United States
Department of
Agriculture

MARYLAND WETLAND DESIGN GUIDE

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Natural Resources Conservation Service (NRCS) – Maryland

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Introduction

The purpose of this guide is to provide program-neutral design guidance and requirements for NRCS-assisted wetland restorations and creations in Maryland. It focuses on the following topics:

- Requirements to restore or create the fundamental conditions to support wetland functions, i.e., hydrology, vegetation, and organic matter;
- Treatments that are used to provide wetland hydrology and vegetation, and restore hydric soils;
- Utilizing hydrogeomorphic classification to determine targets for wetland hydrology;
- Simplified methods for evaluating wetland hydrology degradation.

This guide does **not** provide:

- Specific requirements for individual wildlife species or groups of wildlife;
- Guidance on design of impoundments that are not wetlands (e.g., shallow water areas);
- Design guidance for wetlands that are installed primarily to treat significant point and nonpoint sources of pollution. These wetlands are referred to as Constructed Wetlands (656) or treatment wetlands;
- Any program specific requirements, which may be more specific than requirements in this guide;
- Methods of wetland delineation;
- Regulatory requirements for wetlands.

Refer to the *Maryland Wildlife Habitat Planning Guide* for information on wetland wildlife requirements and development of shallow water area impoundments. Refer to the *Maryland Water and Wetlands Regulatory Guidance for Permits, Authorizations and Exemptions for Agricultural Activities*. Both documents are located in the Maryland FOTG.

Definitions

Wetland Restoration. Wetland restoration is the rehabilitation of a degraded wetland or the reestablishment of a wetland so that soils, hydrology, vegetative community, and habitat are a close approximation, to the extent feasible, of the original natural condition that existed prior to modification. A wetland restoration may be more specifically categorized as wetland reestablishment when the site no longer supports wetland hydrology or vegetation. Wetland rehabilitation typically refers to sites where wetland hydrology and vegetation still exist but have been significantly degraded or altered.

Table 1. Typical examples of significant degradation or removal of hydric soils, hydrology, or vegetation.

Degradation	Typical Restoration Subcategory
Surface or tile drainage that allows for crop production in a prior converted wetland.	Reestablishment
Surface drainage that changes the hydroperiod from seasonal to temporary saturation or inundation. This includes previously isolated, closed depressions that have been connected to surface waters.	Rehabilitation
Removal of natural vegetation, including stumps, and smoothing of the land surface to allow planting of annual crops or introduced forages. This includes areas identified as farmed wetlands or farmed wetland pastures.	Reestablishment
Filling in depressions and low areas to increase the depth to groundwater, resulting in the burying of hydric soils.	Reestablishment
Stream channelization and spoil placement that results in a disconnection between the stream and the floodplain.	Rehabilitation
Development of preferential flow paths in a seepage wetland that result in reduced area and duration of surface saturation.	Rehabilitation

Wetland Creation. Wetland creation is the creation of a wetland on a site which historically was not a wetland. In general, this is any site that occurs on upland soils.

Wetland Enhancement. Wetland enhancement is the augmentation of wetland functions beyond the original natural conditions on a degraded or naturally functioning wetland site, sometimes at the expense of other functions. This is not a common NRCS practice, except for the treatment of invasive species (e.g., phragmites) in natural wetlands. Wetland enhancement may also be used to create macrotopography in former or degraded wetlands.

Note: The above are NRCS definitions. Other organizations may use different terminology or define these terms differently.

Hydrology Requirements

This section provides general guidelines for the hydrology and design of wetlands, and can be useful for assessing the feasibility of a project. Designs can be further refined by using the Hydrogeomorphic Class information in the next section of this guide to plan the depth and extent of surface water on a site.

The planning of hydrology and vegetation for wetland restoration and creation in agricultural lands is more flexible than for wetland restoration in forested lands and lands with natural vegetation. Wetland restoration in forested lands and lands with natural vegetation should be designed to have hydrology and vegetation that approximates the natural and historic wetland conditions to the extent practical. Wetland restoration and creation in agricultural fields may be designed with different hydrology and/or vegetation than may have originally occurred on the site.

Wetland Restoration. On at least 70 percent of the wetland area, wetland hydrology (including natural micro- and macrotopography) should be restored as nearly as feasible to the conditions that originally existed on the site. Microtopography is the fine scale variation in the soil surface that is the result of biological and localized physical processes such as animal burrowing, accumulation of organic matter, and trampling. Macrotopography results from larger scale impacts and processes, such as tree throws, beaver dams, and storm driven changes in channel alignment. The minimum hydrologic conditions of the restored wetland must have sufficient depth, duration, and frequency of surface and/or ground water to support a prevalence of hydrophytic vegetation.

Up to 30 percent of the wetland area may be restored and maintained as shallow open water and/or have wetland hydrology different from that which originally occurred. The purpose of this modification shall be to support a diverse plant and animal community.

Wetland Creation. Wetland hydrology (including natural micro- and macrotopography) should be provided on at least 70 percent of the wetland area. The minimum hydrologic conditions of the restored wetland must have sufficient depth, duration, and frequency of surface and/or ground water to support a prevalence of hydrophytic vegetation.

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Hydrogeomorphic Class

An overall average depth is typically used as a controlling factor in the design water level of a wetland. Water levels in natural wetlands in Maryland typically range from soil saturation to inundation of 1 foot. Some naturally occurring nontidal wetland depressions and macrotopographic features may have water as deep as 3 feet during the wetter portions of the year. The overall water level in natural wetlands is typically determined by hydrogeomorphic setting, which provides natural controls on wetland hydroperiod -- the extent and duration of hydrology. Hydrogeomorphic (HGM) classification should be used as a starting point in the design of wetland restorations and creations. Table 2 lists the common nontidal wetland HGM classes that occur in Maryland.

Table 2. Condensed nontidal wetland hydrogeomorphic (HGM) classification[1]

HGM Class	NWI Classes	Description	Hydroperiod and Water Depth	Examples
Riverine (RV) – Headwater	PFO PSS PEM	Spring-seep wetlands at headwater of, or adjacent to, surface drainage.	Seasonal saturation to permanent saturation, or shallow (≤ 3 inch) flow over surface.	Forested wetlands and fens along 1st, 2nd and 3rd order streams in the Piedmont.
Riverine (RV) – Floodplain	PFO PSS PEM	Adjacent to streams, hydrology supported by combination of groundwater discharge and overbank flow from channel; usually greater than 3rd order streams.	Range of hydroperiods with intermittent flooding and inundation; majority of area saturated or inundated to 6 inches or less during the wet season; flooding following storm events may result in much greater inundation over short periods; backwaters and small depressions may be permanently inundated to a depth of 3 feet.	Riparian forests; bottomland hardwood swamps; may contain backwaters, especially on larger streams and rivers.
Depression (DP)	PFO PSS PEM	Topographic lows within the landscape with precipitation-fed and/or groundwater dominant hydrology, often isolated, but may have surface connections to other waters.	Temporary to semi-permanently flooded; inundation of up to 3 feet at wet season peak, with average depth of 12 inches.	Vernal pools; Delmarva Bays; old farm ponds with sediment accumu-lation; waterfowl impoundments in ag fields.
Estuarine Tidal Fringe (EF)	PSS PEM	Adjacent to bays and the brackish zones of tidal rivers and streams. Highly driven by tidal flooding; Mixture of salt and fresh water; salinities range from 0 to >30 ppt.	May be regularly flooded by semidiurnal tides (low marsh) or irregularly flooded by spring and storm tides (high marsh).	Low marsh consisting predominantly of Spartina alterniflora; high marsh consisting of *Spartina patens, Juncus roemerianus, Iva frutescens*, and *Baccharis halimifolia*.
Flat (FL)	PFO PSS PEM	Flats normally occurring within interstream divides; precipitation and/or groundwater hydrology with vertical fluctuation.	Seasonal saturation and temporarily to seasonally flooded to 6 inches or less; tree throw pits and skid trails may be inundated up to depths of 2 feet.	Pine, hardwood, and mixed pine-hardwood flats; common on the lower Eastern Shore.
Slope (SL)	PFO PSS PEM	Groundwater discharge along or at toe of slope; often isolated.	Seasonal saturation to permanent saturation, or shallow inundation averaging 6 inches or less.	Spring-seeps and forested fens.

[1] Adapted with modifications from Brooks, RP, MM Brinson, KJ Havens, CS Hershner, RD Rheinhardt, DH Wardrop, DF Whigham, AD Jacobs and JM Rubbo, 2001, *Proposed Hydrogeomorphic Classification for Wetlands of the Mid-Atlantic Region, USA*, Wetlands 31:207-219, AND Haering, KC, JM Galbraith and D Clearwater, *Literature review for development of Maryland wetland monitoring strategy: Background information on Maryland's wetland types*, Report prepared for MDE Wetlands and Waterways Programs, USEPA Grant BG 973027-03, Sep 2009, 52 pp.

Most wetland restoration projects in agricultural lands in Maryland fall in the HGM classes of depressions or flats, and many are a combination of the two. Riverine headwater and floodplain wetlands have also been the focus of some restoration efforts. In most cases, allowing the natural HGM setting to drive the design of a wetland project will minimize restoration cost, provide habitats that will be used by local wildlife, and offer the best chances of success. Table 3 provides design criteria targets for water depth and vegetation based on HGM class.

Table 3. Design criteria based upon condensed nontidal wetland hydrogeomorphic (HGM) classification.

HGM Class	Design Criteria
Riverine (RV) – Headwater	At least 90% of the wetland should be able to support woody or emergent wetland vegetation. Water should be allowed free-flow over surface. Depth of water usually not to exceed 3 inches.
Riverine (RV) – Floodplain – Lower Order	At least 80% of the wetland should be able to support woody or emergent wetland vegetation. Hydrologic connection between stream channel and floodplain should be maintained or restored to support floodplain functions. Depth of water on 80% of the site usually not to exceed 6 inches except after large storm events; remaining area may have water depths up to 3 feet to represent backwaters, vernal pools, and tree throws.
Depression (DP)	At least 70% of the wetland should be able to support emergent wetland vegetation. Average depth of water 12 inches on 70% of the site; remaining area may have depths up to 3 feet.
Estuarine Tidal Fringe (EF)	Diurnal or irregularly flooded by tides, typically occurring within 2 feet of sea level. Depth of water varies with tides.
Flat (FL)	At least 90% of the wetland should be able to support woody or emergent wetland vegetation. Depth of water on 90% of the site usually not to exceed 6 inches; remaining area may have water depths up to 2 feet in tree throws and skid trails.
Slope (SL)	At least 90% of the wetland should be able to support woody or emergent wetland vegetation. Depth of water on 90% of the site averaging 6 inches or less.

The water depths described in Tables 2 and 3 are the averages over large areas. Within these areas, however, most wetlands have topographical variations (i.e., microtopography and macrotopography) that promote vegetative diversity and provide varying wetland hydroperiods. Incorporation of micro- and macrotopography into a wetland project creates a matrix of varying water depths and durations, and often best approximates natural hydrology.

On sites where a high level of water level and vegetation management is planned, the topographical variation of a natural wetland may be less desirable. Instead, the variation in water depths should occur as a gradual change in depth over large areas. This type of design is typically implemented in areas where moist soil management techniques will be used.

Wildlife Considerations

The most common purpose for wetland restoration and creation is to provide habitat for wetland dependent wildlife. The hydroperiod of a wetland as well as the structural measures utilized have a large effect on the type of wildlife that will use the wetland as well as the quality of the habitat itself. Some wildlife species may prefer deeper water while others may prefer shallow water. For example, dabbling ducks – those that feed by extending their heads underwater – prefer water depths of 3 to 8 inches, while diving ducks require deeper water of 1 foot or more. Other wildlife species have variable water depth requirements depending on their lifecycle stage. Some salamanders require permanent pools of water 1 to 3 feet deep because they spend over a year developing from the aquatic stage to terrestrial stage. Some toads, however, require only shallow pools that retain water for 3 months or so. Bog turtles inhabit spring-fed wetlands that have perennial flow and soil saturation. Many species require a diversity of water depths and habitats that will be used for different life stages and to provide a variety of food resources and resting and nesting areas.

Hydroperiod plays a large role on vegetation in wetlands, and vegetative composition and complexity affects the type and quality of habitat. Wetlands with only saturated soils and shallow inundation of a few inches or less will typically support the growth of trees. Deeper water depths of 8 to 18 inches will restrict most woody growth and promote growth of emergent herbaceous plants. Depths greater than 18 inches will tend to limit growth of most plants. The duration and year-to-year variability of inundation of wetlands also affects vegetation establishment. Wetlands that remain inundated through the growing season, even at shallow levels, will tend to be dominated by herbaceous plants and shrubs. Wetlands that are inundated sufficiently to restrict the growth of woody vegetation may become colonized by wetland trees during multi-year drought cycles. Wetlands that have variable macrotopography and microtopography with water depths at the beginning of the growing season ranging from soil saturation to 18 inches will tend to have more vegetative diversity.

For more information on the water depths and hydroperiods required for various wetland wildlife and plant species, refer to the Maryland NRCS *Wildlife Habitat Planning Guide*, Section 7, Wetlands and Shallow Water Areas.

Figures 1a and 1b. A variety of water depths ranging from soil saturation to 2 feet provide greater habitat diversity to support a range of wetland-dependent wildlife. Shallow pools provide excellent breeding areas for amphibians, and offer foraging habitat for dabbling ducks (left). Microtopography can result in diverse wetland habitat in forested wetlands, allowing for both a forested canopy and an herbaceous understory (right).

Water Quality Considerations

Wetlands are known for their ability to remove nutrients and sediments from surface waters. The location of a wetland within a drainage basin affects the potential for the wetland to provide water quality benefits. Headwater and riparian wetlands have some of the greatest potential for water quality benefits because they often are downstream of potential pollutant sources. Prior converted headwater wetlands are commonly restored in agricultural fields, where they have great potential to provide water quality benefits.

Vegetation is an important factor affecting the ability of wetlands to reduce pollutants in surface water. The vegetation in wetlands provides resistance to water flow, resulting in lower flow velocities. Lower velocities cause more sediments to drop out of suspension, allowing them to be trapped in the wetland. Lower velocities also result in greater retention times – the amount of time water remains in the wetland – which provides more time for nutrient assimilation and removal through denitrification. Vegetation also provides a source of carbon that is used for biogeochemical processes (e.g., denitrification), and provides attachment sites for the microorganisms involved in those and other important processes.

Another factor in retention time is the capacity of the outflow pathway. More constricted pathways will have lower flow capacities, resulting in higher retention times for a given flow event. Larger outflow paths will have greater capacities, allowing water to leave the wetland at a faster rate. In restored and created wetlands, the outflow path can be designed to be more restrictive so that retention time is maximized.

However, structural integrity of the constructed outflow (i.e., spillway) is another important consideration. The NRCS standards for low hazard structures typically require structures to be designed to carry the 10-year 24-hour storm event. A design for this size event results in a relatively large spillway that will only function at capacity on an infrequent basis. The more common, smaller events will flow out of the wetland at a much faster rate than desirable if the objective is water quality. One way to address this is to design the wetland with staged outflow structures, with smaller flow capacity at lower storm stages and large capacity at higher stages. A simple technique is to use a water control structure as the primary spillway and an earthen spillway as the secondary (or emergency) spillway. Alternatively, a single rock-lined spillway can be staged by constructing a small notch in one portion of it. The small, narrow notch releases water at a much lower flow rate than the larger spillway structure.

Wetland restorations and creations that receive runoff from agricultural areas and other areas with the potential for polluted runoff should be designed to maximize retention time and provide vegetation for filtering and a carbon source.

Marsh Migration Considerations

The projections for sea-level rise in Maryland for the 21st century (1.4 ft by 2050 and 3.7 ft by 2100)[2] present significant implications for salt and brackish marsh habitats and the species that rely upon them. Areas in Maryland of particular concern are the tidal marshes in Dorchester, Somerset, and Wicomico Counties, where a significant proportion of the salt and brackish tidal marshes are located. Even if all tidal marsh was allowed to migrate inland as sea level rises, losses of salt and brackish marsh, and of brackish marsh in particular, will be significant (see Table 4).

Brackish marsh and transitional salt marsh provide the most important marsh habitats for wildlife species of concern such as black rail, American black duck, and salt marsh sparrow. Brackish marshes were put at risk in the past due to salt marsh ditching (i.e., “mosquito ditches”), which allows deeper penetration of salt water into the marsh and faster removal of freshwater from inland. In the coming years, transitional and brackish marshes may not necessarily migrate inland as projected due to the “ghost forest” phenomenon where the understory in forests adjacent to marsh becomes dominated by phragmites, making it nearly impossible for brackish marsh vegetation to colonize these areas after the trees die.

As a result of the threats to brackish marsh and the wildlife that rely upon it, projects that occur adjacent to tidal marsh should consider the effects of design on marsh migration. Freshwater impoundments adjacent to tidal marsh can significantly impede marsh migration. The berm side slopes create a narrow marsh transition zone, and the impounded freshwater area can prevent brackish and salt marsh plants from moving further inland. Shallow excavation on its own can also result in barriers to marsh migration, because most salt and brackish marsh vegetation will not colonize areas that are seasonally inundated to depths greater than 6 inches.

This is not to say that freshwater impoundments and shallow excavation adjacent to tidal marsh are not valuable for wildlife. Areas of freshwater that support emergent and aquatic vegetation are extremely valuable for shorebirds, wading birds, and waterfowl, including the American black duck. Recent information also suggests that birds like the black rail and salt marsh sparrow may partially rely on artificial topographic features for nesting and escape cover during high tide events. Black rails may also benefit from active management of emergent freshwater wetlands adjacent to tidal marsh.

Measures to Provide for Marsh Migration in the Near Marsh Zone. The near marsh zone is defined as an area adjacent to tidal marsh and within 4 feet of mean sea level. Where impoundments or shallow

[2] Boesch, DF, LP Atkinson, WC Boicourt, JD Boon, DR Cahoon, RA Dalrymple, T Ezer, BP Horton, ZP Johnson, RE Kopp, M Li, RH Moss, A Parris, CK Sommerfield. 2013. Updating Maryland’s Sea-level Rise Projections. Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission, 22 pp. Unversity of Maryland Center for Environmental Science, Cambridge, MD.

excavations are proposed within the near marsh zone, develop the plan to allow for marsh migration over the next 30 to 50 years by using the following measures, as applicable:

- Limit embankment heights to 1.5 feet. Very small segments may exceed 1.5 feet in draws or where crossing ditches;
- When embankments need to be taller than 1.5 feet, exclude at least 30 percent of the project area within the near marsh zone from the impoundment area. This area shall be contiguous from the lowest elevation within the project area;
- When excavating to provide deeper water, limit the area of excavation to 30 percent of the pool area;
- Use side slopes of 10:1 on both sides of all embankments within the near marsh zone. This will also deter muskrat tunneling.

Table 4. Projected change in the amount of salt and brackish marsh due to sea level rise for Dorchester, Somerset, and Wicomico Counties, Maryland, based on internal analysis of the Sea Level Affecting Marsh Migration (SLAMM) model for Maryland (2011 model run).[3] Change values are relative to the "Initial" acreage value. Values in parentheses are negative and represent loss.

	Time Period	Transitional Salt Marsh (acres)	Regularly Flooded Marsh (acres)	Irregularly Flooded Marsh – Brackish (acres)	Total of 3 Marsh Types (acres)
Dorchester	Initial Area	12,183	286	72,744	85,213
	2050 Area	21,999	50,719	30,176	102,894
	2100 Area	19,287	30,459	2,758	52,504
	2050 Change	9,815	50,432	(42,568)	17,679
	2100 Change	7,104	30,173	(69,986)	(32,709)
Somerset	Initial Area	2,193	6,251	46,809	55,253
	2050 Area	11,537	20,603	26,399	58,539
	2100 Area	9,360	14,437	2,268	26,065
	2050 Change	9,343	14,352	(20,409)	3,286
	2100 Change	7,167	8,186	(44,540)	(29,187)
Wicomico	Initial Area	955	186	11,988	13,129
	2050 Area	1,645	6,394	6,012	14,051
	2100 Area	554	2,343	417	3,314
	2050 Change	690	6,208	(5,976)	922
	2100 Change	(401)	2,157	(11,571)	(9,815)
Totals for 3 Counties	Initial Area	15,331	6,724	131,540	153,595
	2050 Area	35,180	77,716	62,587	175,483
	2100 Area	29,201	47,239	5,443	81,883
	2050 Change	19,849	70,992	(68,954)	21,887
	2100 Change	13,870	40,515	(126,097)	(71,712)

[3] Maryland Dept. of Natural Resources, 2011. *SLAMM – SLR Vulnerable Wetlands, Ver 1*. Available online at: https://data.imap.maryland.gov.

Evaluating Hydrology Degradation

It is important to determine the types of hydrology degradations that are present on a site, and how they impact the degraded wetland or prior converted wetland. Where drainage has been installed, wetlands may be partially drained to the extent that they still function as wetlands, but the duration and depth of flooding or ponding has been modified. More significant drainage may be sufficient to completely remove wetland hydrology.

Common types of drainage modifications include surface drainage ditches, drain tile, surface inlets, stream channelization, land grading and filling. Drainage ditches are probably the most common form of drainage in Maryland, followed by drain tile and stream channelization. The effects that these modifications have on wetland hydrology varies by technique and soil type.

Drainage ditch systems usually function in one of two ways, dependent on soil types. On sandy soils, drainage ditches function to lower the groundwater table by shortening the subsurface flow path between the soil surface and the nearest open channel. On "heavy" or clayey soils capable of perching water, drainage ditches provide outlets for removal of surface water. Although drainage ditches in heavy soils may also function to shorten subsurface flow paths, their functioning is highly dependent on surface topography. On heavy soils, if there is no surface flow path from a topographically low area to a drainage ditch, surface water in the low area will remain mostly unaffected by the drainage. On the other hand, if a similarly low area occurs on sandy soils, it could still be affected by a drainage ditch that is <u>not</u> connected to it via a surface flow path.

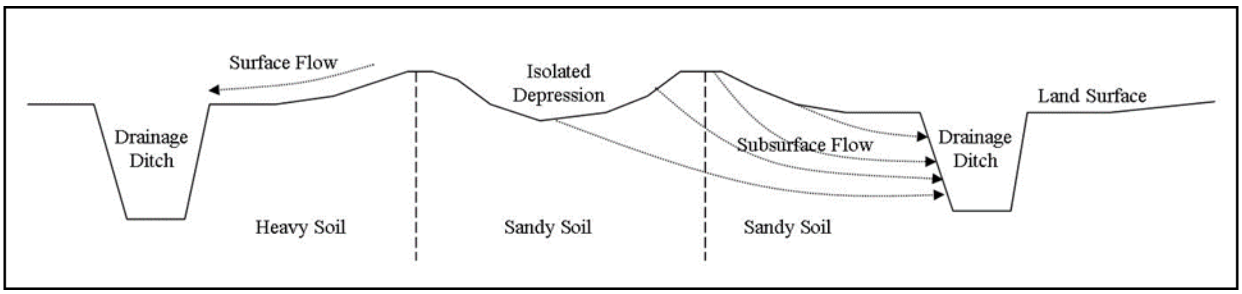

Figure 2. Primary hydrologic flow paths for heavy versus sandy soils.

In sandy soils, drainage ditches can drain areas that are not connected by surface flow paths. The extent of drainage effects in sandy soils is dependent on many variables, such as soil hydraulic conductivity and drainable porosity. However, a single, typical field ditch rarely has a significant groundwater drawdown effect beyond a distance of 200 feet.

Subsurface drain tile works more effectively in sandy soils, because excess water must flow through the soil matrix to reach the tile. However, even in loamy soils, drain tile can be effective when the soils become saturated, if sufficient time is provided for water to move through the soil. Drain tile is often installed in a grid pattern throughout a field to provide a more significant drawdown of the groundwater table, and to reduce the time required for water removal following storm events.

For sites with heavy soils, scope and effect determinations of drainage can be made by utilizing surface topography, HGM class, and soil water features information (e.g., depth of ponding). For sites with sandy soils, knowledge of drainage practices, drainage equations, and soil water features may be used to determine the overall effect of drainage on wetland hydrology. *Hydrology Tools for Wetland Determination and Analysis* (National Engineering Manual, Part 650 – Engineering Field Handbook, Chapter 19) provides tools for scope and effect evaluations of drainage. These tools are especially useful for sites with drainage in sandy soils.

Stream channelization can affect wetland hydrology in multiple ways. Channelization usually involves straightening and deepening of the channel. Straighter channels carry flow at faster rates, and deeper channels provide greater flow capacities. Higher flow rates in main channels can increase the effectiveness of small surface drains by decreasing the amounts of tailwater (downstream water) and providing lower outlets. Deepened channels may also function like surface drains to remove groundwater from adjacent areas. Straightened streams may cut through areas that previously were isolated from surface outlets. One of the larger impacts of stream channelization on larger order streams is the disconnection of the stream from its floodplain. Channelized streams with greater flow capacity and deepened channels will require larger storm events to attain out-of-bank flow. In addition, spoil from the dredging of the channel is often piled along or near the bank, resulting in an artificial levee that prevents overbank flow.

Once the causes of hydrology degradation have been determined, appropriate structural measures can be identified to restore the hydrology. However, when determining the extent to which the hydrology can be restored, consider the following:

- The area and extent to which wetland hydrology will be rehabilitated, and whether it will be completely or partially restored;
- Which drainages can be plugged. Some drainage ditches may not be able to be plugged because doing so would affect areas outside the project boundary;
- Whether a drainage can only be partially blocked, and the type of structure that may be used to accomplish this;
- Whether or not drainages are part of a public drainage association (PDA) network. The installation of structures in the right-of-way or channel of a PDA drainage system require review by the PDA managers;
- Effects, if any, to existing wetlands, and the limitations they present;
- The regulatory requirements for implementing the planned restoration.

Structural Measures to Restore Hydrology

A variety of structural measures, including but not limited to embankments, surface drain plugs, subsurface drain plugs, removal of fill material, and shallow excavation below the natural ground surface, may be used as needed to restore or provide hydrology. The Maryland conservation practice standards for Dike (356), Structure for Water Control (587), and other structural practices may be applicable.

Erosion and Sediment Control. Construction operations shall be carried out in such a manner that erosion will be controlled and water and air pollution minimized both on-site and off-site. State and local laws concerning pollution abatement shall be followed. Construction plans shall detail erosion and sediment control measures to be employed during the construction process.

Site Preparation. Areas designated for borrow areas, embankment, and structural works shall be cleared, grubbed and stripped of topsoil. Remove all trees, vegetation, roots and other debris from embankment fill.

Dispose of cleared and grubbed material outside the limits of the wetland. When specified, stockpile a sufficient quantity of topsoil in a suitable location for use on the embankment and other designated areas. When specified, selected woody debris may also be stockpiled for use within the wetland.

Removal of Fill Material. Where a wetland has been filled by sediment, land shaping, or other activities, hydric soils may be exposed by removing the fill material from the site. Fill material shall be removed to the top of the buried hydric soil, placed on an upland site, and stabilized so that no erosion of the material occurs.

Shallow Excavation. A wetland may be created by excavating below the existing ground surface to create a shallow basin that will hold surface water or intercept groundwater. The basin shall permit storage of water at a depth, frequency, and duration to support the desired plant community and provide other wetland functions.

When planning excavation to create shallow basins that will hold surface water, take soil borings to identify the presence, depth, thickness, and texture of the proposed confining layer. The confining layer shall be a minimum thickness of 12 inches to prevent seepage. A confining layer of not less than an 8-inch thickness may be used if local experience and site conditions indicate it will be sufficient.

When planning shallow excavation to intercept groundwater, take soil borings and use hydric indicators to locate the seasonal high water table. The design grade should be set no higher than 6 inches above the seasonal high water table elevation to provide wetland hydrology and promote growth of wetland vegetation. Deeper excavation will increase depth, duration, and frequency of hydric conditions and standing water.

When using shallow excavation in combination with other techniques like embankments, consider the potential for the excavated area to function as a drain or sump. If the planned hydrology is a perched water table, excavation to a depth below the heavy soil layer can create a drain that functions to remove surface water. Even where the heavy soil layer is thick, deeper holes within an area with a perched water table can reduce the hydroperiod of adjacent areas because they will collect surface runoff that would otherwise be spread over a larger area. Small berms up to 1 foot in height may be constructed around the excavated hole to prevent the drainage of surface water from the surrounding wetland area.

Shallow excavations may also be used along ditches and channelized streams to restore wetlands where drainage cannot be plugged. Instead of plugging the drainage with a surface drain plug, the adjacent land can be excavated down to an elevation that will induce wetland hydrology, typically within 6-12 inches of the channel bottom. The excavated area should be able to support wetland vegetation so it can provide both habitat and water quality benefits, and function like a floodplain during storm events. This type of shallow excavation can also be used in drainages where spillways are used to raise the surface water profile.

Side slopes on shallow excavations should be tapered back to 4:1 or flatter. Steeper side slopes may have trouble establishing vegetation, and can make it more difficult and less inviting for use by amphibians. Steep side slopes can also be a hazard for humans and wildlife when the surface adjacent to the excavated hole is covered with water, making it difficult to discern the steeper slope. Shallow side slopes promote greater vegetative diversity, and greater use by amphibians has been shown to reduce mosquito populations.

Figures 3a and 3b. Shallow excavation adjacent to a channelized stream creates a wetland that supports emergent vegetation and provides water quality benefits without impeding drainage.

Surface Drain Plugs (Ditch Plugs). In areas where open ditches were constructed to provide drainage, wetland hydrology may be restored by filling a surface drain. Refer to the criteria for *Embankments* when fill will be placed perpendicular to or across the ditch.

Surface drain plugs are best used where surface drains cut through higher ground within the drainage basin, so that the primary flow pathway is not directly adjacent to the drain plug. When plugs are installed in the only potential flow path, they are likely to become unstable even with very shallow, low velocity seasonal flows. If the surface drain provides the only possible flow pathway, then consider using a weir spillway instead of a plug, and set the control elevation at 0.5 feet below the top of bank. This will provide a stable outlet for the flow while keeping the soil saturated near the surface. Figure 3 shows a wetland restoration plan that utilizes a combination of structural measures to restore wetland hydrology and natural flow paths.

Another technique for protecting a surface drain plug is to divert the flow around the plug by constructing a separate flow path. The shallowly excavated flow path is usually more stable than the fill placed in the ditch. Stabilize the ditch bank where the flow path returns to the ditch downstream of the ditch plug. Stabilization may be accomplished with geotextile, riprap, or logs and rootwads. Refer to the Maryland conservation practice standards for Streambank and Shoreline Protection (580) or Lined Waterway or Outlet (468), as applicable.

Before filling the ditch, remove all organic material in the ditch bottom to expose mineral soil. All fill shall be relatively impermeable and be compacted to achieve the density of adjacent materials. Crown the fill a minimum of one foot above the top of the lower existing channel bank to account for settling. The fill shall overlap the existing banks by a minimum of 2 feet to provide a minimum 2:1 side slope.

The minimum length of surface drain plugs shall be (6H + 4) feet, but not less than 20 feet. "Minimum length" refers to the length as measured along the top of the plug. "H" is measured from the settled top of the plug to the low point along the centerline of the surface drain.

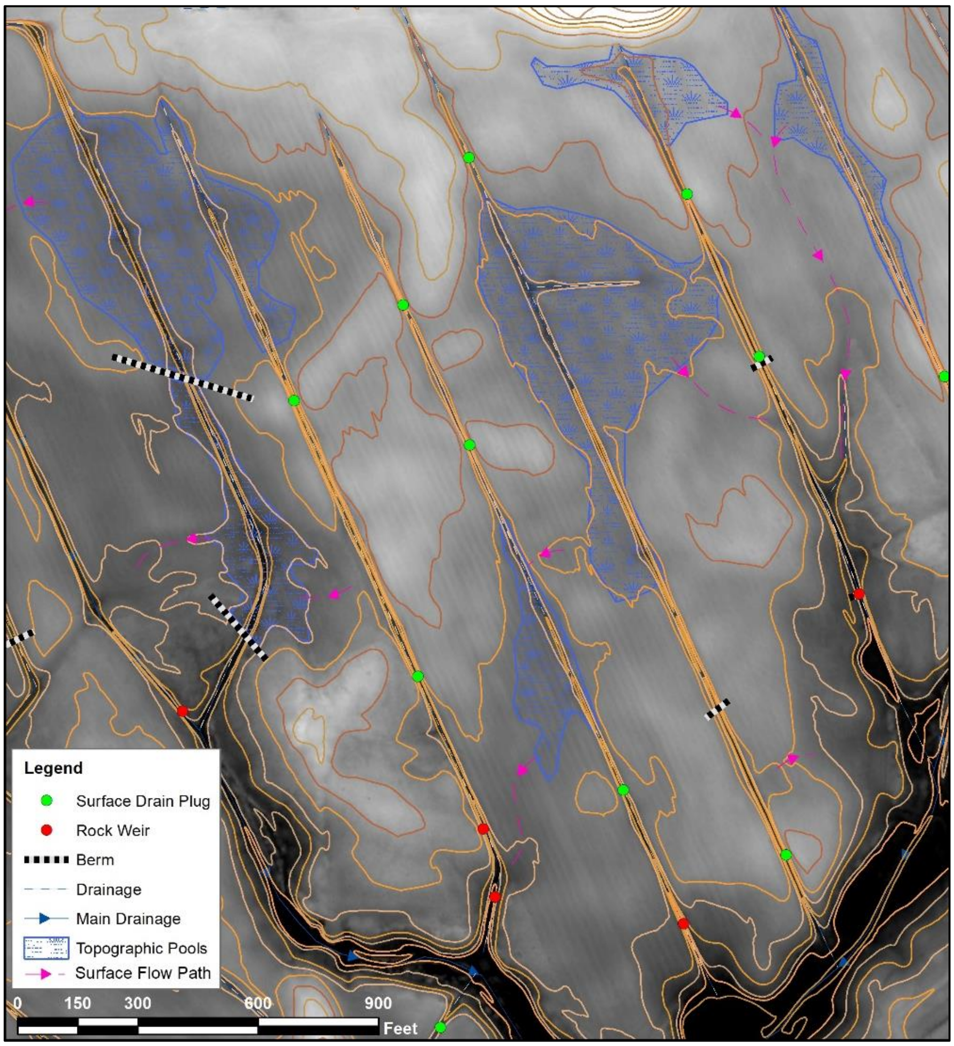

Figure 4. Wetland restoration plan that uses a combination of surface drain plugs (ditch plugs), water control structures (rock weirs), and berms to restore natural hydrology in a ditched crop field. Shown on lidar-based digital elevation model (DEM) with higher ground in lighter shades and lower ground in darker shades. The surface drains cut through ridges surrounding depressions, short-circuiting natural drainage patterns. Ditch plugs were planned at locations that reconnect ridges on either side of the ditch. Berms were used in some locations to tie in ridges over greater distances. Rock weirs were planned where the flow path was to remain in line with the ditch. The surface flow paths (in magenta) show the restored flow paths.

Grading Ditch Banks. Many drainage ditches have steep banks of 2:1 or less. Steep ditch banks that are inundated for long durations (i.e. where surface drain plugs have been installed), especially those under forest canopy, resist vegetation colonization, and provide little habitat value. Where practical, grade banks back to slopes of 4:1 or greater, and use the excess material to raise the bottom of the ditch. This will facilitate growth of vegetation, and provide habitat for amphibians and predatory insects such as dragonflies.

Subsurface Drain Plugs. In areas where subsurface drains were used to lower the water table, wetland hydrology may be restored by removing or plugging the drain or replacing the perforated drain with a non-perforated drain.

Table 5. Minimum length of drain to be removed or plugged, based on hydraulic conductivity.

Length of Drain	Average Hydraulic Conductivity of Soil
50 feet	< 0.6 inches/hour
100 feet	0.6 to 2.0 inches/hour
150 feet	> 2.0 inches/hour

All envelope filter material or other flow enhancing material shall also be removed for this length. The trench used to alter the drain shall be filled and compacted to achieve a density equal to adjacent natural soil material.

When subsurface drains also function as outlets for other drained areas where drainage is still desired, appropriate measures must be incorporated to keep the upstream drainage systems functional. A non-perforated pipe shall replace the perforated pipe through the wetland area to be restored, and shall extend beyond the wetland in all directions at least the minimum length previously specified for length of drain to be removed or plugged. Drains may also be rerouted around the wetland at the same minimum distances from the wetland, or where topography permits, setting a water control structure at a level that does not affect upstream drainage.

A water control structure may be placed on the inlet of an existing drain. The water control structure shall be attached to a non-perforated conduit that extends at least the minimum length previously specified for length of drain to be removed. The connections of the water control structure and the non-perforated pipe shall be watertight. Refer to the Maryland conservation practice standard for Structure for Water Control (587).

Embankments. Embankments may be used to impound water and provide wetland hydrology. Embankments that meet the definition and criteria for an embankment pond, as described in the Maryland conservation practice standard for Pond (378), are not included as components of this design guide. Fills that will be entirely within a surface drainage ditch shall be designed according to the criteria for Surface Drain Plugs, as described in this design guide. Also refer to the Maryland conservation practice standard for Dike (356).

Take soil borings to identify the presence, depth, thickness, and texture of the proposed confining layer and fill material for the embankment. When necessary, use appropriate measures to minimize seepage losses through the embankment and subsoil (e.g., by using a core trench).

Embankments shall be no more than 4 feet in height, with a minimum top width of 4 feet. Wider embankments may be preferable to facilitate mowing or when used for vehicle access. On embankments with top widths of 6 feet or more, the combined upstream and downstream side slopes shall be a minimum of 5:1. On embankments with top widths of less than 6 feet, the combined upstream and downstream side slopes shall be a minimum of 6:1. Side slopes shall not be steeper than 2:1 in either case.

Flatter side slopes of as much as 10:1 provide some benefits over steeper slopes. Where muskrats are common, they often find embankments with steeper side slopes attractive, and dig tunnels with exit holes on the top of the embankment and on the side slope below the water line. A steeper side slope results in a shorter tunnel distance, while a flatter side slope requires that they dig for a longer distance to set the exit hole below the water line. Another advantage to flatter side slopes is that they allow for a larger ecotone from the upland vegetation on the top of the embankment to the deeper water at the bottom. Flatter side slopes are also easier to mow, and they can provide locations for using excess fill material. The main disadvantages of flatter side slopes are the increased amount of fill required to build the embankment, and the larger footprint of the embankment which can result in a smaller area of deeper water.

Water Control Structures. Water control structures may be installed in surface drains or embankments to manage water levels seasonally or to allow drawdown of water levels for maintenance. When a design includes a water control structure for a site that will be actively managed, the management plan should specify the desired water levels and timing for rate of drawdown and return to normal pool. When installed as the primary outlet, remove extra boards from structures that would cause outflow through the emergency spillway at times other than during storm events.

When practical, install water control structures with the invert at an elevation that limits drawdown to 80 percent of the surface area. This leaves 20 percent of the surface area to provide water quality functions during drawdown and when boards are left out for long periods of time. In most years, where the wetland lacks a perennial water source, the area below the invert will dry up sufficiently to conduct maintenance. This requirement is <u>not</u> meant to encourage the development of deep water areas. (Note: Some financial assistance programs require this limit on drawdown.)

Water control structures included in the design only for drawdown purposes shall be designed to release the water in the amount of time appropriate for the desired management. If a water control structure is intended to carry a portion of the design storm, the combined outlets shall be designed to provide 0.5 feet of freeboard above the 10-year, 24-hour storm, and the boards above the normal pool elevation shall be removed from the structure.

Spillways. A pipe conduit, vegetated or rock-lined spillway, or combination of both shall be provided where needed for safe passage of water to prevent against erosion, breaching, or damage to structures and natural features.

The minimum diameter for pipe conduit spillways is 6 inches. Trash racks are required on inlets to pipe conduit spillways, and rodent guards are required on outlets with diameters less than 12 inches.

The spillway capacity and freeboard shall be appropriate for the site conditions and potential damage to the feature or other areas on or off site. Spillways that will carry more than just ephemeral storm flows shall be protected against erosion and scour using rock riprap or a permanent geotextile that integrates with vegetative cover. Spillways designed to carry only ephemeral flows may be protected with temporary erosion control materials and vegetation, according to the EFH, *Chapter 6 – Sod Chute Spillways*. Where embankments are constructed to impound water, the spillway(s) shall be designed to pass the 10-year, 24-hour storm and provide a minimum of 0.5 foot of freeboard above the 10-year flow depth.

The design of spillways should also consider water quality when the wetland will receive runoff from agricultural areas or land uses that may be sources of pollution. Where water quality is a concern, utilize staged spillways to provide safe passage for high flows and slow release for low flows. Design a spillway at a minimum of 0.5 feet above normal pool to pass the 10-year 24-hour storm, and provide a low flow (≤ 1 cfs at 0.5 foot flow depth) spillway at the normal pool elevation to slowly release water after smaller storm events. The high flow and low flow spillways may be a combination of individual spillways or one spillway designed for staged outflows. Also refer to the section on Water Quality Considerations above.

When spillways are constructed within artificial drainage features with seasonal flow, the bottom width of the spillway shall be at least as wide as the existing channel, and the invert of the spillway shall be a minimum of 0.5 feet below the low bank elevation. This design technique provides for the safe passage of baseflow in a seasonal drainage feature on relatively flat terrain (slopes of 1 percent or less). Where the spillway meets the ditch bank, extend the spillway a minimum of 1 foot horizontally beyond the bank and 1 foot vertically above the spillway invert, on a slope of 2:1 or flatter. This will divert storm flows out and around the spillway. The spillway shall be stabilized with 1-foot thick MSHA Class 0 rock riprap (4 – 7 inch) underlain with MHSA Class SE geotextile filter fabric.

Figures 5a and 5b. Rock weir spillways installed within a surface drain to restore wetland hydrology. In these cases, the spillways also function as fords for occasional vehicle crossing.

As an alternative to rock riprap lined spillways, spillways within artificial drainage features with seasonal flow may be stabilized with 4-inch or 6-inch depth geocell infilled with topsoil and seeded with appropriate vegetation. The invert of the spillway shall be 0.5 foot below the low bank elevation. The downstream slope of the geocell must be 10:1 or flatter[4]. The geocell shall extend a minimum of 4 feet on the upstream and downstream ends of the slope. The geocell shall extend up the banks a minimum of 1 foot above the spillway invert, on a slope of 2:1 or flatter.

Other techniques for spillway design within drainage features (e.g., log vanes) may be implemented according to Part 654 of the National Engineering Handbook, Technical Supplement 14J (TS14J).

Spillways may be designed for use in incised channels and drainage features with perennial flow to raise groundwater levels and increase out-of-bank flow during storm events. Refer to Part 654 of the National Engineering Handbook, Technical Supplements 14G (TS14G) and 14J (TS14J) for design criteria. Construction in perennial and seasonal streams requires authorization under Maryland Nontidal Wetlands and Waters regulations and the federal Clean Water Act.

When there is no surface inflow entering the wetland from off-site (i.e., no drainage area), spillway(s) shall be designed to release the volume of the 10-year, 24-hour storm within an appropriate amount of time for survival of the wetland plant community. The amount of time needed for release of excess water from a specific site shall be determined based on the depth of inundation and the species of wetland plants desired on the site. Generally, wetland plants can tolerate excess inundation for periods of five consecutive days or more during the growing season. A minimum of 0.5 foot of freeboard shall be provided above the 10-year flow depth.

Macrotopography Development. On cropland and other lands that have been made smooth by land use, create macrotopographic features to restore the natural topographic variations in the soil surface. Macrotopographic features can be created by shallow excavation to mimic naturally occurring features such as tree throws and backwater areas. Refer to the section on Shallow Excavation for more information.

Microtopography Development. On cropland and other lands that have been made smooth by land use, create microtopographic features to restore the natural topographic variations in the soil surface. Microtopography can be developed using conventional tillage methods (e.g., chisel plow, disk), skid steers with mulching attachments, and heavy equipment with toothed blades or buckets. Microtopography is typically created during earthmoving and when topsoil is replaced on borrow and fill areas. Leaving these disturbed surfaces as they are can often provide sufficient microtopography.

Microtopography can also be created by the placement of coarse woody debris. See the Coarse Woody Debris section under Providing Organic Matter for more information.

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[4] Slopes of less than 10:1 may be permissible based on a hydraulic analysis and manufacturer specifications.

Stabilization of Structural Measures. Embankments and surface drains plugs shall be vegetated as follows:

- Slopes in woodland planned for natural regeneration to trees and shrubs - Refer to the *Maryland Conservation Planting Guide*, Section 3, for herbaceous high density (critical area) plantings. Use Mix 4 with Virginia Wildrye (*Elymus virginicus*), or Mix 15. Apply mulch as per the criteria in the Maryland conservation practice standard for Mulching (484).

- <u>Slopes other than in 1 (above), steeper than 4:1, and vegetated spillways</u> - Specify site treatment and plantings according to the *Maryland Conservation Planting Guide*, Section 3, for herbaceous high density (critical area) plantings. When feasible, select plant species that are native to Maryland and/or beneficial to wildlife;

- <u>Slopes other than in 1 (above), 4:1 or flatter</u> - For optimum wildlife habitat on most sites, specify seeding mixes in accordance with the *Maryland Conservation Planting Guide*, Section 2, for herbaceous low-medium density (conservation cover) plantings. In lieu of permanent seeding, natural regeneration may be used if all of the following conditions are met:

  - There is an adequate natural seed source of desired species in adjacent areas or in the soil seedbank;

  - Site conditions are favorable for establishing the desired number and distribution of plants within a specified time period;

  - Noxious or invasive species are not likely to jeopardize the natural regeneration process; and,

  - A nurse crop of 40 pounds per acre of oats, wheat, or barley, is planted to provide temporary cover.

Vegetated spillways shall be covered with temporary erosion control matting to support germination and growth of seeded vegetation. Select temporary erosion control matting made from completely natural materials (e.g., jute) over synthetic matting to prevent harm to wildlife.

If dense permanent cover is needed in a short period of time (e.g., the site will be intensively used, severe site conditions are present, or significant erosion control is needed), use the *Maryland Conservation Planting Guide* for herbaceous high density (critical area) plantings to specify the appropriate site treatment and plantings.

Final Grading. Grade and shape upland borrow areas to provide proper drainage, and leave in a stable condition so that no erosion occurs.

Pipe Conduits. Pipe conduits shall conform to the requirements in the Maryland conservation practice standard for Pond (378). Anti-seep collars are not required on embankments with a height of less than 4 feet.

Concrete. Concrete shall meet the requirements of Maryland Department of Transportation, *State Highway Administration Standard Specifications for Construction and Materials*, Section 902.10, Mix No. 3.

Rock Riprap. Rock riprap shall meet the requirements of Maryland Department of Transportation, *State Highway Administration Standard Specifications for Construction and Materials*, Section 901.02.

Geotextile. Geotextile materials shall meet the requirements of Maryland Department of Transportation, *State Highway Administration Standard Specifications for Construction and Materials*, Section 921.09.

<u>Establishing Wetland Vegetation</u>

Vegetation can be established by planting or by natural regeneration methods, or a combination of the two. Vegetation may include trees, shrubs, and/or herbaceous species, depending on site conditions, planned functions of the site, and the desires of the client.

Hydrophytic vegetation shall consist of species typical of the wetland type(s) being established and the varying hydrologic regimes and soil types within the site. Adequate substrate material and site preparation necessary for proper establishment of the desired plant species shall be included in the design.

Control invasive species, federal/state listed noxious plant species, and nuisance species (e.g., those whose presence or overpopulation may jeopardize the practice) as necessary to establish desired vegetation.

Add organic matter to the site as needed. (Refer to the next section "Providing Organic Matter" in this guide.)

Planting may be used as appropriate to hasten establishment of desired species or to supplement the natural regeneration process. The use of species native to Maryland is required for all permanent plantings (not including temporary seedings or nurse crops) in a wetland. For additional requirements concerning species selection, planting dates, rates, methods, and care in handling and planting of seed or planting stock, refer to the applicable sections of the *Maryland Conservation Planting Guide*.

Where natural colonization of acceptable species can realistically be expected to occur within 5 years, sites may be left to revegetate naturally. Natural regeneration is the preferred method of establishing the natural plant community where:

- Seeds, rootstocks, and other propagules of desired species are already present in the soil or are likely to be transported to the site from nearby sources;

- Site conditions are favorable for establishing the desired number and distribution of plants within a specified time period; and,

- Noxious or invasive species are not likely to jeopardize the natural regeneration process.

Wetland vegetation shall meet the following criteria for areal coverage and density, regardless of whether natural regeneration or planting is used:

- Herbaceous vegetation shall be designed to achieve a minimum 85 percent areal cover of the desired plant community within five years;

- Woody vegetation shall be designed to achieve a minimum density of 200 trees and/or shrubs per acre (5 plants/1,000 SF) within five years.

Providing Organic Matter

Organic matter can be provided by stockpiling and re-spreading topsoil and/or by adding straw, manure, wood chips, etc. to the site.

Topsoiling. Spread stockpiled topsoil to a depth of 4 to 6 inches where needed to provide a suitable medium for plant growth. Do not redistribute topsoil that is known to contain invasive plants or noxious weeds.

Organic Matter Amendments for Inundated Areas. If an insufficient quantity of topsoil is available, add organic matter such as straw, composted manure, or wood chips where needed on portions of the site that will be inundated with shallow water. Organic matter (organic carbon) is necessary to restore the natural functions of a wetland, including sustaining beneficial microbes and aquatic invertebrates.

If the soil surface horizon (the "A" horizon) has a Munsell value and chroma <3, it will normally contain at least 1% organic matter and does not need to be augmented. However, if the surface layer has a Munsell value or chroma >3, then use one of the following options to add organic matter to the wetland area:

- Straw - Spread straw over the soil surface to a minimum thickness of 3 inches (1.5 to 2 tons per acre); or,

- Composted Manure **-** Spread composted cow or horse manure to a minimum thickness of 4 inches (500 cubic yards per acre); or,

- Wood Chips **-** Spread hardwood chips (not bark) to a minimum thickness of 4 inches (500 cubic yards per acre).

It is not necessary to incorporate the organic matter into the soil if the inundated areas are intended to remain as shallow open water, or if they will be allowed to revegetate naturally. If the inundated areas will be revegetated by planting, mix the organic matter into the top 4 to 6 inches of soil.

Coarse Woody Debris. Consider adding coarse woody debris (CWD) to wetlands when practical. Coarse woody debris provides a longer term source of organic matter than mulch, wood chips, or straw. Coarse woody debris also provides habitat for macroinvertebrates, salamanders, turtles, and other wetland-dependent wildlife. Types of CWD include logs at least 10 feet in length with diameters of 4 inches or greater, root wads, and tree stumps.

Other Considerations

Federal, state, and local regulations may significantly limit activities in or adjacent to streams, wetlands and other aquatic areas. Laws pertaining to protection of streams, wetlands and water bodies, and erosion and sediment control may be applicable. Landowners are responsible for obtaining all necessary permits, and ensuring compliance with regulatory programs before any work is performed.