NNIS establishment; not realistic for extensive infestations	Mature woody species such as honeysuckle, buckthorns, barberry, multiflora rose
Herbicide-Foliar spray	Broadcast spraying of herbicide	Can control larger infestations	Herbicide drift can create impacts on non-target organisms	Common reed, purple loosestrife, reed canary grass, buckthorns, honeysuckle, multiflora rose
Herbicide-Wipe	Manually applying herbicide to individual plants	More targeted than broadcast, reduces drift; can be used on moderate-sized infestations	Not realistic on large infestations	Common reed, purple loosestrife, buckthorns, honeysuckle
Herbicide-Cut Stump / Cut Drip	Cutting invasive plants and manually applying herbicide to plant stem or stump	More targeted than broadcast, reduces drift; can be used on moderate-sized infestations	Not realistic on large infestations	Buckthorns, honeysuckle, common reed, multiflora rose

Challenges and Solutions

- Effort and cost of management: NNIS control can be time consuming, costly and has varying success. Weigh the costs and benefits of restoring a site that has NNIS present. Minimize long-term costs by treating NNIS immediately and managing new populations before they become established.



Sample Baseline NNIS Map

- Mowing and cutting: Simply cutting or mowing invasive species is generally not a recommended control method. Poorly timed cutting or mowing can often increase the growth of NNIS. Research recommended species specific best management practices.
- Long-term management: Effective NNIS control is often only achieved by developing a long-term management plan that is specific to the site conditions, species present and status of the NNIS populations. Multiple years of control are often required to manage NNIS species. Engaging experts for planning and control effort is essential at sites with extensive NNIS.
- Likelihood of NNIS: Since there is a preponderance of NNIS on the landscape in some areas, there is a high likelihood of infestation, especially on open soils. If possible, choose sites with lower NNIS risk, and minimize opportunities for new infestations by minimizing soil disturbance.
- Established infestations: Ongoing monitoring and management of established infestations can be especially time consuming and costly. Research species-specific best management practices, and consider beginning to treat populations a year or more ahead of the main restoration work.
- Reed canary grass: This species can be an aggressive colonizer of wetlands and marginally wet fields throughout our region. Management can be a challenge since it can spread via underground stems (rhizomes) and form an abundant seedbank. The most common and reliable control method involves the use of herbicides and/or shading the grass out over time with woody species. On drier sites, a deep plow can turn the soil enough that other species can become established. Controlled burns (coordinated with local authorities) have also been used to kill or reduce the vigor of large stands of this grass. If reed canary grass is dominant on site, a phased approach to restoration may be required starting with reed canary grass control.

> You cannot apply herbicides on land that you do not own. Contact a Vermont Certified Invasive Plant Control Contractor.
>
> The Vermont Wetland Rules prohibit the use of herbicides in state-classified wetlands without approval by the Wetlands Program.

Complementary Practices:

3.3 Wetland Revegetation and Enhancement

Wetland Revegetation and/or enhancement involves re-establishing site-appropriate natural community characteristics using plantings and/or natural revegetation. This is a low-tech practice that can use on-site native plant materials or a combination of on-site and locally sourced native plant materials. This practice complements most other wetland restoration strategies.

Wetland Revegetation & Enhancement

GOALS

Restore a diversity of plant species and communities

BENEFITS

Protect biodiversity; enhance wildlife habitat and connections; enhance fisheries; protect water quality; prevent erosion; infiltrate stormwater

1. Develop Planting Plan
2. Secure Materials
3. Implement & Install
4. Monitor for Success

DEFINITIONS

Natural Communities: Plants and animals growing and living together in landscapes characterized by specific soil, water, and climate conditions.*

Biodiversity: The abundance and mix of different plant and animal species in an area.

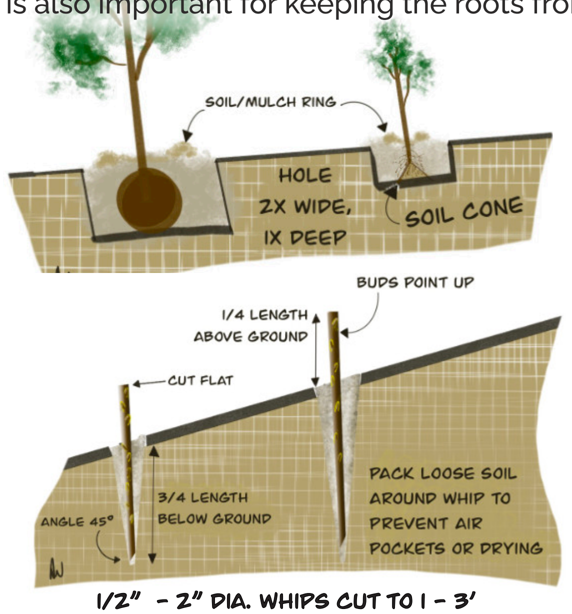
**See the book Wetland, Woodland, Wildland, or the Agency of Natural Resources' online Natural Community Fact Sheets.*

General Planting Guidelines

Tree and shrub plantings for wetland restorations are typically either container, bareroot, or live stakes/whips. Site preparation is critical to the success of plantings. One of the most common errors in tree planting is incorrectly planting the root ball by either digging the hole too deep or too shallow. Maintaining the integrity of the root ball is also important for keeping the roots from drying out.

- Container and Bareroot Plantings: Dig a hole twice as wide and to the depth of the root ball; loosen and detangle the roots a bit (for bareroot plants, make a cone of soil in the base of the hole to spread the roots around); fill soil in and tamp down with your fingers; mulch; and create a soil or mulch ring to hold water.

- Live Stakes/Whips: Harvest whips and install within 24 hours or store in cool, moist, shady conditions wrapped in burlap for up to 2 weeks. Soak stakes in a bucket for a day or two prior to planting. Plant stakes 1 to 3 feet apart.



Planting Plan Basic Components

Develop a planting plan well before work begins. The more detail included, the higher likelihood of success. Information collected in the site assessment (such as site topography, historic vegetation, existing native vegetation, existing invasive vegetation, and reference wetlands) will be used in developing the planting plan.

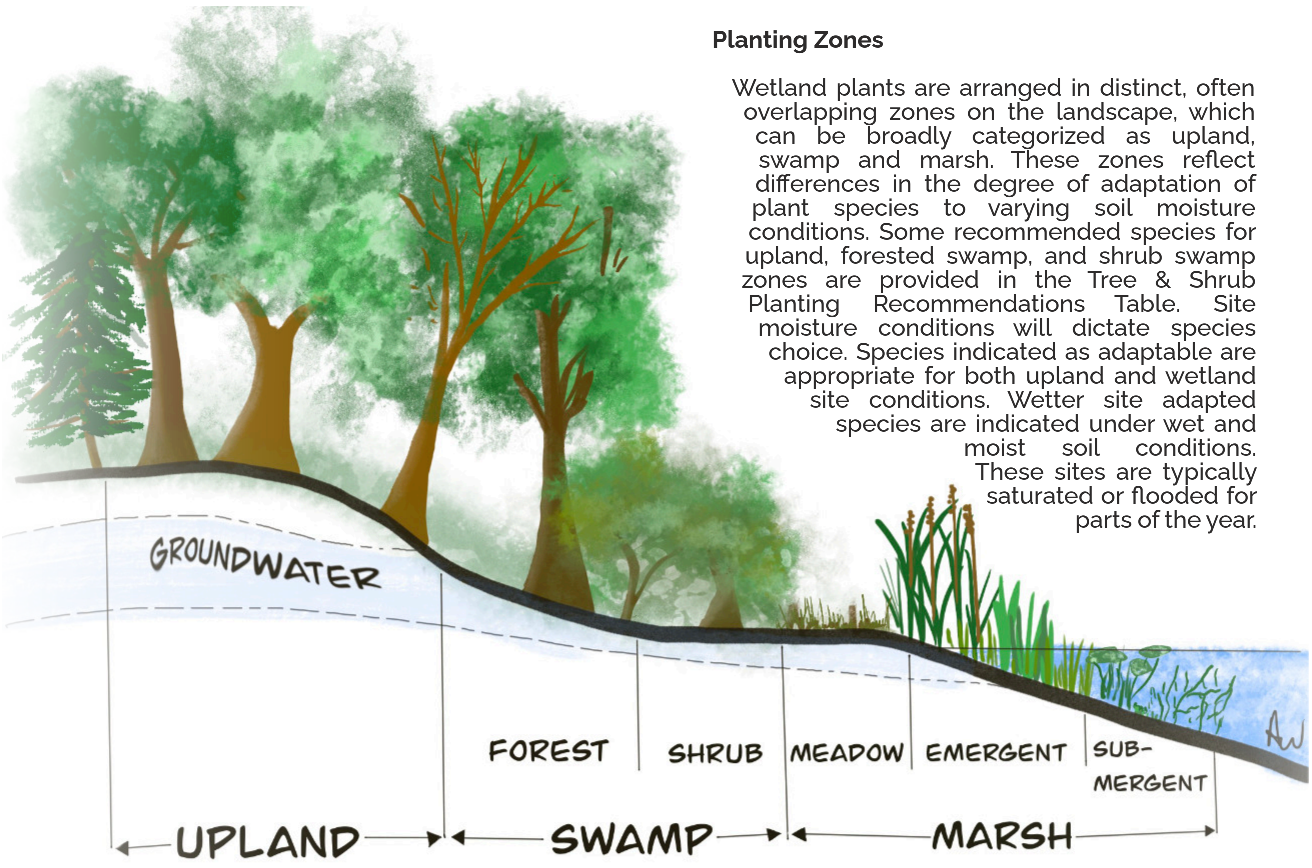
Planting Map	Identify planting zones to distinguish different vegetation communities and planting approaches, including areas to be left to naturally revegetate. Use site topography and hydrology to inform the design of planting zones (i.e. emergent marsh zone within low depressions prone to ponding water).
Plant List by Zone	Create a plant list for each planting zone. This can be done by assigning each planting zone a target natural community or vegetation mix based on expected pre-disturbance vegetation, existing vegetation, and reference wetland vegetation. Target communities can also be inferred from the ANR Atlas mapped soil series, which link to reports that indicate associated vegetation. The wetland indicator status of species can also be used to guide planting design. Show locations and quantities of plantings on the planting map. 500 woody stems per acre is a reasonable planting goal for shrub and tree dominated natural communities. Expect about 20-25% losses.
Planting Materials	Plants should be acquired from nurseries or growers who can provide locally sourced native trees and shrubs. Make sure to provide complete scientific names (genus, species, and subspecies if appropriate) to avoid inadvertently introducing non-native plants. Check availability of desired plants early in the planning process, because nurseries often run out. Another option is to harvest native material on site (or locally from a willing landowner) to save on costs and promote local genetic diversity. This is appropriate for live stakes and seeds, but it is generally not a good idea to dig up and transplant whole plants.
Protection Strategies	Protect plantings from herbivores (deer, rodents, rabbits, cattle, etc.). Options include fencing the planted area, installing wire cages around planted seeds, roots, or shoots, and putting seedlings in plastic tubes.
Site Preparation	Describe site work to be done prior to planting. This will be informed by the other restoration practices you choose to implement. Strategies for weed control in post-agricultural areas can also include disk and/or cultivation (sometimes repeatedly) to remove seedlings and break up roots. Soil amendments can include weed-free compost or mulch (such as straw or bark).
Planting Schedule	Spring (April-June) or Fall (September-October) are the optimum times to plant. Phasing the planting plan is often encouraged, especially in situations where invasive species and/or weeds are being removed from the site. Time plantings to avoid disturbance from other restoration activities.
Maintenance	Provide a schedule for follow-up work including watering, weeding, re-seeding/re-planting.
Seed Mixes	Purchase locally sourced native seed mixes and follow manufacturer's instructions. Wetland seed mixes are typically applied at higher rates and not buried. Apply evenly to avoid bare spots where invasive species can colonize. If the restoration planting is being phased, use of cover crop seed may be necessary for site stabilization between phases.
Containerized and Bareroot Plantings	These plantings have well established root systems and are often used in combination with seeding. Spring planting is generally encouraged.
Live-Stakes/ Whips	Native willows and dogwoods are reliable candidates for live staking, and material can be purchased or harvested. Species happy to be a stick in the mud include pussy willow, black willow, red osier dogwood, silky dogwood, and gray dogwood. Harvest and plant during dormancy while the ground is not frozen (mid-October to mid-November and between mid-April and mid-May).

Tree & Shrub Planting Recommendations

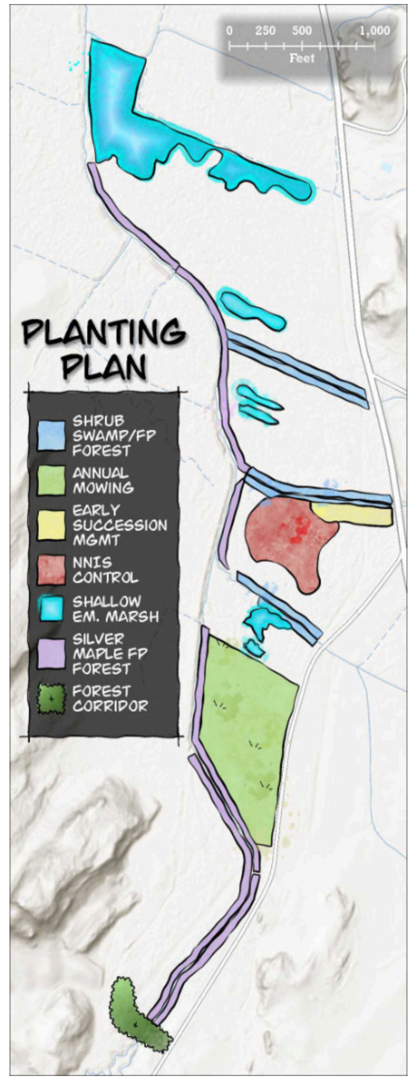
	Common Name	Taxa	Soil conditions	Growth Rate	Mature Height
Trees	Green ash	*Fraxinus americana*	moist	fast growing	50-70'
	N. White cedar	*Thuja occidentalis*	moist	slow growing	20-60'
	Black willow	*Salix nigra*	wet, moist	fast growing	25-40'
	Swamp white oak	*Quercus bicolor*	wet, moist	slow growing	50-70'
	Red maple	*Acer rubrum*	adaptable	fast growing	35-50'
	Cottonwood	*Populus deltoides*	adaptable	fast growing	80-100'
	Silver maple	*Acer saccharinum*	adaptable	fast growing	90-120'
	Eastern hemlock	*Tsuga canadensis*	adaptable	slow growing	60-80'
	Balsam fir	*Abies balsamea*	adaptable	slow growing	35-60'
	Yellow birch	*Betula papyrifera*	adaptable	slow growing	40-60'
Shrubs	Buttonbush	*Cephelanthus occidentalis*	wet, moist	fast growing	3-8'
	Silky dogwood	*Cornus amomum*	wet, moist	fast growing	3-8'
	Red osier dogwood	*Cornus sericea*	wet, moist	fast growing	3-8'
	Sweetgale	*Myrica gale*	wet, moist	fast growing	2-6'
	Winterberry	*Ilex verticillata*	wet, moist	slow growing	4-10'
	Elderberry	*Sambucus nigra, racemosa*	adaptable	fast growing	4-8'
	Arrowwood	*Viburnum dentatum*	adaptable	fast growing	6-10'
	High bush blueberry	*Vaccinium corymbosum*	adaptable	slow growing	3-8'

Planting Zones

Wetland plants are arranged in distinct, often overlapping zones on the landscape, which can be broadly categorized as upland, swamp and marsh. These zones reflect differences in the degree of adaptation of plant species to varying soil moisture conditions. Some recommended species for upland, forested swamp, and shrub swamp zones are provided in the Tree & Shrub Planting Recommendations Table. Site moisture conditions will dictate species choice. Species indicated as adaptable are appropriate for both upland and wetland site conditions. Wetter site adapted species are indicated under wet and moist soil conditions. These sites are typically saturated or flooded for parts of the year.



Bare root and container planting Katie Kain, USFWS

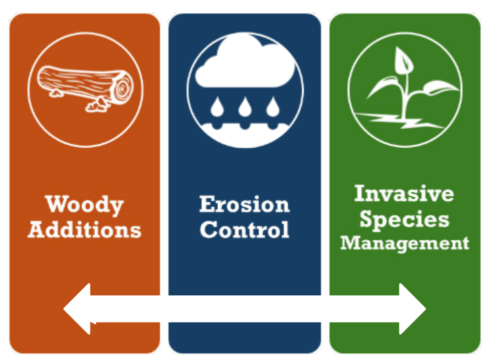


Challenges & Solutions

- Expense: The price of planting material ranges depending on size and volume. Seed mixes for wetland restoration can be expensive, but following the recommended application rates is important to successful establishment of vegetation. To minimize expenses, consider limiting your soil disturbance and subsequent replanting areas, harvesting or growing your own planting materials, or shopping around and contracting with a nursery ahead of time.
- NNIS: Since there is a preponderance of NNIS on the landscape in some areas, there is a high likelihood of infestation, especially on open soils. Ongoing monitoring and management are time consuming and can be costly, but vigilance can save time and resources in the end. Take care to avoid bringing in NNIS plants or seeds during site work and manage nearby populations before breaking ground.
- Herbivory: New tree and shrub plantings are often browsed by animals. Best to assume this will be a problem on your site and prepare in advance with protection strategies. Where heavy browse is anticipated, one strategy is to concentrate and fence plantings in clusters.
- Plant Mortality: 20-25% mortality for woody plantings in the first few years is not uncommon. Provided that enough plants survive and mature, this is OK, but minimize initial losses by choosing site appropriate plants, planting in spring or fall, and protecting against herbivory.
- Irrigation: If site and weather conditions require watering, it can be critical to the success of the project. Planting in already saturated conditions, or timing your planting efforts for the spring or fall most often eliminates the need for watering.

> **!** Don't forget to water! Make sure to water at planting time. Do not select non-native species or cultivars.

Complementary Practices:



3.4 Ditch Plugs

Ditches confine water, lower the water table, and route water quickly through wetlands. Wetlands with artificial drainage patterns have diminished capacity to slow down and store flood waters. Restoring a portion of a ditch to the natural ground level with an earthen wall can impound water, flood the ditch, and reconnect it with the surrounding wetland. These ditch plugs can be a quick and inexpensive hydrologic restoration practice for artificial drainageways but are not appropriate for stream channels, and care must be taken to ensure hydrology is not altered off site.

Ditch Plugs

GOALS

Disrupt altered drainage patterns to restore wetland hydrology; restore functions of flood storage and water quality

BENEFITS

Prevent erosion; slow down and infiltrate stormwater; improve water quality; provide flood resiliency

1. Determine Plug Material
2. Identify Plug Locations
3. Identify Staging and Access
4. Construct Plugs
5. Stabilize Site
6. Monitor for Success

DEFINITIONS

Organic soil: Soils formed from sedimentation and primarily composed of organic matter (i.e. plant materials).

Mineral Soil: Soils formed from weathering of rocks and contains little organic matter.

Hydrology: The movement of water both on and below the ground surface.

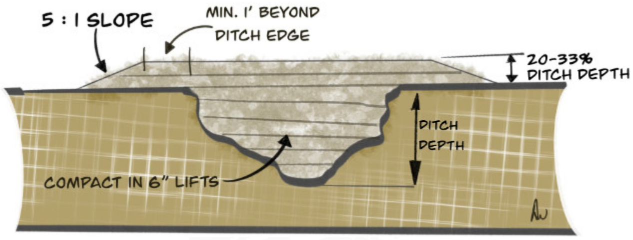
Ditch Plug Example

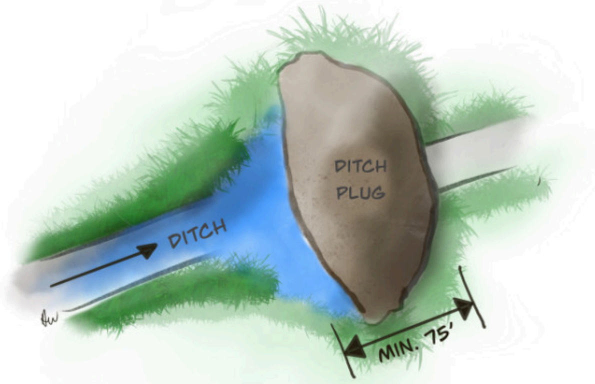
Ducks Unlimited VT ILF Program

Ditch Plug Specification

Ditch plugs are made from soil, which can be either sourced on site or imported from clean off site material.

Length	75'-150'+
Side Slope	5 : 1
Material	Soil collected on-site, or imported
	Mineral Soil- i.e. clay soils
	Plug at least 75' of ditch
	Compact in lifts of 4-6"
	Rise 20% of ditch depth above surrounding ground
	Organic Soil- i.e. peat soils
	Plug at least 150 ft of ditch
	Compact in lifts of 4-6"
	Rise 33% of ditch depth above surrounding ground





Shorter plugs can be used with shallower ditches, generally less than 2' in depth. A length of less than 50' is not recommended.

Pre-Construction Planning

Identify Plug Material

Look for spoils from the original ditching along either side of the ditch. Additional sources of on-site material can come from other restoration practices (i.e. depression excavations). If importing soil, use clean fill from a location where non-native invasive species (NNIS) are not found.

Determine Plug Locations

A single plug can work in a relatively flat/level site. Locate the plug at the downstream edge of the desired wetland restoration area. Multiple plugs are needed on sloped sites. Locate one plug at the lowest elevation of the restoration area with additional plugs moving upslope. Spacing or stepping the plugs every one to three feet of vertical rise is recommended to reduce excessive pressure between the plugs.

Identify Staging Location

Find an onsite upland staging location for temporary storage of imported soils (as needed) and parking of equipment.

Identify Access Routes

Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see Chapter 5).

Select a Contractor & Equipment

Choose a contractor with previous experience working in wetlands and use low ground pressure equipment such as an excavator with wide tracks. Meet with the contractor to review project details including site access and staging location, the specifications for plug material and plug installation, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions with no/minimal flow present in the ditch.

Construction Sequencing

1. Stock pile imported soils in staging area. Use erosion control measures if storing for more than a week, or heavy rain is predicted.
2. Stake out location of plugs along ditch. Stakes at both ends of the plug will guide the contractor and prevent over/under filling.
3. Strip existing material from where the plug will be installed in the ditch. Remove all vegetation, roots, organic matter and unsuitable sediments. Depending on field conditions the stripping could be done by hand or with the machine.
4. Install depending on fill material per specifications above. Replace organic soils removed from the ditch as topsoil on the plug.
5. Securely stabilize the site through appropriate erosion control measures. Seed and mulch all disturbed soils (see Erosion Control).

Plug in process, Ryan Crehan, USFWS

Challenges and Solutions

- ◻ Controlling impacts to upslope and downslope ditch property owners: If the subject ditch is not confined to the project property, do not place plugs where hydrology changes will affect neighboring land and no closer than within 25' of the property line. This will buffer the neighboring property from any unanticipated impacts from the ditch plugs.
- ◻ Settling of fill material: Overfilling the ditch is intended to offset settling, but addition of fill may be necessary over time.
- ◻ Erosion of the ditch plug before vegetation reestablishment: Timing of construction during low flow conditions and quick attention to seeding and mulching when construction is complete will assist with vegetation establishment and stability of the site.
- ◻ Introduction of invasive species: If work crews are used, ask them to clean tools and boots, and to power-wash equipment before entering the restoration site. Work with your contractor to minimize soil disturbance.

Complementary Practices:

> ! Additional permitting may be required for the construction of new access roads or trails, for the stockpiling of soil in a wetland or wetland buffer, or for the addition of fill to a floodplain.

3.5 Fill Drainage Ditches

Ditches confine water, lower the water table, and route water quickly through wetlands. Wetlands with artificial drainage patterns have diminished capacity to slow down and store flood waters. Completely filling a ditch can provide permanent restoration of hydrology and allow for recontouring and restoration of site topography. Ditch backfilling is intended for artificial drainageways, not stream channels.

Fill Drainage Ditches

GOALS

Restore wetland hydrology and native site topography; restore functions of flood storage and water quality

BENEFITS

Prevent erosion; slow down and infiltrate stormwater; improve water quality; provide flood resiliency

1. Identify Backfill Material
2. Identify Staging and Access
3. Construct and Recontour
4. Stabilize Site
5. Monitor for Success

DEFINITIONS

Compaction: Pushing soils together so tightly that there is little air between particles. Compaction is obtained by traveling over thin layers of soil a number of times with heavy equipment.

Ditching: Excavating a channel in a wetland to drain water.

Drainage Ditches

The United States lost over 50% of its wetlands since the early 1600s, and Vermont lost as much as 35%. Wetlands were seen as obstacles to development, agriculture, and travel, and were systematically drained and altered. Conversion of wetlands was an accepted practice as recently as the 1950s, and was even incentivized by government policies. Restoration is essential for rehabilitating wetlands that have been degraded. (VTDEC, website)

Historic Ditching in Bennington County, NRCS

Filling a Ditch to restore wetland function, Shayne Jaquith, The Nature Conservancy

Pre-Construction Planning

Identify Backfill Material

Look for spoils from the original ditching along either side of the ditch. Additional sources of on-site material can come from other restoration practices (i.e. depression excavations). If importing soil, use clean fill from a location where non-native invasive species (NNIS) are not found.

Identify Staging Location

Find an onsite upland staging location for temporary storage of imported soils (as needed) and parking of equipment.

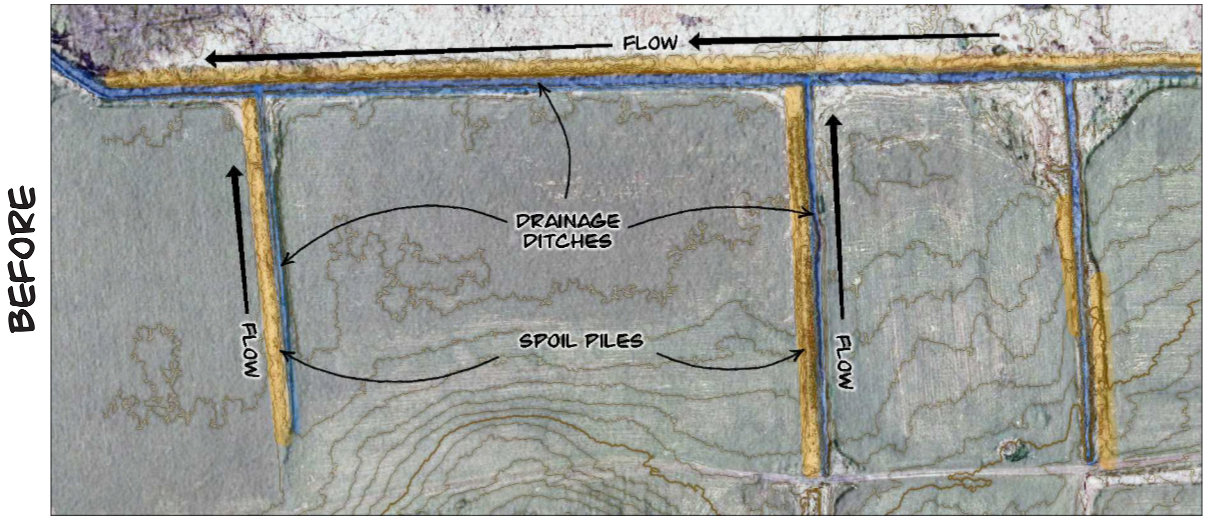
Identify Access Routes

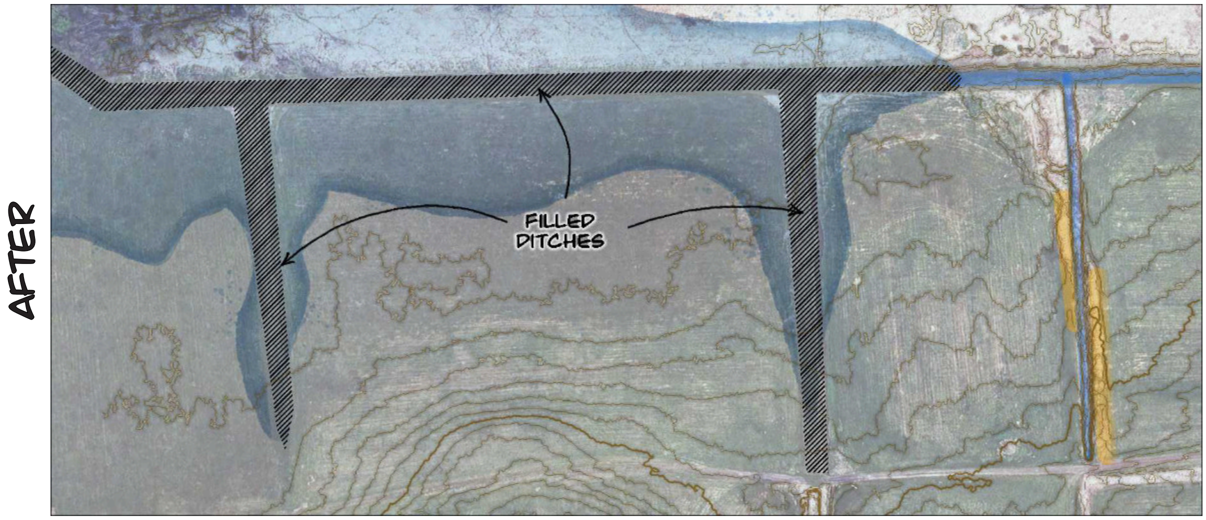
Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see Chapter 5)

Select a Contractor & Equipment

Choose a contractor with previous experience working in wetlands and who has low ground pressure equipment such as a excavator with wide tracks. Meet with the contractor to review project details including site access and staging location, the specifications for fill material and fill installation, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions with no/minimal flow present in the ditch.

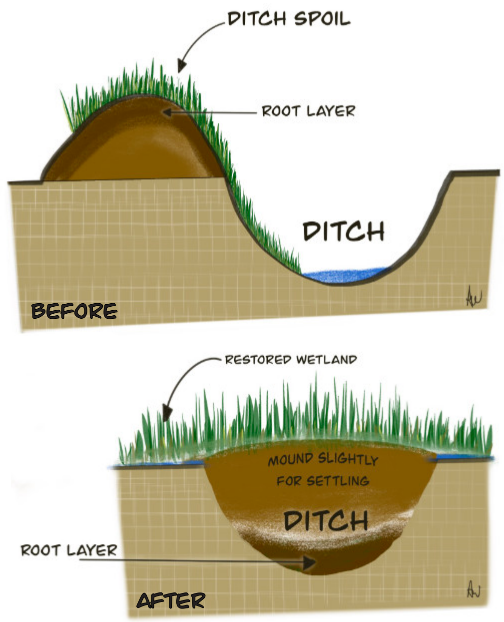
Ditch Fill Illustration





Construction Sequencing

1. Stockpile imported soils in staging area. Use erosion control measures if storing for more than a week, or heavy rain is predicted.
2. Stake out extent of ditch fill. Stakes at both ends of the fill area will guide the contractor and prevent over/under filling.
3. Stripping of existing vegetation, roots, organic matter and sediments in the ditch is not necessary, existing ditch spoil material can be pushed into the ditch without preparing the ditch. If NNIS are present in the fill material, have the contractor remove and push the surface layer first to form the bottom layer of the filled ditch.



4. Compaction of soils is important to prevent excessive settling. It may be difficult to compact the first few feet, especially if the ditch is wet. General guidance is to compact in 12" lifts after a base is established.
5. Build fill up 10%-20% over the level of the ground to allow for settling. This is particularly important in sloped wetlands. The slightly higher ditch fill will help spread surface runoff and prevent erosion of the backfill area.
6. Securely stabilize the site through appropriate erosion control measures. Seed and mulch all disturbed soils. (see Erosion Control).

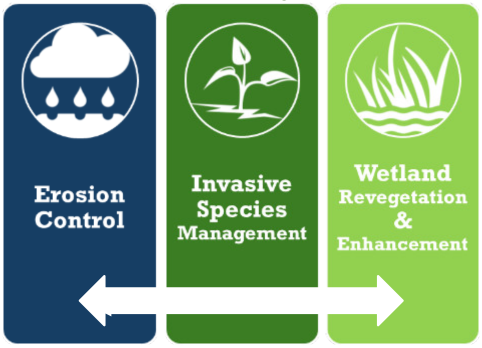
Challenges and Solutions

- Completely filling ditches can take a lot of material and is not feasible at all sites: Targeted ditch filling with ditch plugs can accomplish many of the same goals.
- Settling of fill material: Overfilling the ditch seeks to offset the settling but addition of fill may be necessary over time.
- Erosion of ditch fill before vegetation reestablishment: Timing construction during low flow conditions and quick attention to seeding and mulching when construction is complete will assist with vegetation establishment and stability of the site.

> Additional permitting may be required for the construction of new access roads or trails, or for the stockpiling of soil in a wetland or wetland buffer, or for the addition of fill to a floodplain.

- Introduction of invasive species: If work crews are used, ask them to clean tools and boots and to power-wash equipment before entering the restoration site. Work with your contractor to minimize soil disturbance.
- Controlling impacts to upslope and downslope ditch property owners: If the subject ditch is not confined to the project property do not fill within 25' of the property line. This will buffer the neighboring property from any unanticipated impacts from the ditch filling.

Complementary Practices:



3.6 Remove Sediment and Fill

Wetlands have been historically filled with topsoil, gravel, concrete, rocks, and other waste, and then covered with soil. Another common practice was to construct berms along streams/rivers to prevent flooding of adjoining fields. Wetlands filled prior to the Vermont Wetland Rules are not violations and are good candidate projects for wetland restoration.

Remove Fill

GOALS

Remove historic fill and expose the original wetland soil layer; put back natural contours and microtopography

BENEFITS

Improve water quality; restore wildlife habitat; reestablish hydrology; reconnect floodplains

1. Determine Extent of Historic Fill
2. Identify Staging and Access
3. Identify Disposal Area
4. Excavate Fill and Recontour
5. Stabilize Site
6. Monitor for Success

DEFINITIONS

Floodplain: Level area of land next to a stream or river that floods.

Soil Auger: A hand-held steel rod attached to a large screw that can be used to take soil samples at various depths below the surface.

Solid Waste: Unnatural fill materials such as household garbage, plastic, tires, concrete, and scrap metal that are disposed of at a landfill.

Fill Removal

Finding native soil and removing sediment from a filled wetland

Pre-Construction Planning

Locate Underground Utilities

Mark locations of underground utilities in or adjacent to the excavation area.

Delineate Fill Area

Determine the nature and extent of the fill material to be excavated. Resources to assist with this task include historic and current aerial imagery, soil auger, posthole digger, and/or a backhoe.

Identify Disposal Area

Identify where the removed material will be disposed of (non-wetland/buffer location), depending on the nature of the fill.

Identify Staging Location

Find an onsite staging location for temporary storage of excavated fill material and parking of equipment.

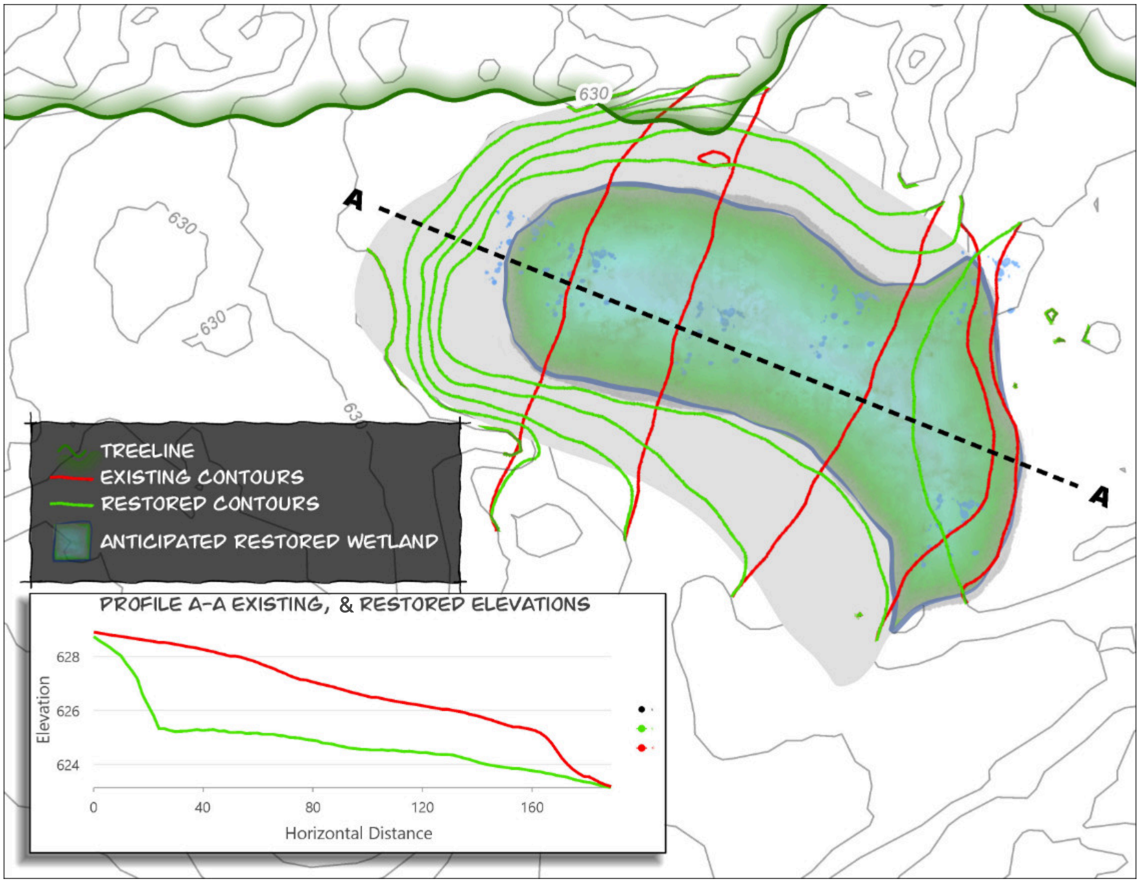
Identify Access Routes

Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see Chapter 5).

Select a Contractor & Equipment

Choose a contractor with previous experience working in wetlands and who has low ground pressure equipment such as a backhoe with wide tracks. Meet with the contractor to review project details including site access, staging location, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions.

Fill Removal Plan Example



Construction Sequencing

1. Flag the limits of the excavation area.
2. Install erosion control measures. Contained sites (depressions without outlets) do not generally need specific erosion control measures during construction. Uncontained sites of greater than 0.5 acres may require installation of silt fence at down slope extent to prevent discharge of sediment to sensitive resources (streams, wetlands) and/or neighboring properties.
3. Excavate the historically deposited fill. It is often easy to identify the native ground surface by looking for decomposing organic material (vegetation, woody stems). Encourage the contractor to work slowly so as not to excavate below that level. Leave the ground surface rough and instruct the contractor that a manicured final grade is not the goal. If all of the fill material is not being removed, or if the native ground surface is not identifiable, a more detailed plan for final grading will be needed. This will likely require site surveys and detailed site plans.
4. Dispose of fill material. Clean excavated material can be disposed of either on-site or off-site. Make sure that the disposal site is not located within wetland or wetland buffer resources. Solid waste needs to be disposed of at a certified landfill facility.

Securely stabilize the site through appropriate erosion control measures. Seed and mulch all disturbed soils. (see Erosion Control Practices).

Filled wetland before restoration

Post restoration-fill removed, rough finish incorporating boulders

Challenges and Solutions

- Hauling and disposing of waste material can be expensive: Identifying nearby disposal sites is most economical. Make sure disposal area is not in wetland or wetland buffer.
- Introduction of invasive species: If work crews are used, ask them to clean tools and boots, and to power-wash equipment before entering the restoration site. Work with your contractor to minimize soil disturbance.

Additional permitting may be required for the construction of new access roads or trails, for the stockpiling of soil in a wetland or wetland buffer, or for the addition of fill to a floodplain.

Complementary Practices:

3.7 Surface Drainage Reroutes

Wetlands targeted for restoration commonly contain surface ditching that disrupts their natural hydrology. This ditching can extend upslope and downslope of the restoration area, as well as onto neighboring lands. Discharge from ditching into the restoration area is not always desired (e.g. water quality concerns), and for these cases a reroute of the approaching drainage system can be implemented. Here, the wetland restoration area would need to have other sources of hydrology to support the restoration effort. This practice is not intended for stream channels and may require consulting or engineering oversight.

Drainage Reroute

GOALS

Relocate or realign a drainage system so that it no longer flows through or impacts the wetland restoration area

BENEFITS

Improved water quality

1. Identify & Stake Out New Drainage Path
2. Identify Soil Stockpile Location
3. Identify Staging and Access
4. Excavate Channel
5. Stabilize Site
6. Monitor for Success

DEFINITIONS

Ditch: Channel or swale constructed in the ground, intended primarily for drainage.

Stream: A stream has a channel that periodically or continuously contains moving water, has a defined bed, transports sediment, and has banks that serve to confine water at low to moderate flows.

Surface Drainage Reroute, Ryan Creehan, USFWS

Surface Drainage Reroute, Shayne Jaquith, TNC

Pre-Construction Planning

Drainage Channel Siting

A new drainage section should be as far as possible from the wetland restoration area to avoid unintended lateral drainage impacts. Avoid significant ground elevation rise, which can result in increased cut depths, lengths, and costs.

Drainage Channel Design

Identify dimensions of the new drainage segment based on cross sectional dimensions of upslope and downslope connection points to the existing drainage system. Establish upslope and downslope elevations to blend into the existing system, avoiding steep slopes. Match grades in the new segment to grades in the existing system.

Locate Underground Utilities

Mark locations of underground utilities in or adjacent to the excavation area.

Identify Disposal Area

Identify where the excavated soils will be disposed of in an upland location.

Identify Staging Location

Find an upland staging location for the temporary storage of excavated fill material and parking of equipment.

Identify Access Routes

Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see chapter 5).

Select a Contractor & Equipment

Choose a contractor with previous experience working in wetlands and low ground pressure equipment such as an excavator with wide tracks. Meet with the contractor to review project details including site access and staging location, the specifications for drainageway construction, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions.

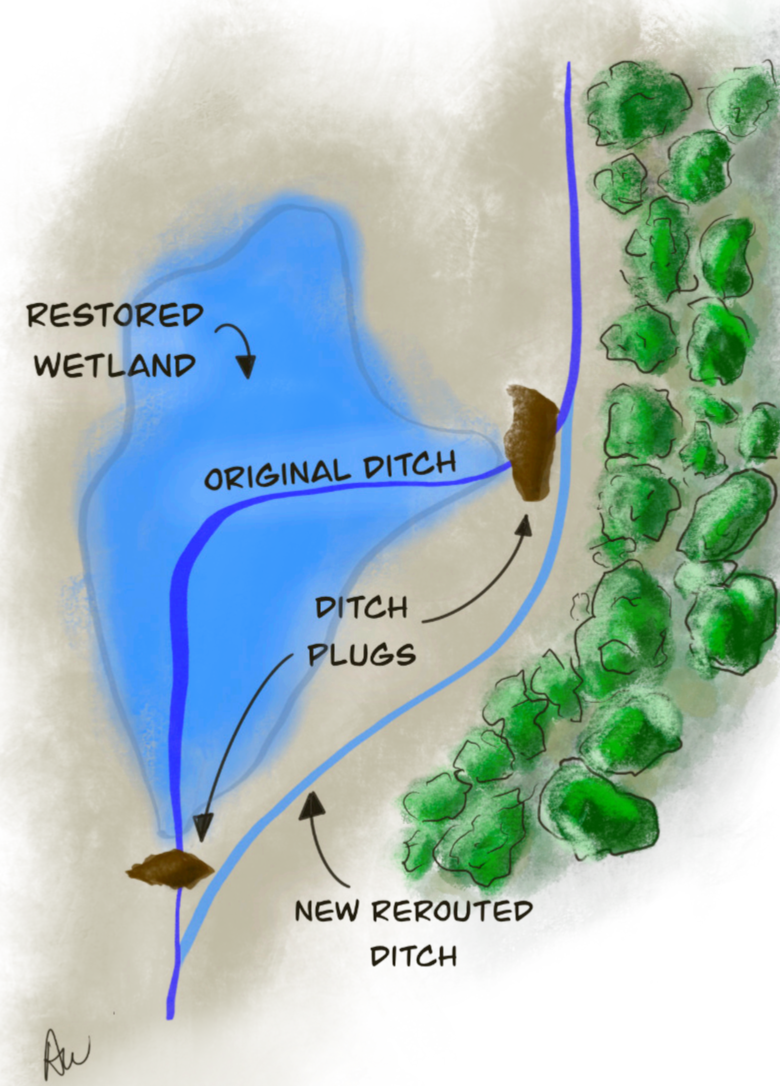
Construction Sequencing

1. Stake out limits of new drainage segment.
2. Excavate new drainage segment to match depth, width, and grade of upslope and downslope drainage connection. Do not make final connection with existing ditch system.
3. Securely stabilize new segment through appropriate erosion control measures. Secure the bed and walls of the channel with appropriate materials, and seed and mulch all disturbed soils (see Erosion Control).
4. Construct ditch plugs on abandoned portion of ditch upslope and downslope of wetland restoration area (see Ditch Plugs).
5. Connect new drainage segment into existing network after stabilization has been achieved.
6. Securely stabilize remainder of new segment through appropriate erosion control measures. Seed and mulch all disturbed soils. (see Erosion Control).
7. Proceed with restoration practices in area of abandoned segment (i.e. Ditch Plugs and/or Fill Drainage Ditches Practices).

Challenges and Solutions

- Construction costs: Hauling and disposing of excavated soil material can be expensive. Identifying nearby disposal sites is most economical.
- Maintaining wetland restoration area hydrology: It is important to understand the water inputs to the restoration area to make sure rerouting of a drainage does not starve the wetland of the hydrology needed for successful restoration.
- Controlling adverse impacts to upslope and downslope ditch property owners: If the subject ditch is not confined to the project property, leave 25' sections intact before the property line. This will allow a buffer to the neighboring property from any unanticipated impacts from the ditch rerouting.
- Erosion of the new drainage segment: Properly stabilize new channel segment before connecting into the existing network.
- Introduction of invasive species: If work crews are used, ask them to clean tools and boots, and to power-wash equipment before entering restoration site. Work with your contractor to minimize soil disturbance.

Drainage Reroute Example



Poorly executed surface water reroutes can lead to significant erosion problems, both upslope and downslope. In some cases, erosion risks may be too great to overcome, and a reroute should not be attempted.

Additional permitting may be required for the construction of new access roads or trails, for the stockpiling of soil in a wetland or wetland buffer, or for the addition of fill to a floodplain.

Complementary Practices:

3.8 Tile Drain Blocks

Underground drainage systems remove water from saturated soils, usually through a network of perforated tubes, or pipes commonly called tile drains. Drainage tiles are often buried (typically 2 to 5 feet below ground) in wetlands to improve their use for farming. Restoration of wetland hydrology involves rendering the drainage system ineffective by strategically removing or plugging some of the tiles. This is referred to as tile "blocking," and may result in less ground disturbance and reduced construction costs compared to removing the full tile drain system.

Tile Drain Blocks

GOALS

Restore hydrology to a drained wetland system

BENEFITS

Improved water quality; increased flood storage; improved erosion control

1. Map Tile Network
2. Map Out Plug/Block Locations
3. Acquire Plug/Block Materials (i.e. caps, grout)
4. Locate Backfill Material
5. Identify Staging and Access
6. Construct Blocks and/or Plugs
7. Backfill Trench
8. Stabilize Site
9. Monitor for Success

DEFINITIONS

Tile Blocking: Excavating and then removing or plugging a length of tile at strategic locations, followed by capping the exposed tile ends, and then backfilling and compacting the trench.

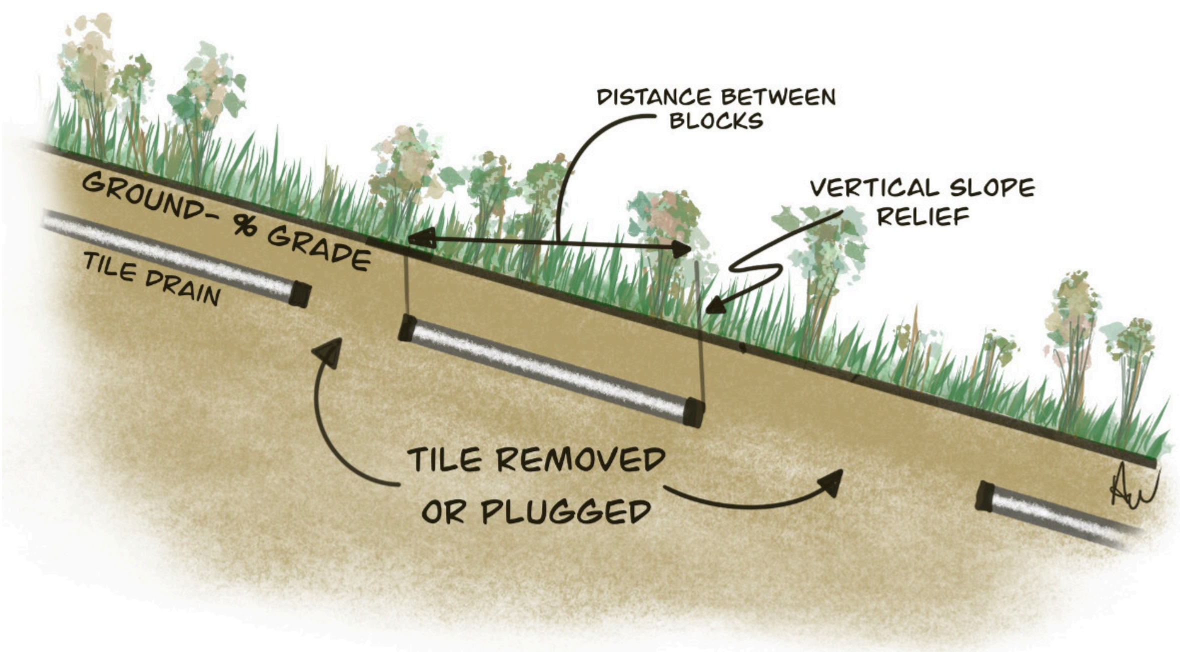
Tile Probe: A long, small diameter steel rod with a pointed tip mounted on a handle. Used to locate buried drainage structures.

Tile drain installation

Joshua Faulkner

Tile Block Specification

Plug Material	Concrete grout or clay.
Property Line Setback	Offset impacts 25' or more from project or property boundaries.
Level/Flat (<4%) Wetlands	*(Subsurface drainage is typically provided by just a single tile line or tile main. There may be one or more branches of the tile system that tie into the main tile line.)*
	Blocking one section on the main tile line will likely be sufficient to restore hydrology.
	Block spacing: 1-2' vertical slope relief.
	Begin the tile block at the anticipated restored wetland's edge and extend downslope.
	Minimum length of block: 50' in heavy clay soils to 150' in sandy or organic soils.
Sloped (>4%) Wetlands	*(Restoration of hydrology in sloped wetlands is challenging and may require more advanced design help.)*
	More than one block may be needed depending on the size of the restoration area and extent of the existing tile. The design will include tile blocks on each tile line running upslope through the wetland.
	Block spacing: Every 2-4' of vertical slope relief.
	Primary Block: Begin the lowest tile block at the anticipated restored wetland's edge and extend downslope 100'.
	Supplemental Blocks: Block 30' to 50' of tile upslope of anticipated wetland edge, spaced every 2-4' of vertical elevation change.
	Close spacing of the blocks in a stepped fashion will produce the best results for reestablishing hydrology. Longer lengths can be used in areas with more organic or sandy soils.



Pre-Construction Planning

Map Tile Drain Network

Determine type (clay, concrete, or plastic), sizes (diameter), locations, flow directions and outlets of existing drainage tile within and adjacent to the restoration area. Potential sources of this information include landowners, the Natural Resource Conservation Service (NRCS), and aerial photos.

Plan Block Locations

Identify the location and sizing of blocks per specifications for either sloped or level sites. Decide whether removal or plugging is most appropriate.

Acquire Block Materials

Caps are needed for both tile removal and plugging. These can often be found at a local hardware store. Plug material can include redimix concrete, clean clay fill and expandable foam.

Identify Trench Fill Material

Additional sources of on-site material can come from other restoration practices (i.e. depression excavations). If importing soil, use clean fill from a location where non-native invasive species (NNIS) are not found.

Identify Staging Location

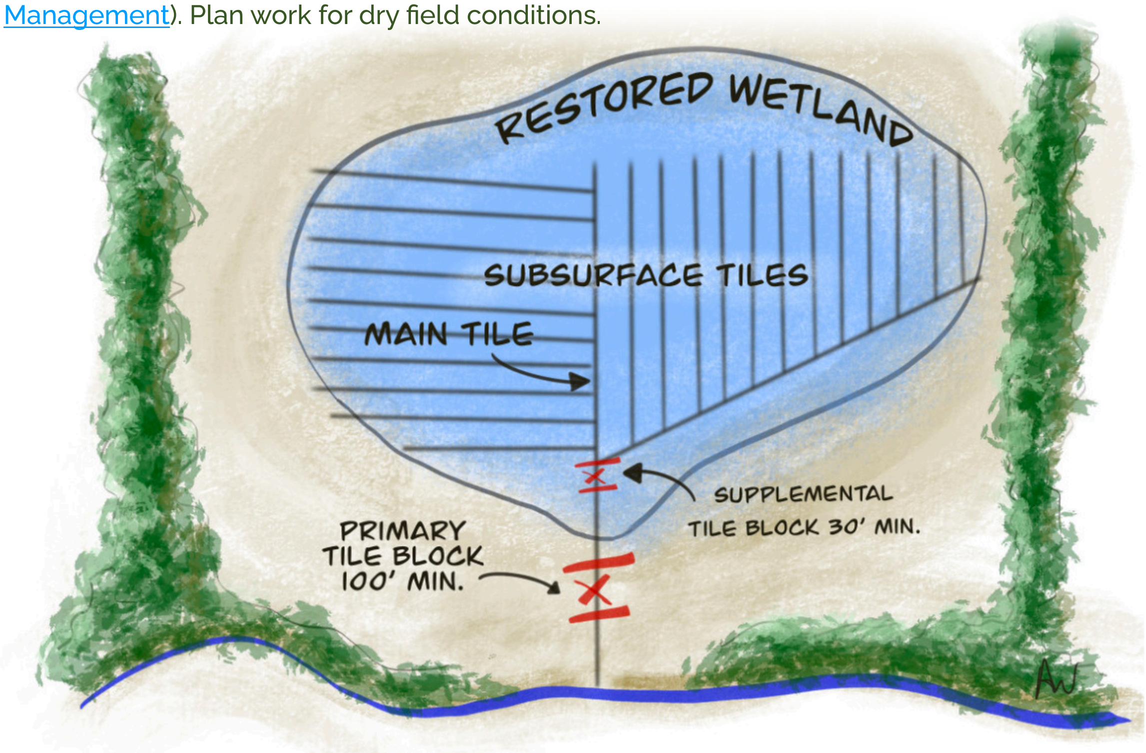
Find an upland staging location for temporary storage of imported soils (as needed), removed tile drains, and parking of equipment.

Identify Access Routes

Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see chapter 5).

Select a Contractor & Equipment

Choose a contractor who has previous experience working in wetlands and use low ground pressure equipment such as an excavator with wide tracks. Meet with the contractor to review project details including site access and staging location, specifications for tile blocking construction, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions.



Construction Sequencing

1. Stockpile imported soils in staging area. Use erosion control measures if storing for more than a week or if heavy rain is predicted.
2. Stake out block and plug locations. Stakes at both ends of the block will guide the contractor.
3. Excavate trench and block tiles.
4. Seal or cap two exposed ends of tile system with manufactured cap. To ensure the tile is sealed from future flow, install a cement plug in the end of the tile break first. Pour enough concrete or grout to fill a couple of feet of line.

Tile drain removal for wetland restoration, Ducks Unlimited

5. Refill trench.
6. Compact spoils in the ditch (generally in lifts of 4-6"). Build spoils up 10%-20% over the level of the ground to allow for settling.
7. Securely stabilize the site through appropriate erosion control measures. Seed and mulch all disturbed soils (see Erosion Control).
8. Proceed with restoration practices in the area of the abandoned tile drainage.

> **!** Additional permitting may be required for the construction of new access roads or trails, for the stockpiling of soil in a wetland or wetland buffer, or for the addition of fill to a floodplain.

Challenges and Solutions

- Sizes, grades and locations of existing tile lines may be unclear: Ask the landowner, look at air photos for linear patterns that are unnatural, look for surface intakes, look for outlets, look for tile blowouts, look for changes in vegetation, and explore with a tile probe.
- Leaky blocks: Incorrect sealing of blocks can result in leaking and erosion.
- Settling of fill material: Overfilling the ditch seeks to offset settling, but addition of fill may be necessary.
- Controlling adverse impacts to upslope and downslope property owners: If the subject drainage network is not confined to the project property, leave a 25' section of the existing system intact before the property line. This will buffer unanticipated impacts from the tile blocking.
- Introduction of invasive species: If work crews are used, ask them to clean tools and boots, and to power-wash equipment before entering the restoration site. Work with your contractor to minimize soil disturbance.

Complementary Practices:

3.9 Hummock/Hollow Creation

Hummocks, also called mounds, are typically initiated as the root masses and trunks of fallen trees rising above the wetland floor. The low-lying areas between hummocks are called hollows or pits. Hummocks provide necessary growing conditions for certain plants, while hollows provide breeding areas for amphibians and insects, feeding and drinking holes for birds and mammals, and contribute to ground water recharge.

Hummocks and Hollows

GOALS

Create diversity of wetland habitats by restoring or creating microtopography

BENEFITS

Wildlife habitat diversity; groundwater recharge

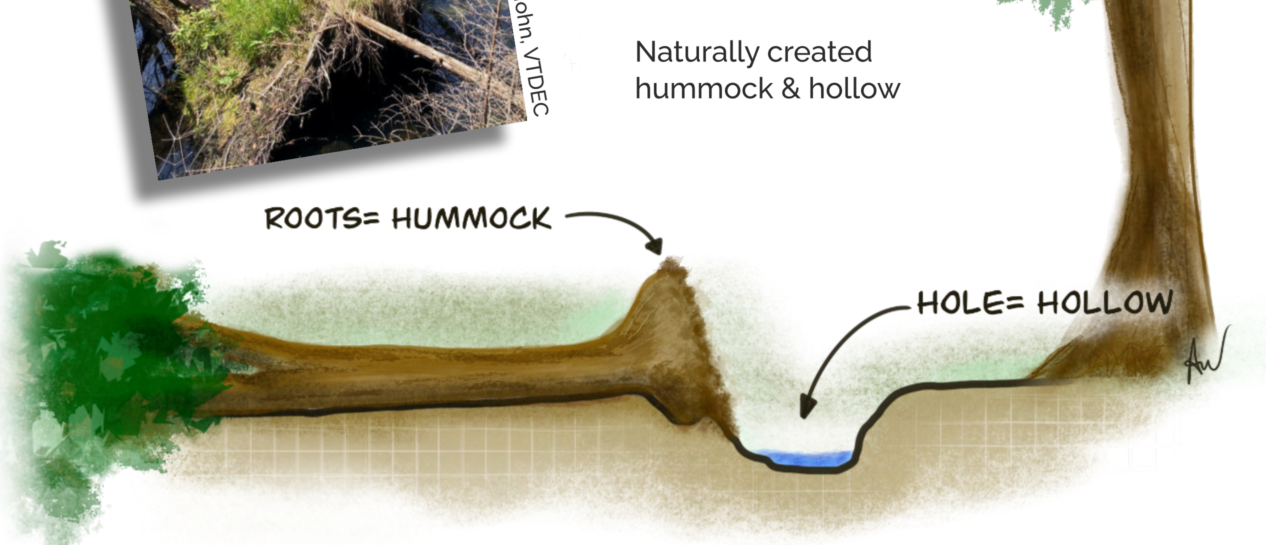
1. Design Hummock/Hollow Schematic
2. Identify Staging and Access
3. Excavate Hollows and Shape Hummocks
4. Stabilize Site
5. Monitor for Success

DEFINITIONS

Compaction: Pushing soils together so tightly that there is little air between particles.

Backhoe: A machine mounted on rubber tires with a wide bucket on the front for carrying soil and a smaller bucket attached to an arm in the back for digging holes.

Charlie Hohn, VTDEC



Naturally created hummock & hollow

Hummock/Hollow Specification

Hollow Depth	Less than 6" of water (water stands for short durations)
Hummock Height	6" to 2' (variable)
Width	Not less than 3'
Side Slopes	5 : 1 Slope (where subject to wave action)
Surface Finish	Rough bottom and sides and a ragged boundary
Hummock Material	Excavated material from hollow/pit - do not compact

Hummocks & hollows constructed in a small sloped forested wetland restoration

Hummocks & hollow creation in a low-gradient wetland restoration. Adam Huggins, Galiano Conservancy Association

Pre-Construction Planning

Schematic Plan

Develop a general detail for hummock/hollow sequence and specify an average density and spacing per acre of restoration. Random variations in shape, depth, and spacing are preferred.

Locate Underground Utilities

Mark locations of underground utilities in or adjacent to the excavation area.

Identify Staging Location

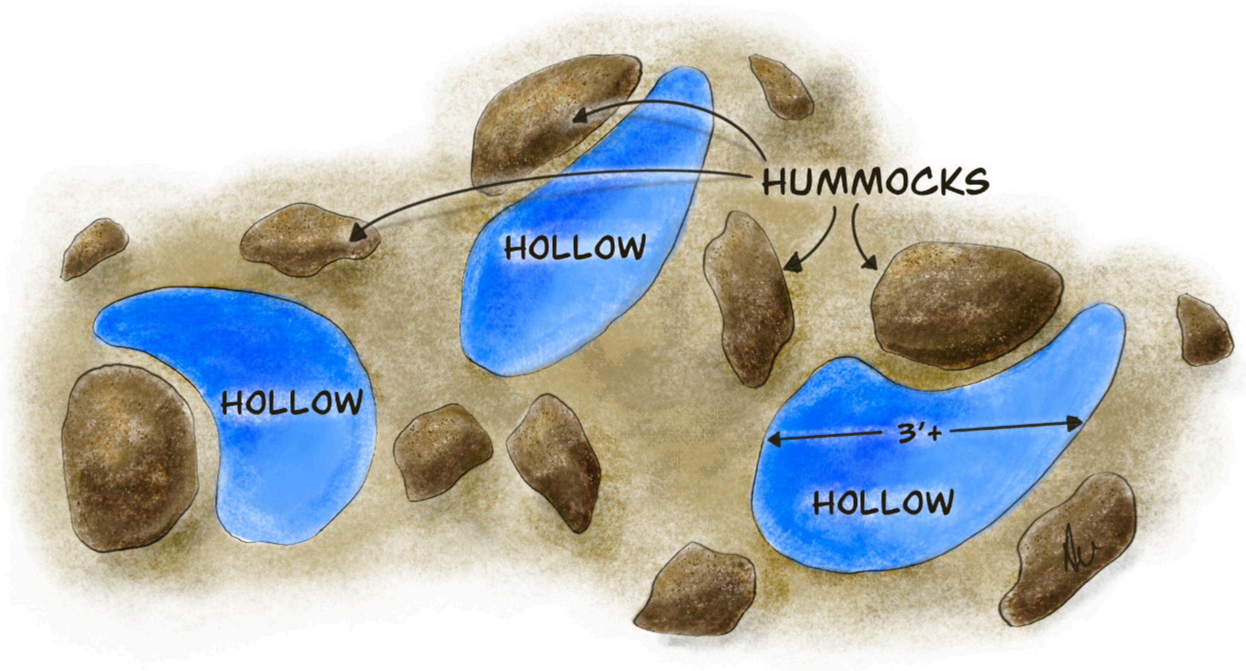
Find an upland location for temporary equipment parking. For this practice, soil for the hummocks comes from excavating the adjacent hollows, and you shouldn't need to store any soil.

Identify Access Routes

Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see chapter 5).

Select a Contractor & Equipment

Choose a contractor with previous experience working in wetlands and use low ground pressure equipment such as a backhoe with wide tracks. Meet with the contractor to review project details including site access and staging location, the specifications for hummock/hollow construction, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions.



Construction Sequencing

1. Stake out location of each hummock/hollow treatment area.
2. Excavate hollows and shape hummocks, working from the interior of the restoration site to the exterior to avoid compaction by equipment.
3. Securely stabilize the restoration area through appropriate erosion control measures. Seed and mulch all disturbed soils (see Erosion Control).

> Additional permitting may be required for the construction of new access roads or trails, for the stockpiling of soil in a wetland or wetland buffer.
>
> This practice may not be appropriate in floodplains, so seek qualified advice. Additional permitting may be required.

Challenges and Solutions

- Introduction of invasive species: If work crews are used, ask them to clean tools and boots, and to power-wash equipment before entering the restoration site. Work with your contractor to minimize soil disturbance.

Complementary Practices:

3.10 Shallow Depressions/Scrapes

Many shallow, depressional wetlands have been filled by sedimentation from intensive land cultivation practices and other soil disturbing activities. Excavations within drained or altered wetlands improve wetland habitat by increasing wetland depths and providing microtopography. Depressions allow for water ponding which provides a degree of water storage capacity.

Shallow Depressions

GOALS

Restore wetland hydrology and microtopography

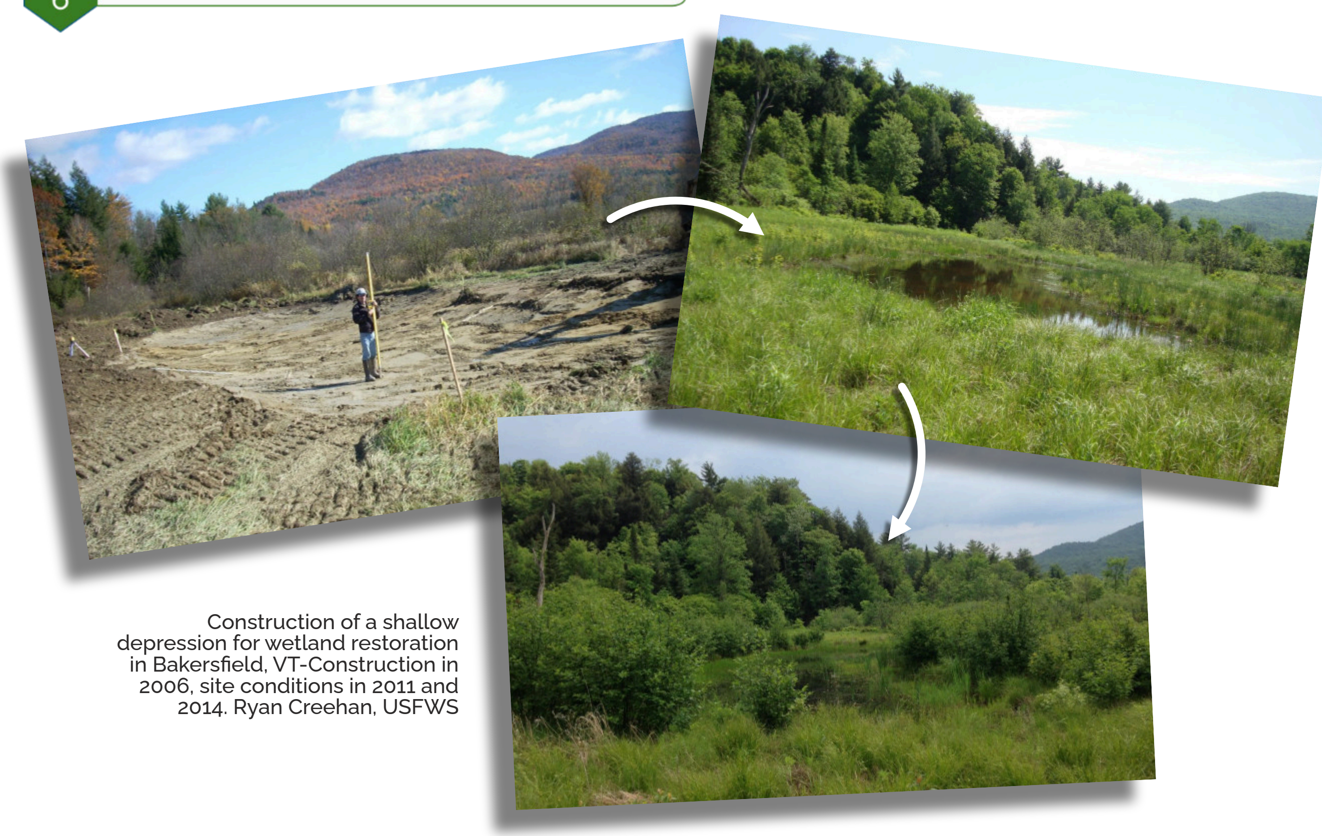
BENEFITS

Diversified wildlife habitat; improved water quality; increased flood storage

1. Design Depression/Scrape Schematic
2. Stake out Depression/Scrape Locations
3. Identify Staging and Access
4. Excavate depressions
5. Stabilize Site
6. Monitor for Success

DEFINITIONS

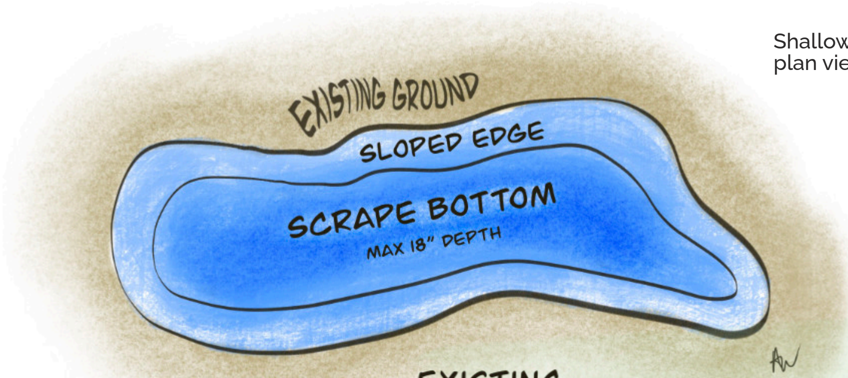
Scrape: a slight excavation in a wetland that allows for open water ponding.



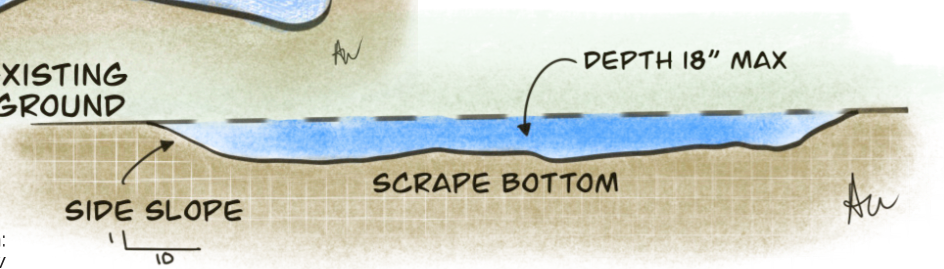
Construction of a shallow depression for wetland restoration in Bakersfield, VT-Construction in 2006, site conditions in 2011 and 2014. Ryan Creehan, USFWS

Shallow Depression/Scrape Specification

Depth	Maximum 18"
Slope	10:1 or flatter
Minimum Area	250 Square Feet



Shallow depression: plan view



Shallow depression: section view

Pre-Construction Planning

Develop Schematic Plan

Specify an average density and spacing per acre of restoration. Random variations in shape, depth, and spacing are preferred.

Locate Underground Utilities

Mark locations of underground utilities in or adjacent to the excavation area.

Spoils Removal Plan

Incorporate into other restoration elements. Spoils should not be shaped into a berm or disposed of in the restoration area, but intentionally incorporated into the restoration design. Excavated soils can be utilized to plug and/or fill ditches. The soil could also be loosely shaped into upland mounds, adding topographic diversity around the constructed depressions. Care should be taken to not obstruct floodwaters in known or potential floodplains.

Identify Staging Location

Find an upland location for temporary storage of materials and equipment parking.

Identify Access Routes

Use of existing roads and trails without improvement is allowed. Temporary use of swamp mats is also allowed if removed within one growing season, provided their use meets the US Army Corps of Engineers General Permit conditions (see chapter 5).

Select a Contractor & Equipment

Choose a contractor with previous experience working in wetlands and use low ground pressure equipment such as an excavator with wide tracks. Meet with the contractor to review project details including site access and staging location, the specifications for depression construction, and NNIS control/management procedures (see Invasive Species Control and Management). Plan work for dry field conditions.

Construction Sequencing

1. Stake and flag excavation locations: Clusters of depressions with varying size/depth/ dimension create greater habitat diversity.
2. Conduct surface stripping.
3. Clearing and grubbing of woody vegetation or other material.
4. Native materials may be harvested for use in replanting.
5. Topsoil is stripped away to expose sub-surface soils and stockpiled.
6. Excavate sub-surface soils and follow spoils removal plan.
7. Create irregular edges and undulating bottom depths.
8. Redistribute topsoil over the surface of the newly formed depression.
9. Finish grade should be semi-rough and not smooth.
10. Minimize excessive use and travel of construction equipment to avoid compaction of soils, working from interior to exterior of the restoration site.
11. Securely stabilize the restoration area through appropriate erosion control measures. Seed and mulch all disturbed soils. (see Erosion Control).

> Topsoil containing NNIS species is not suitable for this restoration practice and should be removed from site.
>
> Additional permitting may be required for the construction of new access roads or trails, for the stockpiling of soil in a wetland or wetland buffer, or for the addition of fill to a floodplain.

Challenges and Solutions

- Introduction of invasive species: If work crews are used, ask them to clean tools and boots and power-wash equipment before entering restoration site. Work with the contractor to minimize soil disturbance.

Complementary Practices:

3.11 Supplemental Practices

Depending on your project, the following practices may enhance or augment the functions and values provided by your primary restoration treatments.

Woody Additions | Erosion Control | Beaver Dam Analogs | Conservation Easement

WOODY MATERIAL ADDITION

Woody Additions

Decaying woody material is an important component of healthy ecosystems. In wetlands, logs, stumps, and smaller branches provide habitat and shelter for animals, store sediment, increase water storage and infiltration, reduce erosion, and provide a carbon source for the microbial food web.

Woody Material Specification

Source	Look for logs, stumps, and/or branches onsite in upland locations.
Size	Select a range of sizes and stages of decay.
Staging	Utilize staging and access locations identified for the primary restoration practices.
Distribution	Scatter material throughout the restoration area to provide a variety of ecosystem functions.

Woody addition in restored wetland

> Do not scavenge woody material from surrounding wetlands.
>
> Do not transport ash wood outside of the Emerald Ash Borer Infested Area in Vermont.
>
> Do not use woodchips or mulch for this supplementary practice.

EROSION CONTROL PRACTICES

Erosion Control

Sediment washing into streams is one of the largest water quality problems in Vermont. Excess sediment can kill fish and other aquatic organisms and damage aquatic habitat. Sloped sites have a higher risk of erosion than flat sites, though gullying can occur on flat sites if water flows are concentrated. Basic approaches can control erosion and prevent the discharge of sediment.

Causes of Erosion
Vegetation removal
Topsoil and organic matter removal
Changes to drainage
Failure to cover bare soil

Avoidance Measures
Avoid work in the rain
Avoid work in high flows
Avoid work in winter conditions: October 15 to April 15

Seeding and Mulch

Seeding and mulch is the best and cheapest erosion control tool for use with wetland restoration practices that involve earth disturbance and stockpiling of soils. Temporary seeding is used to quickly establish vegetation on disturbed soil to reduce erosion during construction and/or late in the growing season. For best results, seed and mulch disturbed areas as quickly as possible after completion of grading and work activities. Apply seed first. Straw (not hay, which can contain NNIS seeds) can be hand scattered or blown to a depth of 1 inch. Track mulch in as needed to prevent removal by wind. In winter, apply mulch to a depth of 3 inches. Seed and mulch soil stockpiles if storage is for more than a week or if heavy rain is predicted. Reapply mulch as needed to ensure bare soil is 80-90% covered.

> Except for temporary erosion control, use native seed mixes from Vermont or New England.

Timing and Application Rates for Typical Temporary Seeding Species

Complete all erosion control seeding by September 15 to ensure adequate growth and cover.

May 1 - Sept 15	Annual Rye at 20 lbs./acre
Sept 15 – May 1	Winter Rye at 120 lbs./acre

Mulch Timing and Application Rates

Mulch is used to stabilize soil and prevent erosion prior to vegetative growth. Mulch also holds seed in place and allows it to become established. Use weed free straw mulch to avoid the introduction of nuisance plant species to the restoration site.

April 15 - Sept 15	1-2 inches deep
Sept 15 – April 15	3 inches deep

Erosion Control Blankets

Erosion control blankets are a temporary practice used on steeper slopes (3:1 or steeper) and level drainage ditches (less than 20:1 slopes). They are designed to hold soil in place until vegetation can grow through them and they biodegrade. For wetland restoration projects, erosion control blankets must be netless and comprised of natural fiber to avoid wildlife mortality. Anchoring devices are used to secure the blankets in place during heavy rain or wind. Anchors are often made of metal, but live stakes from native plants could serve a dual purpose.

Eroson control blankets on slope above wetland restoration

Erosion Control Blanket Specification

Preparation	Seed area first.
Short Slopes	For slopes less than 8 feet, install blankets across the slope (horizontal).
Long Slopes	For slopes greater than 8 feet, install blankets up and down the hill (vertical). Unroll mats from top of the hill.
Key In	Trench matting in 8 inches at top of hills.
Anchor	Unroll mats and staple/anchor as unrolled. Use plenty of staples to keep blankets flat.
Coverage	Overlap blankets 6 to 8 inches on sides, tops, and bottoms. Staple through both blankets at areas of overlap.

Wetland Matting

Wetland matting ("swamp mats") provides temporary access for large equipment within the restoration area by giving machines traction and preventing equipment from becoming stuck. Mats are placed directly on top of existing vegetation (vegetation removal may require a permit), and then removed within one growing season. To avoid the need for permitting, use of swamp mats must meet the US Army Corps of Engineers General Permit conditions (see Chapter 5).

Wetland Matting Specification

Position	Run mats across wet areas until they reach solid ground.
	Place mats parallel to the direction of travel to distribute weight.
	No gaps should exist between mats.
Installation	Use machinery (such as track excavators) to place mats.
	More than one layer of mats may be necessary in areas that are inundated or have deep organic wetland soils.
	Use lifting bolts to install. Timber mats have two lifting bolts on each end, making it easy to lift and place them with machinery.
Removal	Matting is removed by backing out of the site while removing mats one at a time. Any rutting or significant indentations should be regraded, taking care not to compact soils.

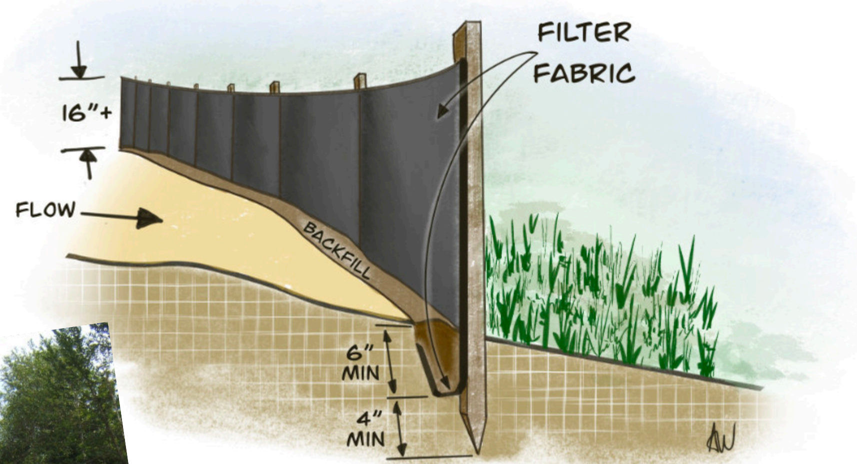
Layered wetland matting providing temporary wetland crossing

Silt Fence

Silt fencing is a type of sediment barrier recommended for use in large areas of soil disturbance (>0.5 acres) on slopes or near surface waters. The fence works by trapping sediment as water flows through it. Silt fences are made of geotextile fabric and supported by wooden stakes or metal posts.

Silt Fence Specification

Location	On sloped site, locate the fence downhill of the soil disturbance activity.
	On a site adjacent to surface waters, install the fence between the disturbed soil and the waterway.
Installation	Dig a trench 6" deep across (not up and down) the slope.
	Ensure stakes are on the downhill side of the fence.
	Join fencing by rolling the end stakes together.
	Drive stakes in against downhill side of trench.
	Push fabric into the trench, spreading it along the bottom.
	Fill trench with soil and pack down.
Maintenance	Remove accumulated sediment before it rises halfway up the fence.
	Ensure that the silt fence is trenched in the ground and that there are no gaps.
	Remove fence when restoration site is stabilized with vegetation.



Poorly installed silt fence-note lack of keying into soil at base

Silt fence failure

BEAVER DAM ANALOGS & POST-ASSISTED LOG STRUCTURES

Beaver Dam Analogs

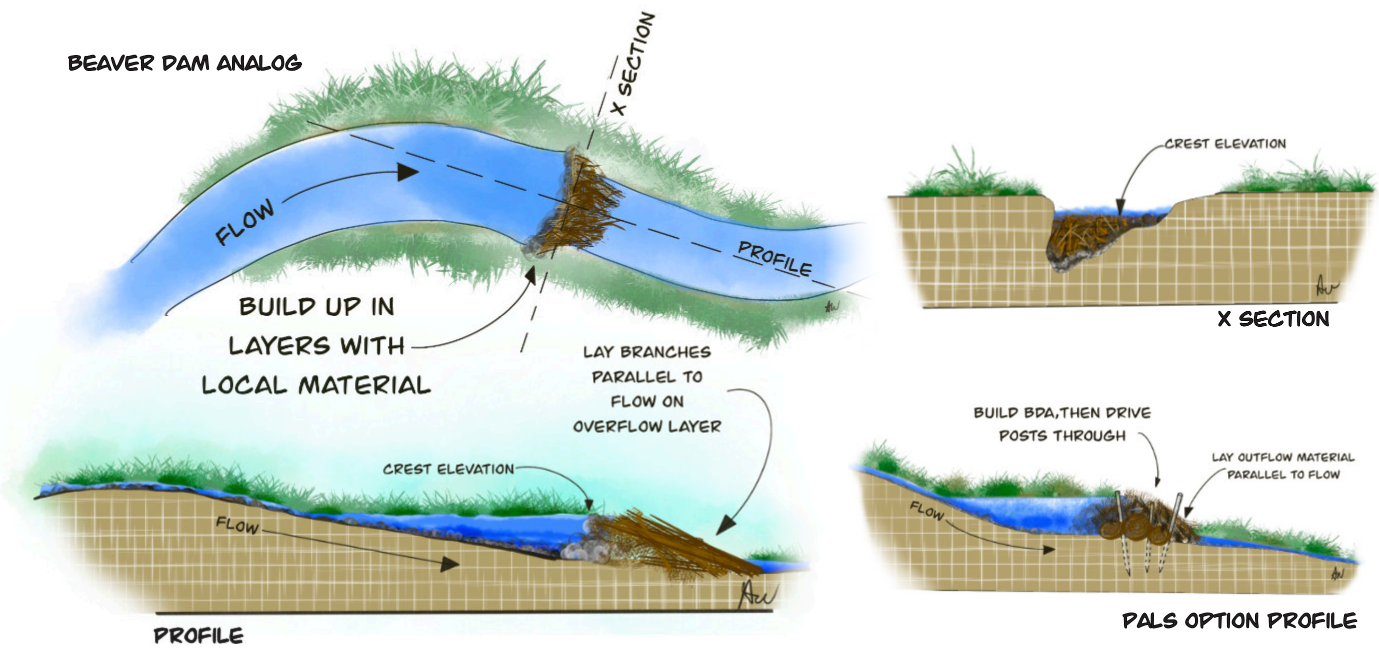
Beaver dam analogs (BDAs) and post-assisted log structures (PALS) are stream restoration practices that may complement a wetland restoration project that involves degraded streams lacking woody structure. These practices promote a self-sustaining riverscape with appropriate obstructions to flow, which create diverse habitats and reduce erosion. BDAs and PALS are non-engineered and hand-built with natural materials.

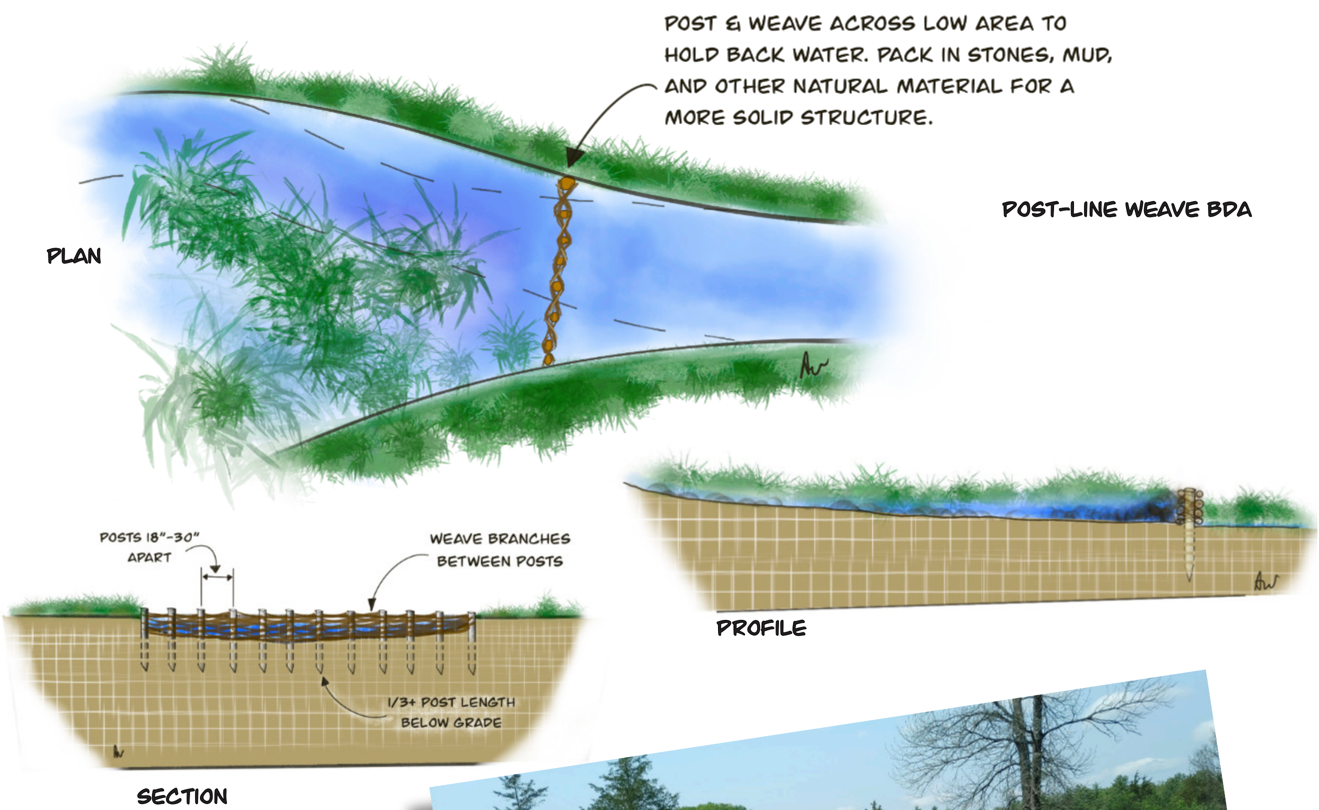
BDA: A permeable, channel-spanning structure with a constant crest elevation, constructed with a mixture of woody debris and fill materials to form a pond and mimic a natural beaver dam.

PALS: Woody material of various sizes pinned together with untreated wooden posts driven into the substrate to mimic natural wood accumulations. Can be channel spanning, bank-attached, mid-channel, or on the floodplain.

Specification

Source	Collect locally sourced materials to construct BDAs. Non-treated natural wood commercial posts may be used in PALS.
Material	Use mud, stones, and a range of sizes and species of wood. Living stems, branches, and trunks from native willows can be used, which may root and form a living structure. Average diameter for weaving branches is 2”.
Layering	Build up in 6” to 12” lifts, make sure each layer is holding back water and ponding. Start with wide base to support the desired height.
Overflow Mattress	Branches woven parallel to flow at downstream end of structure. Combination of branches, brush and cobble.
Posts	Optional. For higher flow conditions. Untreated wood, or robust native live stakes. Min 2” diameter for post and weave, 6” diameter for PALS. 18-30” gap between posts. Drive post through entire structure, with at least 1/3 the length of post into the underlying streambed.





Post weave BDA, Shayne Jaquith, The Nature Conservancy

Challenges and Solutions

- Can be too robust: BDAs and PALS that are too robust may be barriers to fish, hold back too much water, and flood neighboring properties. Build them only high enough to flood areas where inundation is appropriate. If fish passage is an issue, design strategic gaps in the structure.

- Can be too fragile: BDAs and PALS are temporary structures that will break down over time, and this should be planned for. Loose wood can block downstream culverts and flood roads if the structures are built too near upstream, and maintenance will be required if the structures break down before a self-sustaining riverscape becomes established. Thoughtful planning and regular monitoring can mitigate these challenges.

> Installation of BDAs and PALS likely triggers other State and Federal approval or permitting. Consultation with ACOE and State River Engineer is encouraged early in the design process, and further design support from a consultant may be necessary. See State of Vermont Policies for more information on requirements (Vermont Rivers Program Policy on Wood and Structure Addition as a Restoration Strategy. 12/16/21).

CONSERVATION EASEMENTS

Conservation Easement

The restoration practices described in this guide are intended to enhance the functions and values of degraded wetlands across the landscape. These efforts are worthwhile because they help reduce flood damage, increase water quality, improve wildlife habitat, and more. Conservation easements are a unique practice in that they don't directly enhance wetland function, but instead ensure that restoration efforts aren't reversed as land ownership changes hands.

Conservation easements permanently protect a wetland restoration area through a legal agreement between the landowner and a land trust or government agency. Easements indicate the location and acreage of a Wetland Protection Zone (WPZ) and establish what uses and management activities are supported there. Management activities typically supported within a WPZ include the control of NNIS, management of beaver dams to the extent necessary to prevent or mitigate flooding outside the restoration area, and revegetation planting.

Resources

There are many organizations and agencies in Vermont that support conservation easements and deed restrictions. Examples include:

- Department of Environmental Conservation, Vermont Agency of Natural Resources
- Natural Resources Conservation Service, U.S. Department of Agriculture
- The Vermont chapter of The Nature Conservancy
- Vermont Land Trust
- Other local land trusts