SECTION

4 Engineering Design and Construction

The Engineering Design and Construction Section of the Minnesota Wetland Restoration Guide provides comprehensive instruction for the use of hydrologic, hydraulic, and engineering design analyses, principles, and construction strategies that can be applied to most types of wetland restoration and creation projects. It also provides guidance and considerations for preparing construction plans, specifications, and contracts for projects along with information about wetland and construction related permits and regulations.

Figure 4.1

Finally, implementation of the construction plan including: hiring contractors, staking and laying out construction plan components, inspecting the work of contractors during the construction work, and performing final project inspections and certifications.

A primary goal of this section of the Guide is to provide current and reliable information with regard to engineering analyses and design of wetland restoration and creation projects across Minnesota's diverse landscape. Guide-recommended design strategies and construction processes will result in wetland restoration and creation projects that are of high quality and are long lasting, with minimal maintenance needs during the life of the project. The intent is to give practitioners an understanding of strategies and techniques that have proven to be successful on actual projects. The information presented uses accepted engineering design standards and practices which follow hand-in-hand with consideration to the safety and welfare of the public and surrounding infrastructure.

Section 4 Technical Guidance Documents

4-1 Introduction to Engineering Design and Construction

Figure 4.2 *Excavation Work on a Construction Site*

The topics covered in this chapter of the Guide include general information about the engineering process including discussion of scope, design goals, and considerations for designing and constructing restored and created wetlands.

- **Scope**
- **General Design Goals**
- **Design Considerations**
- **Construction Implementation Considerations**

Achieving a functioning wetland ecosystem that mimics natural wetlands should be the primary goal for any wetland restoration or creation project. The success of a well-functioning restored or created wetland requires a carefully developed plan with respect to the design and construction needs for the project. This includes consideration of existing site conditions, identified project constraints, and established goals. The project design must also consider the current and anticipated hydrology of the site as floods, droughts, stormwater runoff, and groundwater influences are to be expected and will affect project outcomes and wetland function.

Implementation success requires a well-coordinated, multi-disciplined approach to site design and development, with regular communication and planning between biologists, botanists or plant materials specialists, technicians, engineers, contractors, landowners, and others involved in the project. Project designers should be informed about the processes involved in implementing other, non-engineering project components including site preparation, seeding, planting, and management of site vegetation. Conversely, those individuals responsible for the project planning and vegetation establishment should understand the basic fundamentals of engineering design and the construction implementation process. Success is best achieved when the design and the planned implementation activities are well coordinated and consider all aspects of a project.

> A multi-disciplined approach to design and construction is critical to success.

Prior to the actual design, site investigation, planning, and surveying will need to be completed. With that information, certain assumptions and design decisions will need to be made with regard to identified project opportunities as well as limitations. Section 3 of the Guide contains detailed information about the informational needs and site assessment process for planned projects. Decisions regarding engineering design and construction should be based on a review of the site assessment data, concept plans prepared for the project, goals and objectives that have been established and, perhaps most importantly, the collective experience of resource professionals involved in the project. Those professionals must be committed to applying their collective experience, expertise, and judgment in a cooperative manner that results in the best possible project.

Scope

This section of the Guide provides a practical approach to wetland design from a technical perspective. The use of information in this Guide is limited to low hazard wetland restoration and creation projects. Using this information to design other related water resource practices such as farm ponds, fish ponds, stormwater ponds, etc. will not be applicable and is not recommended.

Every effort has been made to provide useful and practicable design and construction advice through guidance and discussion of available strategies. The information presented is intended for resource professionals who are responsible for designing and implementing wetland restoration and creation projects. Much of the information is comprehensive in nature and will apply to projects in a variety of landscape settings and project situations.

The engineering design principles discussed and presented are intended for small and moderate-scope projects where extensive engineering efforts and analysis are usually not necessary. For larger structures and sites with more complicated design needs and issues, this Guide will provide an overview of important design considerations and strategies. More demanding engineering investigations and design methods associated with these more complex projects may be beyond the scope of this Guide.

Some restorations will be relatively simple and straightforward. Others will be quite complicated and involve significant engineering, technical, administrative, and legal efforts to complete. The variability of wetland types, watershed conditions, and methods used to drain and alter former wetlands makes it difficult to identify design and construction techniques and strategies that work in all situations and landscape settings. While applicable to many project situations, it is not practicable or feasible for the information presented in this Guide to address every possible project situation. It is expected that designers will appropriately use and apply the information presented. The use of other reference materials for certain project types or design situations may be necessary and is encouraged.

Figure 4.3 *Waterfowl using a Restored Wetland*

The information in this section of the Guide should not supersede existing local, state, or federal design standards or other program requirements.

General Design Goals

The primary goals of any wetland restoration or creation should be to provide a long-lasting project that blends into the landscape, provides the intended functions, and meets the long-term outcomes identified for the site. However, individual projects may have more specific goals such as direct replacement of lost wetland functions, flood control, waterfowl and wildlife habitat, etc. Consider and understand these goals- they can have a significant influence on the design strategies used to develop the site.

Also understand that goals will not always be compatible with each other. For example, projects that desire to maximize natural ecosystem benefits, including habitat and nesting cover for wetland wildlife, will tend to emphasize diverse native vegetation communities and relatively stable wetland water levels. Conversely, wetlands being restored or created with a primary goal of providing flood control benefits will likely desire to maximize flood detention by allowing greater fluctuations in wetland water levels. This can limit the establishment of diverse native vegetation communities within the wetland and be harmful to some wildlife species that nest in and around the wetland. Fortunately, wetlands can be designed to accommodate multiple goals, including increased wildlife habitat, flood control, and improved water quality. Design compromises may be needed, however, as a focus on any one function or goal can limit the benefits of the others. More importantly, the specific attributes of a planned wetland may lend themselves to a particular function that will be most benefited by its completion. This highlights the importance of site selection and comprehensive site as-

Figure 4.4 *Curvilinear Shaped Embankment*

sessments as part of determining appropriate goals and functions to target.

While targeted goals can often be met when restoring wetlands, success from a functional perspective is often best achieved when hydrology is restored as close as possible to the pre-drained or original condition of the site. This ensures that restored hydrology will closely match the type, soils, plant communities, and other functions of the former wetland. The challenge when evaluating and designing potential restoration sites is to be able to determine from available information and collected data the hydrologic regime of the former wetland, demonstrate similar hydrologic conditions through analysis, and then be able to achieve successful restoration results through implementation with consideration to watershed changes and restoration constraints.

Design Considerations

A number of important decisions need to be made when designing a wetland restoration or creation project. This can include but will not be limited to: the selection of the wetland's depth or elevation, the type, size, or location of an outlet structure, the extent of site preparation and grading that may be needed, or even the location and source of borrow or fill materials that will be used in the construction. Given all of these considerations, successful projects will require the designer to fully understand the project site, its opportunities as well its limitations, and the design options and construction strategies that are available for use.

> Wetland restoration and creation projects are usually completed to meet specific goals and provide certain desired functions.

The selection of appropriate design strategies can enhance and help meet identified goals. The design should ensure that constructed features will be sustainable and accommodate both the engineering and biological requirements of the project. This can be accomplished by using sound design and construction techniques that will provide long-lasting results with minimal maintenance.

Whether it is through a complex hydrologic analysis of the project, the development of a report to facilitate project reviews and approvals, or preparation of construction plans and specifications, the design stage provides the foundations for all restored or created wetlands.

Figure 4.5 *Construction Implementation*

Construction Implementation Considerations

The requirements of a wetland project should be clearly defined in the plans, specifications, and other prepared construction documents. Contractors that are selected and hired to implement the construction plan should have the equipment and experience needed to ensure satisfactory results. Good communication between the engineer, project manager and contractor will ensure the requirements of the plan are clearly understood and followed. Frequent conversations or meetings before and during the course of construction may be necessary to accomplish this.

Prior to commencing construction, ensure all necessary permits are obtained and notifications made. Significant project delays can result if these items are not adequately planned or addressed in advance of construction.

Construction activities will need to be staged and coordinated to ensure appropriate preventive measures for erosion and sediment control are taken. Timing the completion of one activity can significantly impact the implementation and success of another. When important, a construction work or sequencing schedule should be considered and become part of the project plan. It should clearly identify the sequence of construction activities and define key items for inspection.

The engineer, project manager, and contractor should discuss how inspection work is to be scheduled. Enough lead time should be provided to ensure appropriate personnel are available for inspection and oversight when specific project components are being constructed.

The final step in the construction process includes verifying, measuring and certifying work that has been completed. This will allow for final project negotiations and payments to be made for the completed work. It should also allow for preparation of final as-built drawings for the project file.

4-2 Wetland Hydrology

This section is currently under development

4-3 Drainage System Modifications

Minnesota's landscape has changed dramatically since the early 1900's. Landscape changes have included the establishment of an extensive network of drainage systems that have altered the hydrology and landscape of many wetlands and their watersheds, particularly in the southern and western regions of the state. To a large extent, the purpose for these drainage systems was to increase the extent of farmable and developable land, to increase the rate of removal of water that normally ponds on the landscape, and to lower and manage water tables to improve agricultural productivity. The manipulation and abandonment of these drainage systems will therefore be a necessary component of most wetland restorations.

It is important to follow appropriate design strategies, standards, and procedures when manipulating or abandoning an existing drainage system. This will not only ensure successful restorations but will also demonstrate to adjoining landowners, the agricultural community, drainage authorities, and other land and water resource managers that wetland restoration can be effective, fully functional, and oftentimes beneficial to surrounding properties, drainage systems, and watersheds.

The methods used to manipulate or abandon existing drainage systems to restore wetlands will typically fit one or more of the commonly-used design strategies presented in this chapter of the Guide. Recognize that one or any combination of these design strategies may be necessary for any given wetland restoration project.

Discussion on the following drainage-related topics and strategies for their manipulation to restore drained and altered wetlands occur in this chapter of the Guide.

- **General Considerations**
- **Surface Drainage Systems**
- **Subsurface Drainage Systems**
- **Drainage Systems Manipulation Strategies**
  - *Blocking and Filling Surface Drainage Ditches*
  - *Blocking/Removing Drainage Tile*
  - *Outletting Upstream Drainage Tile*
  - *Re-Routing Drainage Systems*
  - *Ditch Bank Improvements*
  - *Removing/Relocating Lift Stations*
- **General Design Components**

Figure 4.3.1 *Installation of Drainage Tile*

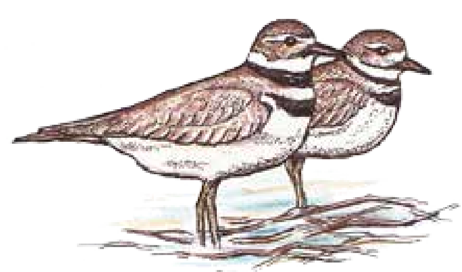


Figure 4.3.2 *Aerial photo showing wetland drainage*

General Considerations

> Drainage in Minnesota primarily exists in the form of surface ditches and subsurface tile systems.

Understanding how these drainage systems work and how they influence landscape hydrology is fundamental to designing and implementing drainage system modifications as part of a wetland restoration. The specific characteristics of a drainage system will affect available flow capacities, system performance, and, ultimately, drainage effectiveness. For subsurface tile drainage systems, these characteristics include tile size, depth, spacing, grades, materials, and outlet conditions. For surface drainage systems, they include cross sectional areas, grades, vegetative condition, and outlet condition. In addition, a basic understanding of the scope and lateral drainage effects of ditch and tile drainage systems may be a necessary design component for some projects.

To successfully restore site hydrology to wetlands affected by drainage systems, it will be necessary to manipulate or abandon all or portions of the drainage system. This requires a functional design and construction strategy that considers available site and drainage system information along with an understanding of associated drainage rights for neighboring properties. A thorough assessment and evaluation of the drained wetland and its associated drainage system needs to be made as part of its design. Section 3 of the Guide provides discussion and information on the site assessment process and data collection needs for drainage systems including requirements for mapping, field investigation, and surveying. When designing modifications to a drainage system, it will be important to understand the scope of the system and whether it extends upstream, beyond the boundaries of the project, and provides drainage benefits to any neighboring properties.

Drainage systems are regularly shared and managed among several landowners, often under legal agreements as part of a private drainage system or, more formally, as part of a public system. When attempting to modify shared drainage systems, it will be necessary to address any associated legal or administrative drainage issues and requirements that may exist. A discussion on the legal and administrative issues associated with modifying drainage systems occurs in **Section 4-9 Construction Related Laws, Regulations and Permits**.

Surface Drainage Systems

Surface drainage ditches are above ground conveyance systems that collect drainage water through a variety of pathways from both surface and subsurface sources. Most ditches are capable of transporting high flows and volumes of drainage water and, under most conditions, are very effective at providing drainage to wetlands. In low-lying wetland areas where an adequate gravity outlet is unavailable, lift stations or pumps are sometimes used in combination with surface ditches to provide drainage.

The design complexity to restore ditch-drained wetlands varies. Many designs will be straightforward, requiring a simple ditch plug or filling of the ditch. Others will require a more comprehensive engineering analysis

Figure 4.3.3 *Surface Drainage Ditch*

because of geological conditions, extent of ditching in the project area, type of wetland proposed for restoration, watershed size, outlet structure requirements, or concern for adjacent property impacts.

Earthen embankments are often utilized when restoring ditch-drained wetlands. Whether through the design and installation of a simple ditch plug or with a longer embankment or dike, an understanding of design issues associated with constructing earthen embankments is necessary. A thorough discussion of these design issues occurs in Section 4-5 Earthen Embankments.

Subsurface Drainage Systems

Subsurface drainage systems primarily exist as older concrete or clay tile along with more technologically-advanced polyethylene pipe. Subsurface drainage systems can be in the form of a single tile line draining small depressional wetlands to an extensive network of pattern tile located in wetland flats, floodplains, sloped wetlands, and in larger depressional wetland basins. Lift stations or pumps are often used in combination with subsurface tile to allow drainage in low-lying wetland areas where an adequate gravity outlet is unavailable.

The complexity of restoring tile drained wetlands varies and is dependent on many factors. These include geological and topographic conditions; size, elevations, grades, extents, and condition of the tile drainage system; type of wetland that existed prior to drainage; requirements for any associated outlet structures; and concerns for adjacent property impacts. A thorough assessment of the project should provide information relative to these important items.

Figure 4.3.4 *Subsurface Drainage Tile*

Drainage Systems Manipulation Strategies

Strategies for manipulating both surface and subsurface drainage systems to restore drained wetlands include:

- Blocking and Filling Surface Drainage Ditches
- Blocking and Removing Drainage Tiles
- Outletting Upstream Drainage Tile
- Re-routing Drainage Systems
- Ditch Bank Improvements
- Removing/Relocating Lift Stations

It is common to use more than one of these drainage manipulation strategies to effectively restore a drained wetland.

A general overview of each of these drainage manipulation strategies follows. More comprehensive information and design guidance for each of these strategies can be found in **Technical Guidance Documents for Drainage Systems Manipulation**, which are located in Appendix 4-x of the Guide.

Figure 4.3.5 *Construction of a Ditch Plug*

Figure 4.3.6 *A Drainage Ditch Being Filled In*

Blocking and Filling Surface Drainage Ditches

Many wetlands that are drained by surface drainage ditches can simply be restored by placing a small amount of earthfill at strategic locations within and across the ditch to block the flow of water (**Figure 4.3.5**). This relatively inexpensive construction practice is commonly referred to as a "ditch plug". For many ditch-drained wetlands, a single ditch plug at the wetland's outlet may be all that is needed to effectively restore hydrology to the site. In other situations, multiple ditch plugs may be needed, such as in larger wetland complexes with varying topography or in sloped wetlands.

Ditch plugs should be designed to block the flow of water in the ditch. They are often used in combination with a vegetative spillway or other type of outlet. In limited situations, ditch plugs can be designed to function also as a vegetated or armored spillway that allows wetland discharges to flow over them.

In this Guide, the term "ditch plug" is used interchangeably with the term "embankment." Discussion of specific design requirements for these and other types of earthfills is included in **Section 4-5 Earthen Embankments**.

The landscape setting or geological conditions for most sloped wetlands and some depressional wetlands that are ditch-drained will require the entire ditch system within the wetland be filled in order to successfully restore site hydrology. This more-extensive restoration strategy is used when topography, geology, ditch size and depth, and the relationship of the wetland to groundwater warrant it and where restoration of the true, former wetland is the goal (**Figure 4.3.6**).

The wetland landscape setting, extent of drainage, fill location, foundation condition, requirements for site preparation, source of fill material, fill height, length, shape, and outlet considerations are the essential elements to be considered in the design of all ditch plugs and fills.

> In certain situations, the complete filling of a drainage ditch may be necessary for effective restoration.

Additional details on this restoration strategy can be found in the Blocking and Filling Surface Drainage Ditches **Technical Guidance Document** located in **Appendix 4X-1**.

Blocking/Removing Drainage Tile

The most common strategy to restore wetlands drained by subsurface drainage is to block and remove portions of the tile system to render it inoperable (**Figure 4.3.7**). It is usually not necessary to remove the entire length of tile within the wetland to successfully restore

Figure 4.3.7 *Construction of a Tile Block*

optimum hydrology to these wetland systems. Instead, a single, well-placed tile block at the wetland's outlet may be all that is needed to abandon the desired reach of tile and achieve full restoration of wetland hydrology. In other situations, multiple tile blocks may be needed, such as in larger wetland complexes with varying topography and in sloped wetlands.

The location and number of tile blocks needed, length of tile to be removed, backfill and compaction methods, and considerations for managing wetland discharges are the essential design elements of this restoration strategy.

More detailed information on this restoration strategy can be found in the Blocking/ Removing Drainage Tile **Technical Guidance Document** located in **Appendix 4X-2**.

Outletting Upstream Drainage Tile

Before blocking tile to restore a wetland, it will be necessary to address and protect any upstream properties that also use and receive drainage benefits from the tile drainage system. This is most often accomplished by shallowing or flattening the grade of a portion of the upstream tile drainage system so it can discharge freely into the wetland being restored (**Figure 4.3.8**). This strategy requires the existing tile system to have sufficient grade prior to entering the wetland to allow its elevation to be raised and outletted at the surface. The length, size, material, grade, and location of the new outlet are the essential design elements of this restoration strategy.

More detailed information on this restoration strategy can be found in the Outletting Upstream Drainage Tile **Technical Guidance Document** located in **Appendix 4X-3**.

Re-Routing Drainage Systems

When surface ditches or subsurface drainage tile systems extend upstream of and out of the project area, protecting those upstream benefited areas and their drainage rights becomes a necessary component of the restoration design. When necessary, it may be practical and cost-effective to consider re-routing the upstream drainage system around or away from the wetland being restored. The applicability of this restoration strategy is limited by high construction costs. It is used at select project sites where the re-alignment and construction of a new drainage system is a practical option and where the potential benefits or outcomes of the project can justify the costs.

The design of any drainage system re-route or re-alignment needs to consider potential excavation depths, soils, construction methods, lengths, size, grades, and required flow capacities to ensure that upstream drainage benefits are not impacted. Just as important will be the coordination and agreement of the planned modifications with the affected landowners.

Note that re-routing upstream drainage tile through or under the wetland area being restored is not advised. Issues with floatation and future drainage system maintenance are the primary reasons for this.

More detailed information on re-routing can be found in the Re-routing Drainage Systems **Technical Guidance Document** located in **Appendix 4X-4**.

Figure 4.3.8 *A Constructed Tile Outlet*

Ditch Bank Improvements

In many locations, there will be no feasible or practical means to plug, re-route, or otherwise manipulate a surface ditch that is draining a wetland without adversely impacting the drainage benefits and rights to upstream or adjoining properties. Examples of this could include ditches constructed along property lines, in road right-of-ways, or large ditches through a project area that cannot be blocked and would simply be too expensive to consider moving. A restoration strategy that addresses this common problem is to leave the ditch system intact and restore wetland hydrology on one or both sides of the ditch. This strategy does not allow full restoration of a drained wetland but, in limited situations, functional wetland areas can be achieved.

Establishing a physical earthen barrier or embankment between the planned wetland and the adjacent ditch is the essential design element of this strategy. To restore wetland hydrology and prevent or minimize continued drainage losses by the adjacent ditch system, construction improvements to the spoil bank or area immediately adjacent to the ditch may be needed. At the very least, this can require reconstruction or additional fill being added to an existing ditch bank to achieve minimum design requirements (**Figure 4.3.9**).

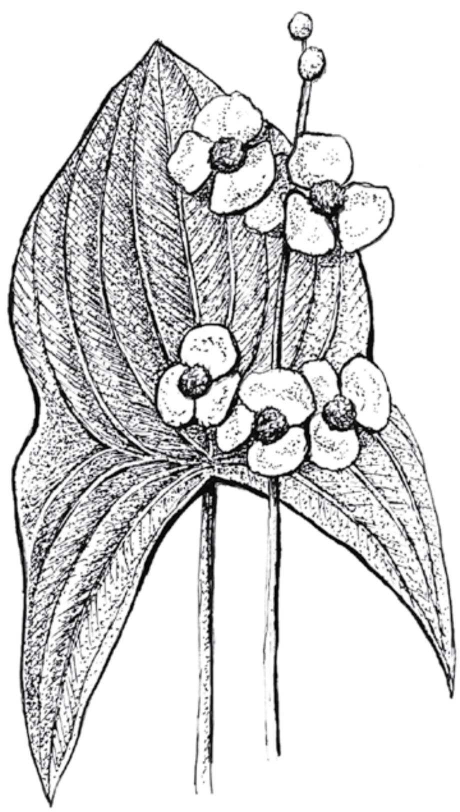
For this strategy to be effective, the embankment and underlying soils need to be relatively impervious to prevent or minimize the loss of wetland hydrology through lateral drainage into the adjacent ditch. Preventing or managing the loss of hydrology while maintaining a stable ditch slope becomes an important component of the design. A clear understanding and assessment of elevations, dimensions, and composition of soil materials in and under the existing ditch bank, along with site topography, elevations, dimensions and drainage effects of the existing ditch, are necessary to determine the feasibility of this strategy.

Figure 4.3.9 *Improving a Ditch Bank to Restore a Wetland*

In some situations, the adjacent ditch can overflow to provide hydrology to the restored wetland during certain flood or high water conditions. This can occur through appropriately designed and placed pipes, spillways, or overflow weirs within the ditch bank.

It will be important to consider the right-of-way that is associated with the existing ditch. The design should ensure that lawful maintenance of the ditch can occur and must consider the need for future access and spoil placement.

More detailed information on this restoration strategy can be found in the Ditch Bank Improvement **Technical Guidance Document** located in **Appendix 4X-5**.



Removing/Relocating Lift Stations

Lift stations are used in combination with both surface and subsurface drainage systems to provide wetland drainage to low-lying wetland areas where a suitable gravity outlet is not possible or available (**Figure 4.3.10**). When planning to restore wetlands that are drained by a lift station, restoration strategies typically include the complete removal and abandonment of the lift station. When upstream drainage benefits need to be maintained and protected, consider relocating the lift station upstream of the project and allowing it to discharge into the wetland being restored.

When performing this strategy, remove all the components of the lift station including the power supply that leads to it and properly backfill and compact the sump and other excavated areas.

More detailed information on this restoration strategy can be found in the Removing/Relocating Drainage Lift Stations **Technical Guidance Document** located in **Appendix 4X-6**.

General Design Components

There are many site-specific issues to analyze and address in the design of all drainage manipulation strategies. Managing and addressing the drainage rights of neighboring properties along with water resources within the project becomes a necessary design function for every wetland restoration project. If ignored or improperly assessed and evaluated, necessary project approvals and permits may be jeopardized and restoration results may be compromised.

Drainage rights of adjoining properties must be considered

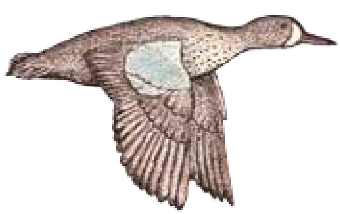
A comprehensive assessment of existing drainage systems is crucial to a successful restoration design and implementation strategy. This includes research of available drainage maps and aerial photos, on-site surveys and investigations, and landowner discussions. Obviously, the scope of the project will dictate the importance of these items and associated design concerns. Some drainage manipulation strategies will be quite simple with no real concern for off site impacts

Figure 4.3.10 *A Relocated Tile Drainage Lift Station Discharging into a Restored Wetland*

or infringement of drainage rights. Most, however, will require the involvement of experienced engineers and other resource professionals in their design. It takes a combination of training and experience to ensure that drainage capacities, discharge rates, drainage rights, and safety issues are addressed and that required design standards are followed for functionality and sustainability.

Drainage rights, whether they are perceived or real, can become a significant issue for neighboring landowners as well as for entities such as Watershed Districts and Drainage Authorities who manage and permit water- and drainage-related projects. The manipulation of existing drainage systems often requires their involvement and should be done early in the process to ensure the likelihood of project approval and success.

Additional discussion of drainage rights and associated legal aspects of drainage systems manipulation occurs in **Section 4-9 Construction Related Laws, Regulations, and Permits**.



4-4 Outlet Structures

With every wetland restoration or creation, there comes a need and responsibility to understand and manage site hydrology. A component of the project design includes analyzing and estimating hydrologic inputs, available storage capacities, and outflows that will be expected or necessary for a project to function and achieve its design goals. Because hydrologic inflows often exceed losses due to evaporation and infiltration, outlet structures are often needed for restored and created wetland projects.

A number of considerations and analyses are needed when designing a wetland's outlet. An understanding of site hydrology, structure hydraulics, outlet types and materials, and specific knowledge of site elevations, soils, downstream conditions, and potential future maintenance needs will all be necessary to evaluate and design an outlet. While a variety of outlet types and configurations may be available, there is usually one general type of outlet that best meets the needs of a planned project.

Discussion on the following general topics as they relate to designing and constructing wetland outlet structures occurs in this chapter of the Guide.

Figure 4.4.1 *Wetland Outlet Structure*

General Considerations

The type of outlet chosen for a wetland must address the physical requirements of the project. A variety of structure types and materials exist and can be considered for use in a project's design. The primary factors that influence the type of outlet include: the size and condition of the contributing watershed, wetland size and available storage, site conditions and soils at the wetland's outlet, and the condition of the downstream conveyance system or discharge area. Selecting the proper outlet or combination of outlet types for a given location and site condition is an important part of the project design. Outlets can serve a number of different purposes, including to:

> Most wetland restoration or creation projects will need to incorporate an outlet of some type in their design to manage and regulate expected outflows.

- Regulate or manage wetland water levels
- Control and manage expected wetland discharges
- Prevent uncontrolled flooding or excessive variation of wetland water levels
- Safely convey wetland discharges into a downstream drainage system (ex. a ditch or tile)
- Protect and/or minimize flooding problems for downstream areas
- Provide water quality treatment benefits
- Provide a physical barrier preventing undesired or nuisance wetland species from entering the wetland system being restored or created

Figure 4.4.2 *Rock Weir Structure*

The design must consider the function and sustainability of all planned construction components, including the selection of outlet type and materials. When determining the type of outlet to use, consider the following questions:

- What are the primary goals of the project?
- What are the expected flow capacities at the wetland's outlet?
- Are there any design limitations or constraints with regard to capacity or flow conditions downstream of the outlet?
- Could downstream water level conditions (tailwater) affect the hydraulic performance of a planned outlet?
- Is water level management of the wetland desired or necessary?
- Are there design limitations or constraints with regard to the conditions of the site or project boundaries that could affect wetland water elevations or the type and size of outlet used?
- What is the expected elevation difference (head) from the wetland water surface to the downstream outlet?
- What is the expected or desired lifespan of the structure?
- What are the potential maintenance requirements?

Types of Outlets

Wetlands that are hydrologically isolated or that have little or no contributing drainage area may not need an outlet, provided that base flows from tile outlets, springs, or other groundwater sources do not exist. However, when wetlands are influenced by groundwater flows or will receive runoff from a contributing drainage area, an outlet of some type will usually be needed to manage wetland discharges.

Outlets that control primary wetland discharges and regulate water levels are referred to as **principal outlets**. Principal outlets are designed to manage and control wetland base flows in addition to runoff from storm events. The limited flow capacity of most principal outlets will usually not allow for the management of all expected wetland outflows. In these situations, a secondary or **emergency spillway** is used to discharge excess wetland outflows. The combination of a principal outlet with an emergency spillway provides a practical and economical means to manage and safely pass all expected outflows from most restored or created wetland systems.

Six general types of outlets are most commonly used when restoring and creating wetlands. They are:

- Trickle drains
- Culverts
- Drop inlets
- Weirs
- Vegetated spillways
- Armored spillway

Each of these outlet types has a different design purpose and application. An overview of each of these outlet types follows.

Additional information and discussion with regard to application, materials, design considerations, installation guidelines, maintenance requirements, and costs for outlets that are associated with restored and created wetlands can be found in **Technical Guidance Documents** located in Appendix 4-XX of the Guide.

Trickle Drains

Trickle drains are used to manage base flows from the wetland, protect vegetated spillways from potential prolonged discharges and saturation, and provide additional flood detention storage or water quality benefits.

Trickle drains can be configured in a variety of ways with an outlet that is free flowing or is connected to a downstream subsurface tile drainage system (**Figure 4.4.3**). They can be installed as horizontal conduits through or around constructed embankments, through other elevated areas, or configured as simple, small-diameter drop-inlet structures. They are typically used in combination with other outlets. Their use in combination with secondary vegetative spillways is often all that will be necessary for many wetland projects where more-consistent runoff in the form of base flows is expected.

> Trickle drains are typically constructed with small conduits that usually range between 6 to 12 inches in diameter.

More detailed information on this type of outlet can be found in the **Trickle Drain Structures - Technical Guidance Document** located in Appendix 4XX.

Figure 4.4.3 *Construction of a Trickle Drain*

Culverts

Horizontal pipe culverts are used to control outflows and maintain wetland water levels. Culverts can be a variety of sizes, materials, and lengths depending upon the design needs of a project. Horizontal pipe culverts are typically new structures that are installed as part of a project; however, existing culverts through a roadway, ditch bank, or other earthen structure can often be inexpensively manipulated to serve as an outlet. Relatively inexpensive, culverts can be very effective at managing small discharges or base flows and are often used in combination with earthen embankments (**Figure 4.4.4**).

More detailed information on this type of outlet can be found in the **Horizontal Pipe Culvert Structures - Technical Guidance Document** located in Appendix 4XX.

Figure 4.4.4 *Flow at Entrance to Horizontal Culvert*

place 4.4.3

Figure 4.4.5 *Construction of Drop Inlet Structure*

Figure 4.4.6 *Steel Sheet Pile Weir Structure*

Drop Inlets

Drop inlet structures are used to manage and convey wetland discharges to a stable, downstream conveyance system or outlet. Drop inlet structures vary in size, type, and material. They typically consist of a vertical riser pipe or some type of catch basin attached to a horizontal outlet pipe or barrel (**Figure 4.4.5**). Drop inlets can manage a wide range of wetland discharges and are used in a variety of situations including when conveying wetland discharges into a downstream subsurface tile or surface ditch drainage systems. They can also be ordered or fabricated with adjustable stop logs or gates to allow for management of wetland water levels.

More detailed information on this type of outlet can be found in the **Drop Inlet Structures - Technical Guidance Document** located in Appendix 4XX.

Weirs

Weir structures are mechanical or constructed barriers that are often placed across open drainage ditches. They allow wetland discharges to flow over a fixed crest or vertical wall down to a stable outlet near the base of the structure (**Figure 4.4.6**). Weir structures are constructed with steel, vinyl, or other composite piling materials or are cast in place as a reinforced concrete drop structure. Certain rock or armored outlets can also function as weir structures.

There are several possible design configurations of inlet or cross-section geometry for weirs that will influence discharge rates and hydraulic performance. They can have long, flat control sections that provide large discharges with relatively small stages or flow depths. Or, they can be multi-staged, with rectangular or v-shaped notches that provide controlled or metered flow rates at low stages of the wetland, yet allow larger discharges to occur at higher stages (**Figure 4.4.7**).

Depending on materials used, weir structures can also be fabricated with gates or bays to allow control and management of wetland water levels.

More detailed information on this type of outlet can be found in the **Weir Structures - Technical Guidance Document** located in Appendix 4XX.

Vegetated Spillways

For the purpose of this Guide, spillways will be considered as broad channels that are intended to safely pass some or all of the expected wetland discharges. Spillways can be used to effectively control wetland water levels and safely pass relatively large discharges compared to other types of outlets. For these reasons, they are regularly used as an auxiliary or emergency outlet, designed to work in combination with another type of principal outlet. This combination provides a practical and economical means to manage and pass

Figure 4.4.7 *2-Stage Weir*

Figure 4.4.8a *Vegetated Spillway After Large Runoff Event*

all expected outflows from many restored or created wetland systems.

For some projects, discharges at the wetland's outlet will be infrequent, relatively low, and of short duration. Under these low-stress flow conditions, a simple vegetated spillway alone may be used as the principal outlet (**Figure 4.4.8a**). This situation is limited to sites with relatively small drainage areas and where little to no base flow is expected at the outlet. Given the uniqueness of every potential project as well as the variety of site conditions that exist across the state, no specific design guidance can be given for when a vegetated spillway alone can safely function as the primary outlet for a restored or created wetland. Agency, program, or other design standards, if they exist, should be referenced to help in this determination.

Avoid placing vegetated spillways over embankments or other constructed fills.

Vegetated spillways are wide, open channels, usually trapezoidal in shape. They will consist of an inlet channel, a flat control section, and an exit channel. The control section is constructed at some predetermined design elevation, either at the design wetland water surface when it functions as the principal outlet or at some elevation above it when it serves as an emergency spillway. The expected discharge rates and desired flow depths within the spillway will govern its design width. The most common configuration for a vegetated spillway is to construct it around one or both ends of an embankment at the wetland's outlet. It is not recommended to construct vegetated spillways to flow over an embankment or other constructed fills, unless specifically designed as "flow over" type ditch plug.

More detailed information on this type of outlet can be found in the **Vegetated Spillways - Technical Guidance Document** located in Appendix 4XX.

Armored Spillways

Where more frequent, excessive, or longer duration flows are expected or when vehicle or equipment travel across the spillway is expected, spillways, if used as a principal outlet structure, will need to be armored with rock, concrete, or other engineered synthetic products (**Figure 4.4.9**).

More detailed information on this type of outlet can be found in **Armored Spillways - Technical Guidance Document** located in Appendix 4XX.

Multi-Stage and Combination Outlets

Most principal outlets will function as a single-stage outlet. A horizontal culvert that provides discharge at a fixed elevation would be an example of a single-stage outlet.

The use of multi-stage outlet structures or a combination of outlet structures provides opportunities to improve flood storage and water quality benefits of a project. This can also address other unique design challenges.

Principal outlets such as drop inlets and weirs can be configured to function as multi-stage outlets. Multi-stage outlet structures can regulate and provide varying hydraulic outlet controls where additional flood detention storage, water quality benefits, or reduced

Figure 4.4.9 *Cable Concrete Armored Spillway*

outlet maintenance requirements are desired. Separate openings or devices at different elevations within the riser portion of the structure can be used to control discharge rates and provide the desired benefit. This usually entails a first stage low-flow device or opening to control the wetland's normal water elevation in combination with a second stage device or opening, set higher in elevation, to accommodate higher flows from larger runoff events (**Figure 4.4.10**).

In addition, outlet structures can be combined to provide a unique or desired design objective or range of hydraulic flows or conditions that cannot be attained with a single structure. Examples where multiple outlets are used in combination include:

- A single-stage principal outlet used in combination with a vegetated emergency spillway (most common).
- Multiple outlet devices of the same or different sizes set at the same or different elevations to achieve a desired hydraulic condition or design outcome. This occurs when wetland discharges need to be split into separate outlets. An example would be a trickle drain structure that outlets into a downstream subsurface tile system used in combination with another principal outlet, such as culvert through an embankment or road, to manage higher-stage outflows.
- Multiple smaller culverts used through an embankment or road where inadequate cover would otherwise exists over a single, larger culvert.
- Weir structures used in front of and in combination with a culvert through a roadway or field crossing.

General Design Components

There are many components that need to be analyzed and addressed in the design and construction of an outlet structure. Each component, if ignored or improperly assessed and evaluated, can lead to structure failure and eventually require corrective actions that could be difficult and expensive to perform. The scope of the project will dictate the importance of these items. For example, many wetland restorations and creations are small and will have very simple outlet needs. The design components for these types of outlets are likely to be minimal.

In contrast, when larger or more complex outlet structures are needed, when concerns exist with the condition of the outlet (soils, grades, channel stability, etc.), or where there is a potential for upstream or downstream impact as a result of the project, the design and installation of the outlet requires the involvement of an experienced engineer and other design professionals. Performance and safety issues must be addressed and required design standards followed for functionality and sustainability.

Figure 4.4.10 *Multi-Staged Concrete Drop Inlet Structure- Note Orifice Opening at Water Surface*

Following are some general components that should be considered in the design of every outlet structure.

Additional design guidance and information can be found in the **Technical Guidance Documents** for wetland outlet structures, which are located Appendix 4-XX of the Guide.

Hydrologic/Hydraulic Analysis

Flow rates, durations, and available storage within the wetland are just a few of the items that will affect the type and size of the outlet needed. Structure hydraulics or the range of flow capacities provided by the outlet will affect overall wetland hydrology and the extent and duration of any flooding that may occur.

The wetland's outlet needs to be designed to function for the full range of anticipated flow conditions. A proper design analysis will provide data on the minimum required outlet capacity for the expected design storm and associated runoff and its impact on the wetland and surrounding properties. That, along with information on the condition and capacity of the downstream outlet and the desired goals for the project, will contribute to the final determination of the type and size of outlet to be used.

Most designs will require some type of hydrologic and hydraulic analysis.

More detailed discussion on the considerations and methods to analyze site hydrology and for determining hydraulic requirements and sizes of any planned outlet structures occurs in Section 4-2 Hydrologic and Hydraulic Analysis of the Guide.

Construction Materials

All outlets should incorporate durable, long lasting materials. Preferred materials include concrete, plastic, metal, rock, or other durable natural or synthetic materials. To the extent practicable, natural products such as rock rip rap or even vegetation should be considered over man-made products when attempting to stabilize outlets.

All structures and their associated materials will have advantages and disadvantages in terms of cost, ease of use, adaptability, strength, and durability. With proper design, installation, and protection, the materials used should provide for a long-lasting, sustainable outlet with little required maintenance.

Use materials that meet agency, program, or industry standards. This includes minimum specifications and requirements for substance, size, thickness, gauge, coatings, and fabrications. Structures and their materials should be designed to withstand all anticipated external loading forces without yielding, buckling, or cracking. Metal materials should include provisions for protective coatings to reduce corrosion.

Pipe materials, if used, should be selected to support the maximum design loads with a maximum deflection of five percent.

Plastic materials such as HDPE or PVC pipe warrant additional concerns with surface exposure. Natural elements such as ultraviolet radiation, fire, ice, and even vandalism are of concern and can affect the material and its lifespan. These materials should be fully covered or buried to the extent possible. Consider using more durable protective sleeves and aprons along with placement of rock rip rap to limit exposure of plastic pipe ends. HDPE and other plastic pipe materials will require additional design analysis to address issues with external loading especially in poor soil conditions or in situations with greater installation depths.

Location and Foundation Suitability

Whether it is a principal outlet or an emergency spillway, the location, layout, and type of outlet should be chosen based on design analyses of several site variables including but not limited to: elevation, grade, and soils, susceptibility of excessive scouring and erosion, and condition of the downstream outlet.
Potential issues with foundation and structural stability

Figure 4.4.11 *Installation of a Reinforced Concrete Catch Basin Outlet Structure*

will exist for almost every type of outlet structure. The design needs to address stability and provide a reasonable factor of safety against floatation, overtopping, settling, or other factors that could lead to failure. For example, most drop inlet structures will need to include appropriately-sized concrete footings to establish a stable foundation and to address potential for uplift or floatation of the structure (**Figure 4.4.12**). A qualified and experienced engineer or other design professional should assist in the analysis of the foundation conditions and the design of any foundation controls or footings.

Internal Erosion or Seepage

The design should also consider the potential for seepage or internal erosion of soils along the surface of the outlet structure. Pipe structures often require the use of anti-seep collars or drain diaphragms and filters to prevent this (**Figure 4.4.13**). Other types of seepage controls may be needed for other types of structures. A qualified and experienced engineer or other design professional should assist in the analysis and design of seepage controls for outlet structures.

Erosion/Scour Protection

When locating and designing an outlet structure, provide for stable flows without excessive scour erosion at either the inlet or outlet. Outflows must occur at safe design velocities and appropriate outlet protection measures must be utilized. All outlet structures should be resistant to erosion from either base flows or periodic high flows. An analysis of potential velocities through a structure is necessary to determine this.

The use of rock riprap or other protection strategies should be considered at all locations where the potential for scouring exists. Structures with excessive outlet discharges might also require a properly designed stilling basin. Poorly designed outlets inevitably can lead to increased maintenance, excessive erosion, and even failure of the structure.

Guards, Grates, Skimmers and Other Protections

Principal outlets need to be designed to function as free flowing structures able to pass wetland base flows and runoff from snowmelt and storm events. Unfortunately, when used in restored and created wetlands, many of these structures are highly susceptible to being blocked or plugged by floating debris, vegetation, and sediment. In addition, animals such as beaver and muskrat have a natural tendency to plug structures if they have access to them (**Figure 4.4.14**). Efforts to keep outlets functioning and clear of debris are a cause of significant frustration for landowners, project managers, and wetland designers. The design of every wetland outlet needs to incorporate design measures to address these issues.

> Outlets are highly susceptible to becoming blocked or plugged by wetland vegetation.

The primary means to prevent plugging or blocking of outlet structures is to deny or limit the ability for floating debris, sediment, or animals from accessing the structure, without affecting its overall hydraulic performance. While no strategy can completely protect an outlet from being plugged or blocked, certain measures can be taken to keep them functioning and to reduce

Figure 4.4.12 *Preparing for a Concrete Footing on an In-Line Water Level Control Structure*

Figure 4.4.13 *Installing Sand Drainage Diaphragm and Filter at Outlet End of Pipe Structure*

Figure 4.4.14 *Plugged Outlet Caused by Beaver*

future maintenance. These measures include, but are not limited to, using **guards, grates, trash skimmers, fence barriers,** and **drain filters** as part of the outlet structure. Information about each of these measures is discussed below.

Guards/Grates

Guards and grates are often a critical element of the outlet structure design and serve several functions including preventing debris or animals from entering the structure. They can also provide an element of safety and protection against vandalism and safety at structure inlets, particularly those structures that are larger in size and where potential safety and vandalism issues exist. The design and fabrication should consider:

- Guards must have a combined total open surface area such that partial plugging of it will not adversely restrict flows or affect hydraulics of the structure.
- Bar spacing should be wide enough to allow small debris to pass and to avoid interference with structure hydraulics but close enough to provide the level of clogging and safety protection required.
- The spacing of trash guard bars must be proportioned to the size of the smallest outlet device being protected.
- They should be designed to allow debris to be easily removed or be shed from the structure as wetland flood waters fluctuate.
- They should be located both on the inlet and outlet ends of a structure, where applicable.

Pipe structures will be most prone to plugging, especially those that are 15 inches in diameter and smaller. When pipes are used as a drop inlet, a domed or conical type trash guard should be incorporated onto the inlet. For small-diameter drop-inlet pipes, several manufactured guards are available through pipe and drainage product suppliers (**Figure 4.4.15**). Some of these guards will have bar spacing too small for wetland applications; avoid using them as they readily plug and will require frequent maintenance to keep them clean (**Figure 4.4.16**). **Table 4.1** provides the recommended minimum bar spacings, diameters, and guard heights for trash guards associated with various sizes of vertical pipe inlets. Guards for larger size drop inlets need to be

Figure 4.4.15 *Heavy Duty Bar Guard Type Trash Guard*

Table 4.1 ***Minimum Fabrication Requirements for Trash Gaurds***

Pipe Diameter (inches)	**6**	**8**	**10**	**12**	**15**	**18**	**24**
Bar Spacing (inches)	2	2.3	2.7	2.7	2.7	3.1	4
Bar Diameter (inches)	1/4	5/16	5/16	1/2	1/2	1/2	1/2
Guard Height (inches)	4.75	6	7	9	11	13	14

Figure 4.4.16 *Removing Debris from Plugged Trash Guard*

Figure 4.4.17 *Trash Guard on Culvert End*

specially designed for additional strength and to allow debris removal.

Guards and grates are also available for horizontal culvert applications. On the pipe inlet, they are incorporated onto end sections that are attached to the pipe; this provides a larger surface area for improved debris blockage without compromising the hydraulics of the structure (**Figure 4.4.17**). Smaller culverts are at the greatest risk of plugging.

For pipe outlets 18 inches in diameter and smaller, self-cleaning, hinged type guards should be installed onto the outlet end of the pipe to prevent animal access into the structure (**Figure 4.4.18**).

Trash Skimmers

The use of trash skimmers in addition to, or in lieu of, trash guards is recommended, when applicable. A trash skimmer is designed to keep floating debris from approaching and clogging outlet structures. Water that is forced under a skimmer or through a submerged opening in a structure is generally free of debris, thus limiting the extent of clogging and future maintenance that will be needed for the structure.

Skimmers are used around or in front of trickle drains, drop inlets, culverts, and some weir structures. A variety of types and configurations for skimmers exist. The type of skimmer device will be governed by the type of outlet structure used. For example, catch basins or drop inlet structures that utilize an internal weir for elevation control can incorporate submerged inlet pipes or submerged orifice openings in the

Skimmers can reduce long-term maintenance.

Figure 4.4.18 *Hinged Rodent Guard on Pipe Outlet*

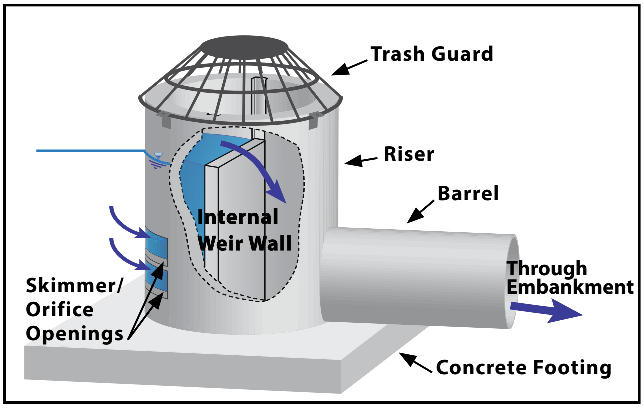


Figure 4.4.19 *Skimmer Orifice in a Catch Basin with Internal Weir Wall.*

front of the structure, which will function similarly to a skimmer device (**Figure 4.4.19**). When catch basins or drop inlet structures do not utilize an internal weir wall, a reversed-sloped pipe as part of multi-staged inlet can function as a skimmer (**Figure 4.4.20**).

To be most effective, skimmer devices should be submerged a minimum of six inches below the normal wetland water surface. The wetland depth as well as the potential risk of sediment deposition at the entrance to the outlet structure both need to be evaluated when designing the elevation and type of skimmer device to use.

For other drop inlets, trickle drains, culverts, and weir structures, skimmer devices may be constructed as a separate structure. They will either be secured to the outlet structure or installed as a free-standing system in front of or completely around the structure inlet. The top elevation of the skimmer device is usually set to a specific design flood elevation for the wetland. This elevation must not be set so high as to affect frequency and use of the emergency spillway should the opening under the skimmer device somehow get blocked.

For most wetland applications, surface skimmers will consist of treated boards that are a minimum of 12 to 14 inches in height. The midpoint of the board should be set at the normal wetland water surface elevation. A gap or space a minimum of 6 inches in height should exist under the board to allow water to freely flow under the skimmer (**Figure 4.4.21**). There are several variations to how surface skimmer systems are designed and constructed. They can either be constructed around an inlet or across an approach channel in front of an inlet. When placed across an approach channel, two boards placed in the shape of a "vee" is the recommended design layout.

Materials such as composites, composite liners over wood or treated metals can be used as the skimmer device in place of treated lumber. The use of these materials can increase the life expectancy of the structure.

Rock riprap with an appropriate underlayment such as geotextile or landscape fabric is often used to inhibit the growth of vegetation in the area between the surface skimmer and the wetland's outlet structure.

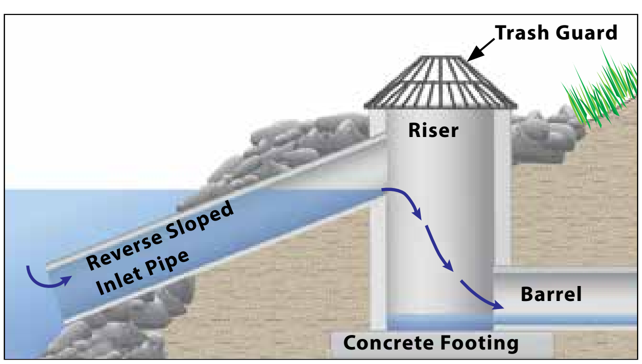


Figure 4.4.20 *Reversed Slope Inlet Pipe to Drop Structure*

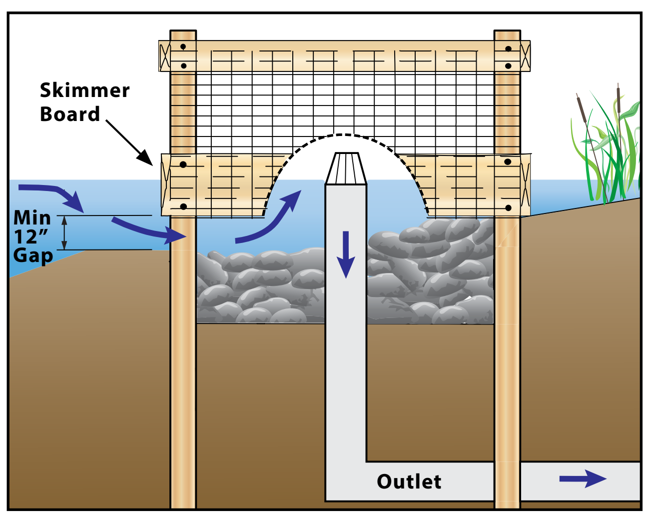


Figure 4.4.21 *Skimmer Enclosure Around Drop Inlet*

Figure 4.4.22 *Fence Barrier Around Drop Inlet Structure*

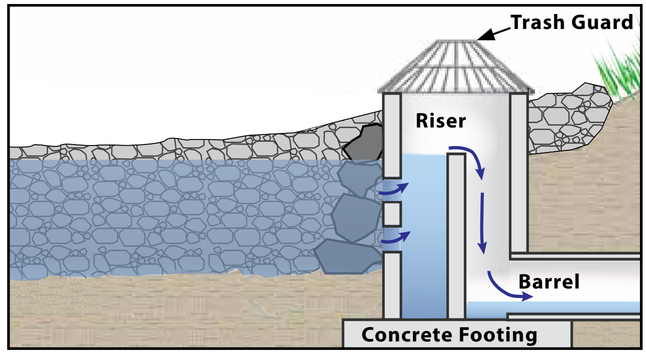


Figure 4.4.23a *Inlet System with Drain Filter*

Fence Barriers

Properly designed fence barriers or enclosures can be used to deny or deter animals and debris from access to an outlet structure. Fence barrier designs have been successful at deterring beaver from constructing dams in front of culverts and other outlets (**Figure 4.4.22**). Fence systems can also be incorporated above free standing surface skimmers to further inhibit the passage of debris where more extreme water level fluctuations are expected. Fence systems are sometimes extended below the skimmer device to prevent muskrats and beaver from having access to the wetland's outlet structure.

The use of a fence barrier system, whether for rodent control or to block debris, will not be maintenance free. Floating debris blocked by the wire must be routinely cleaned.

Drain Filters

Drain filters or infiltration systems can provide an effective method to address potential issues with plugging or blocking of certain outlet structures. These structures require an internal weir or other similar device that can control wetland water levels independent of the structure's inlet system (**Figure 4.4.23a**). Rock aggregate placed around and in front of the structure serves as the drain field. When properly designed and installed, the aggregate drain field will filter out and prevent debris, sediment, or animals from entering the outlet structure (**Figure 4.4.23b**). These systems can also provide an effective means at controlling fish passage into a wetland.

An appropriately designed filter will usually include multiple gradations of aggregate placed in layers within the drain field. The size of the drain field along with the size and gradation of aggregate needed will be a function of site conditions and type of outlet. Drainage efficiency of the inlet system can be improved by incorporating one or more short sections of small diameter perforated conduit within the submerged aggregate drain field.

Figure 4.4.23b *Rock Filter Enclosure of Riser*

Figure 4.4.24a *Trickle Drain with Aggregate Drain Filter*

This type of inlet system is generally limited to settings where little to no sediment will be introduced to the drain field and where relatively small wetland discharges are expected. This type of inlet system is therefore ideal for trickle drain structures as they are intended to pass low flows and are otherwise highly susceptible to plugging (**Figure 4.4.24a.**) Greater wetland discharges can be accommodated with larger drain fields containing multiple conduits (**Figure 4.4.24b**). Complex hydraulic analyses will be needed to properly design these larger infiltration systems.

Other Design Considerations

Managing Wetland Water Levels

Wetland hydrology in terms of depth, area, and duration of wetland flooding after runoff events will be affected by characteristics of the wetland and its watershed, hydraulic capacity of any planned outlets, seasonal rainfall and climate conditions, and other natural wetland functions and processes. These natural processes will invariably have an effect on annual wetland water levels and other wetland functions including type and diversity of plant and animal communities found in and around the wetland.

Most wetland restoration and creation projects will not allow for or need a great degree of flexibility in managing wetland water levels once established. These projects, once completed, will tend to function as they did prior to their drainage and adequate management will occur through seasonal hydrologic changes.

Having the ability to adjust water levels can benefit a variety of wetland functions.

For some projects, however, there will be a desire or need to physically manage wetland water levels. Water level management can be especially beneficial during the initial establishment phase of a project, as the germination and establishment of desired wetland plant species may best occur with low water levels or moist soil conditions. Over time, as projects continue to develop, water level adjustments can allow for better management or control over wetland vegetation, fish, and animal species and may provide easy access for repairs or maintenance to wetland outlets, embankments, and other structures. Managing water levels also provides opportunities for maximizing the flood storage benefits of a project through timed drawdown events.

Figure 4.4.24b

Figure 4.4.25 *Concrete Drop Structure with Stoplog Bay*

With those added management benefits comes the additional cost to design and install this outlet feature. There will be increased costs for maintenance and management, potential for increased vandalism and for undesired or unauthorized management of water levels. The benefits of being able to manage water levels with a control structure need to be weighed against the drawbacks. Additional discussion on the benefits of managing water levels occurs in **Section 6-2 – Management Strategies, Water Level Management**.

Figure 4.4.26 *Steel Sheet Pile Weir with Stoplog Bay for Managing Water Levels*

Water level management typically occurs through the use of specially-designed outlet features or devices that are incorporated as part of a drop inlet or weir-type principal structure. A limited number of pre-manufactured outlet devices exist that provide for water level management and their use is encouraged, where applicable. Where the outlet type or other requirements of the project prevent the use of manufactured structures, it will be necessary to specially design and fabricate a structure that provides this option. This entails the incorporation of stop log bays, gates, or valves as part of the structure (**Figures 4.4.26 and 4.4.27**). The potential configurations for these various devices are numerous and, if used, should provide the following features:

- Allow incremental regulation of water levels
- Be relatively simple to operate
- Be watertight when necessary to prevent the loss of wetland hydrology
- Be durable, secure, and protected from vandalism
- Require minimum maintenance
- Not be susceptible to blocking or plugging with sediment or debris
- Prevent or inhibit blockage by muskrats or beaver.

Water levels in many restored and created wetland systems with fixed outlets can still be occasionally managed; however, it will require more drastic measures such as a temporary breach in an embankment, temporary ditching, or possibly even pumping.

Fish Passage/Barriers

The design of a wetland's outlet needs to take into consideration any concerns that may exist for managing the movement of fish or other aquatic species. This can include designing to either allow or to prevent their passage.

Many restored wetland systems are located along or connected to a riparian system or other water resources

Figure 4.4.27 *In-Line Water Level Control Structure*

that contain desirable fish and other aquatic species. The restoration of these wetland systems can provide an opportunity to improve conditions for habitat, migration, and reproduction of these target aquatic species. A wetland outlet that allows fish passage may be a desired goal for a particular wetland site. If so, the hydraulic performance of the structure will be critical to its success. Structures with high discharge rates or vertical drops can be effective at preventing the passage of certain aquatic species such as fish. To design these systems it will be necessary to understand both the project goals as well as the biological characteristics of the target aquatic species. For example, the passage of a desired species of fish through an outlet structure might require a specific range of flow depths and velocities. Project designers are encouraged to consult with other resource professionals or literature for design guidance.

In contrast, the presence of certain fish species in a restored wetland can be detrimental to water quality and wetland function. Bottom feeding fish such as carp and bullhead can be problematic to many wetlands. These nuisance fish species are often introduced to shallow wetlands each year via their annual upstream migration from other, more permanent downstream wetlands, lakes, and rivers. Upon gaining access to these shallow wetlands, they uproot wetland vegetation that, in turn, suspends bottom sediments and nutrients. The resulting algal blooms negatively affect water quality and desirable vegetation within the wetland system. Recent studies have shown that even fathead minnows can have a significant impact on invertebrate communities and biological health of a wetland.

To some extent, the introduction of these and other undesirable aquatic species to restored wetland systems may be controlled by the design of the wetland's outlet. In certain situations, outlets can be designed to function as a barrier to prevent the upstream movement of nuisance fish and other aquatic organisms. Fish barriers, under the right circumstances and design, can be an effective management option for a restored or created wetland. The use of barriers as a management strategy is not uncommon in the design of wetland restoration projects in Minnesota, although their use is more common at larger sites where protection of the resource is more highly valued.

The applicability of fish barriers is highly dependent on site conditions. A fish barrier is either a natural or man-made structure typically incorporated as part of a wetland's outlet. Barriers are most common across open ditch systems to prevent the upstream movement of aquatic species. Considerations for a barrier should not, however, be limited to open ditch systems. Surprisingly, fish movement through larger, subsurface tile drainage systems is common when fish have access to and can enter the tile system at its outlet.

Natural barriers are preferred because they function passively, requiring only that sufficient vertical grade or elevation difference exists from the wetland's water surface to that of the downstream outlet. However, most potential restoration sites are not able to utilize a natural barrier and other design considerations are needed if a barrier is desired.

Barriers can exist in several forms. A brief discussion of the more commonly used barriers including **vertical**, **hydraulic**, and **mechanical** systems occurs below. Specific information on the biology of various fish species is needed to design an effective barrier and should be obtained from consultation with other literature and resource professionals.

Vertical Barriers

A vertical barrier is simply a vertical wall or dam that prevents the upstream passage of aquatic species. The vertical height of the barrier needs to exceed the leaping abilities of target fish species. To be completely effective at controlling the passage of carp for example, the vertical barrier must create a vertical drop between upstream and downstream water levels of at least four to five feet, with six feet or more being preferred (**Figure 4.4.28**). This difference needs to be main-

Figure 4.4.28 *Vertical Fish Barrier*

tained over the entire opening of the structure and for all potential flow conditions. The tailwater condition becomes critical to the design of this type of structure not only because of its potential to reduce the vertical elevation difference during high flow conditions but also because deeper water on the downstream side of the barrier allows fish greater opportunity for propulsion, which can increase their leaping abilities. Drop inlets and weir structures are commonly used for this type of barrier.

Hydraulic Barriers

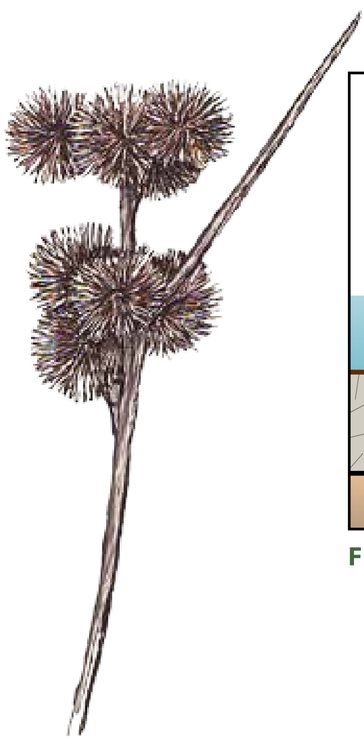
Hydraulic barriers utilize both the vertical relief of the outlet and the velocities of water that flow through it to preclude upstream fish passage. Hydraulic barriers can resemble vertical barriers under most hydraulic conditions, the difference being that high flow rates or velocities will occasionally exist that exceed fish swimming abilities, thereby augmenting the effectiveness of the barrier. The vertical height of the barrier controls fish passage under low flow conditions and fast-flowing water controls passage during high flow conditions.

Another form of hydraulic barrier is the high velocity tube or culvert. A single culvert or series of culverts designed with sufficient grade and length with little to no tailwater influence can create flow conditions that are an effective barrier to fish passage (**Figure 4.4.29**). Pipe lengths will often need to exceed 60 feet more for this type of barrier to be effective. The minimum pipe grade needed will be a function of the length, size and type of pipe used. Tailwater conditions must also be considered; any submergence of the culvert at the outlet will reduce its effectiveness as a barrier. For each specific project situation, design software for fish passage should be used to determine the minimum requirements for an effective high velocity tube fish barrier.

Culverts of sufficient length and grade can be effective fish barriers

Mechanical Barriers

A variety of types of mechanical barriers exist. They are typically a grated or screened device that prohibits or blocks the passage of fish. The advantage of these types of barriers is that they are not as dependent on velocities, vertical relief, or fall as are **vertical** or **hydraulic** barriers. The disadvantage is that in addition to fish, they also can block debris and are subject to plugging, potentially requiring a great deal of maintenance. Mechanical barriers should be designed for the full range of potential hydraulic conditions while considering the frequency and cost of maintenance.



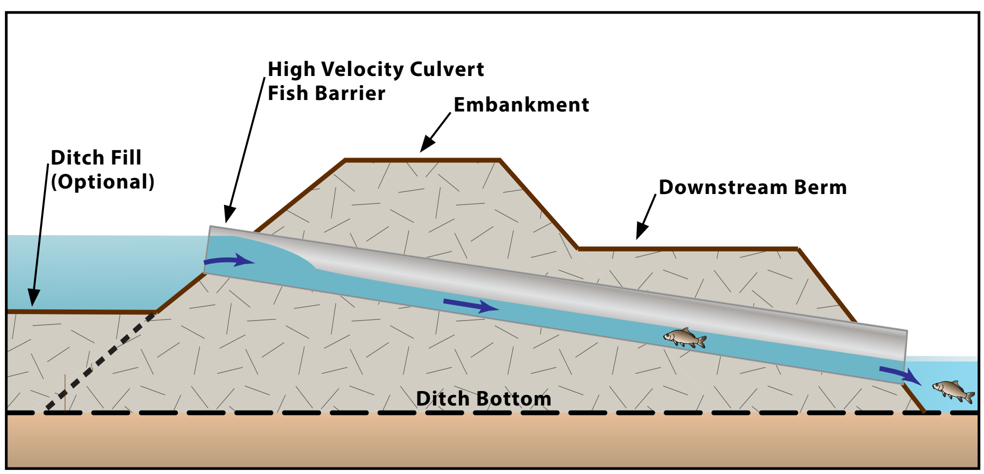


Figure 4.4.29 *High Velocity Culvert Fish Barrier*

A common type of mechanical barrier is the vertical screen, which utilizes a series of closely-spaced bars to prevent the passage of fish. Vertical screens can be used in a variety of ways, with the bar orientation being governed by the application and design preference. Vertical screens are often placed as stationary devices on the end of culverts but also can be fitted into specially-designed bays or channels within weirs and other drop structures (**Figure 4.4.30**). Consider a design that incorporates removable screens, to simplify maintenance.

Figure 4.4.30 *Vertical Screen Barrier*

A common variation to the stationary vertical screen is a screen with vertical, swinging bars otherwise known as swinging or hanging fingers. The concept behind swinging fingers is to periodically allow debris to pass through the barrier from the pressure of flowing water. The swing finger device must be properly designed in terms of weight and screen angle to ensure its effectiveness. As with stationary screens, swinging fingers can be fitted onto the downstream end of culverts or installed as part of a weir or drop structure (**Figure 4.4.31**).

Another type of mechanical barrier is the horizontal screen or grate. This type of barrier entails fastening horizontal screens or grates to the downstream crest of weirs or other drop structures. This type of barrier requires some vertical relief within the structure to be effective. Water that flows over the structure's crest is allowed to pass down through the extended horizontal screen. Fish moving upstream through the structure will tend to congregate against the downstream wall of the structure, under the horizontal screen where water is falling. The horizontal bars should have some slope to them to more efficiently pass debris over the screen or grate and they must extend far enough downstream of the structure to block jumping fish. This length will vary with each situation, however, a minimum projection length of six feet is recommended. Tailwater submergence can compromise the effectiveness of a horizontal screen. This can be addressed by adding swinging vertical fingers on the downstream end of the horizontal screen (**Figure 4.4.32**).

When using grates or screens as a mechanical fish barrier, the bar type, size, and opening space between the bars or grates become important design considerations. Round bars can be used and are fairly effective at shedding vegetative matter and other debris. However, round bars can decrease the opening size or area of the grate and can influence potential flow rates through the structure. For that reason, narrower flat bars are more commonly used, even though they may be slightly more susceptible to plugging. Bar spacing and weight are perhaps the most important elements of the design. To prevent the passage of all but the

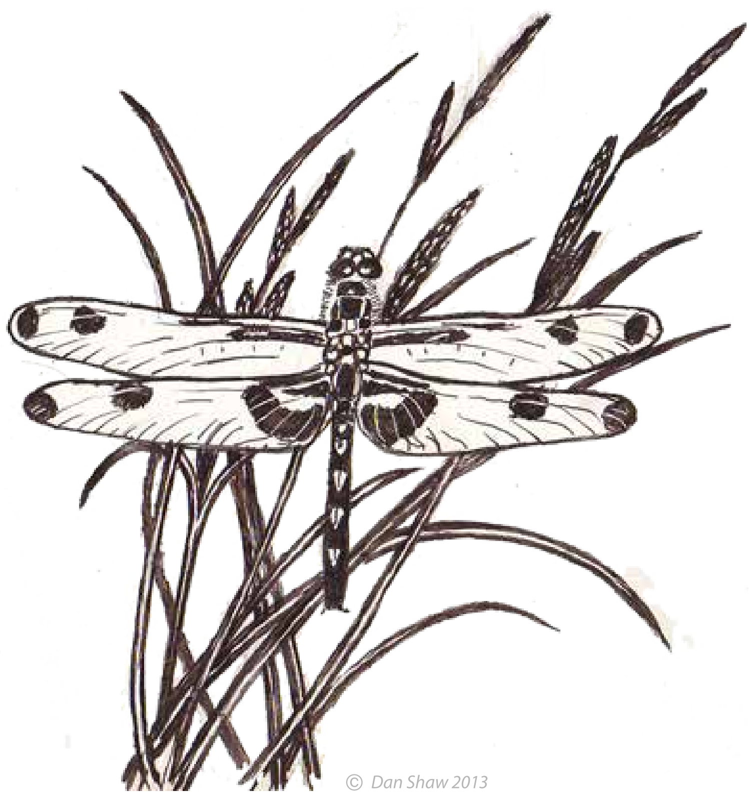
Figure 4.4.31 *Swinging Fingers on Box Culvert Outlet*

Figure 4.4.32 *Horizontal Screens with Vertical Swinging Fingers*

smallest of fish, the maximum open space between the bars should be 1 ¼ inches.

Other Types of Barriers

Other types of barriers including rotating slotted drums, baffles, and electric barriers do exist but are rarely used as part of wetland restoration projects in Minnesota either due to their cost or effectiveness considering the climate. These types of barriers are more commonly used in restoration efforts on lakes and other larger, riparian systems. They are more adept at preventing the passage of all sizes and types of fish. The disadvantage with these types of barriers is that they will require extensive effort and staff resources to the keep them functioning and maintained.



4-5 Earthen Embankments

Figure 4.5.1 *Wetland Embankment*

Earthen structures are an integral component of many wetland restoration and creation projects. They are used to block, control, retain, and manage or divert the flow of water into or out of project sites. Embankments, dikes, ditch plugs, levees, dams, and berms are all terms used to describe earthen structures.

In this Guide, the term **embankment** will be used as a general representation for all types of earthen structures. In specific instances, however, **ditch plugs**, which are earthen fills strategically located within a drainage ditch, and earthen **berms**, which are built along and adjacent to embankments, roads, and other infrastructure to reinforce and protect them from saturation, wave damage, and rodent damage, will be discussed separately from embankments.

This chapter of the Guide discusses considerations and strategies for the design and construction of earthen embankments. The application of this information must be consistent with the scope of the project. The engineering design information discussed and presented is applicable to earthen embankments planned for small and moderate-scope projects. For larger structures and sites with more complicated geotechnical issues, the information presented will provide a general understanding of important design features. The more demanding engineering investigations and design methods associated with those projects may, however, be beyond the scope of this Guide.

An overview of the following list of strategies is discussed in this chapter of the guide with more specific and detailed information provided in Technical Guidance Documents that are located in Appendix 4 and referenced accordingly.

- **General Considerations**
- **Location and Alignment**
- **Types of Embankments**
- **Construction Materials**
- **Embankment Seepage and Stability**
- **General Design Components**
  - *Foundation Preparation*
  - *Height*
  - *Top Width*
  - *Side Slopes*
  - *Compaction*
  - *Stabilizing the Constructed Fills*
- **Other Design Considerations**
  - *Protection from Wave Action*
  - *Controlling/Minimizing Animal Damage*
  - *Constructing Embankments Across or Adjacent to Surface Ditches*
  - *Constructing Embankments in Floodplains*

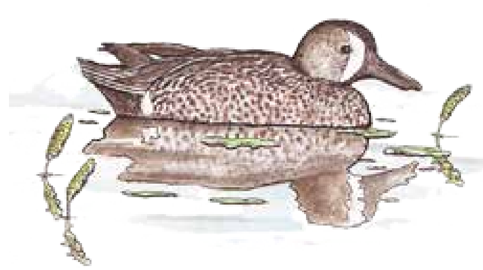


Figure 4.5.2 *Wetland Embankment Under Construction*

General Considerations

Earthen embankments are constructed by hauling selected earthen material into place and compacting it layer upon layer with heavy equipment or rollers to form a bonded mass that is relatively water-tight. With thorough investigations, comprehensive planning, and sound design and construction, earthen embankments can be successful, sustainable components to any wetland restoration or creation project.

Design information presented in this Guide applies to embankments constructed in rural or agricultural areas where minimum damage is likely to occur from failure. Design guidance for embankments is limited to, exclusive of crossings at ditches and channels, a maximum water stage against the embankment of six feet for mineral soils and four feet for organic soils.

Although earthen embankments are used to help restore or create wetland hydrology, their use in managing wetland runoff or protecting adjacent properties and other infrastructure from hydrologic impacts is often overlooked, despite being necessary for the success of many projects. The use of embankments to restore or create wetlands needs to be consistent with the goals of the project and the program under which it is being completed. Constructing embankments for the purpose of enhancing wetland water depths or to restore only portions of a drained wetland basin requires careful consideration in regard to the project scope and the long term maintenance issues that will be associated with the project.

Embankments need to be designed and constructed to be long lasting with limited risk of failure. When used in wetland restoration and creation projects, embankment failures can occur when any of the following conditions exist:

- The embankment is overtopped during flood events
- The embankment is exposed to excessive wave action
- Excessive seepage occurs through or under the embankment
- Poor materials or improper compaction methods are used
- Excessive settlement or the consolidation of under lying soils
- Burrowing animals such as muskrats or beaver are allowed access to the constructed fills.
- Excessive soil erosion or rilling due to poorly established or improperly maintained vegetative cover

All of these potential sources for failure can be eliminated or greatly minimized through careful and proper planning, design, and construction. The importance of this cannot be overstated, considering the frequency of embankment use on wetland restoration and creation projects.

To properly design and construct embankments requires a basic understanding of soil behaviors and engineering properties, along with knowledge of design and construction strategies and techniques that are appropriate for the scope of the project. The majority of earthen embankments for wetland restoration and creation projects will be relatively straightforward structures to design and construct. These are low-head structures that require a moderate amount of site investigation and preparation work. They utilize on-site materials that are in close proximity to the construction area and suitable for their intended purpose.

Certain embankments, however, will require a more comprehensive approach to their design and construction. These include embankments that will have varying or poor foundation conditions, have a limited supply of quality materials for the embankment fill, are relatively high or will have deep water against them, are associated with large open water wetland systems, will be used as a road surface, or have other site constraints or concerns.

Location and Alignment

Embankments constructed for wetland projects are most often located across drainage ditches or swales at the wetland's outlet. They are also located along property or project boundaries and, in some situations, parallel to drainage systems that will remain functioning after the project is completed.

The placement or location of an embankment within a project can be critical to its success. Site topography will be a major factor in determining an embankment's location; however, the site's geology, drainage features, and outlet or spillway needs must also be considered. An example of this occurs when constructing an embankment or ditch plug across a ditch with a vegetative spillway around one end of the constructed fill. The location and layout of the associated spillway should be designed to minimize excavation but also to provide a safe, stable outlet slope back into the downstream ditch. These design concerns for the spillway will often be the controlling factor in determining the location and alignment of the associated embankment (**Figure 4.5.3**).

> Careful planning is required to identify when and where embankments are used.

Complete a comprehensive review of the site's topography and geology to determine the location and feasibility of any planned embankments. Embankments should be located on soils that will provide the best foundation conditions possible, allowing the most appropriate materials in their construction.

Embankments may also be constructed to protect adjacent areas from wetness or flooding that will result as a consequence of restoring or creating a wetland. Drainage may need to be established downstream of these embankments as a part of protecting these adjacent areas, especially when constructed along property lines. In these situations, consider setting an adequate buffer or setback distance from the adjoining property.

To improve habitat features and general project aesthetics, it is recommended that, to the extent practicable, embankments be constructed to blend into the existing topography. This is best accomplished by incorporating curvilinear features to the embankment's alignment and finishing it with relatively flat side slopes (**Figure 4.5.4**).

Types of Embankments

Earthen embankments must be designed and constructed to be stable and relatively impervious. Two types of embankment designs address these basic requirements. The selection of one or the other type will be governed largely by the availability of suitable construction materials.

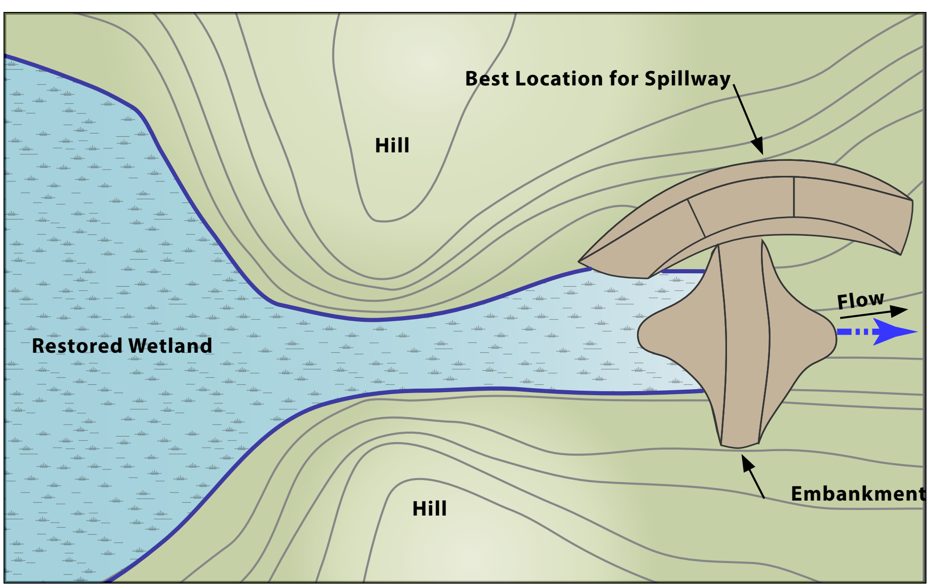


Figure 4.5.3 *Most Suitable Location for Spillway and Associated Earthen Embankment*

Figure 4.5.4 *Curvilinear Embankment Alignment with Relatively Flat Side Slopes*

Homogenous Type

Most earthen embankments will be constructed with a homogeneous soil material throughout. The embankment is uniformly constructed with the same soil material and is joined to an impervious foundation stratum (**Figure 4.5.5**).

This is the most common method of embankment design and is used when sufficient quantities of suitable borrow material are available.

Zoned or Core Type

When the availability of suitable soil material for embankment construction is limited or when excess random excavated soil material needs to be disposed of, a core or zoned type of embankment should be considered. With this design, a central section of highly impervious soil material is constructed within an embankment that is finished with less-permeable or lower-quality material (**Figure 4.5.6**). This type of embankment design can effectively restore wetland hydrology and control seepage through the embankment while reducing the percentage of high-quality fill material needed for construction.

The design elevation of the inner core is set to a predetermined, designed flood stage. The dimensions of the inner core will vary depending on project scope and construction equipment used. Recommended minimum top widths for the inner core are four feet; however a top width of six to eight feet is easier to construct. Recommended minimum side slopes of the inner core are one-to-one.

Upon completion of the inner core, the outer surface or shell of the embankment is then constructed. The outer shell will typically be constructed with more readily-available, less-impervious mineral, or organic soils. The dimension of the outer shell will vary. Broad top widths and flat slopes should be utilized. The outer shell should be graded to fit the existing site topography, to improve the finished appearance of the structure. This provides a great opportunity to utilize excavated soil material from the other areas of the project. For example, material excavated from scrapes or sediment removals within a drained or altered wetland can be used for this purpose, which avoids the necessity of moving this material to other, more distant areas on the project.

Ditch Plugs

Ditch plugs commonly describe earthen embankments that are strategically placed within and across surface drainage ditches to restore wetland hydrology. Either the homogenous or zoned type embankment can be used when designing ditch plugs. More detailed discussion on designing and constructing ditch plugs and associated ditch fills occurs in the Blocking and Filling Surface Drainage Ditches **Technical Guidance Document** located in Appendix 4X-1.

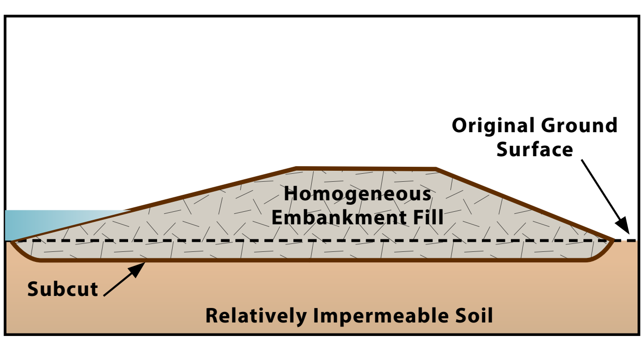


Figure 4.5.5 *Embankment Section with a Homogenous Fill*

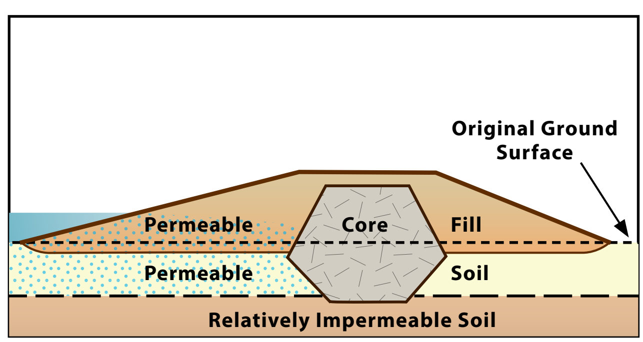


Figure 4.5.6 *Embankment Section with a Core or Zoned Fill*

Berms

Berms are a secondary earthen structure built adjacent to and along newly constructed or existing embankments, roads, and other infrastructure. They reinforce and provide additional protection from seepage, saturation, wave damage, and rodent damage. Additional discussion on the use of berms occurs later in this Chapter under Other Design Considerations.

Construction Materials

Soil materials used in the construction of earthen embankments are taken from what are generally referred to as "borrow areas". Borrow areas should be located where the most suitable material for construction of the embankment is available. Determine their locations by reviewing soil survey information and performing on-site geological investigations.

The best borrow material for embankment construction will be from upland soils on the project site. However, borrow material can be taken from within a drained wetland, provided the soil materials and moisture conditions are suitable.

General considerations for locating and constructing borrow areas include:

- Locate and utilize the best material available. Consider using materials resulting from other on-site excavation activities (i.e. construction of spillways, ditches, shallow scrapes, etc.).
- Borrow excavations should be kept at least 100 lineal feet from any planned embankment (**Figure 4.5.7**).
- Most borrow sites will require stripping the surface layer of topsoil or sediment material as it will likely be unsuitable for use in embankment construction. The stripped topsoil material should be spread on the finished borrow area surface to provide a suitable medium for new plant growth.
- Borrow areas should be investigated at time of construction for material suitability and soil moisture content. Soil moisture may influence selection of borrow areas or excavation depths. Deeper excavations are more likely to encounter groundwater or soil material that is simply too wet for use.
- Borrow areas taken along an edge or shoreline of a planned wetland may provide for better and drier soil material than from the wetland bottom and can provide opportunities to increase the size and diversity of the restored wetland basin.

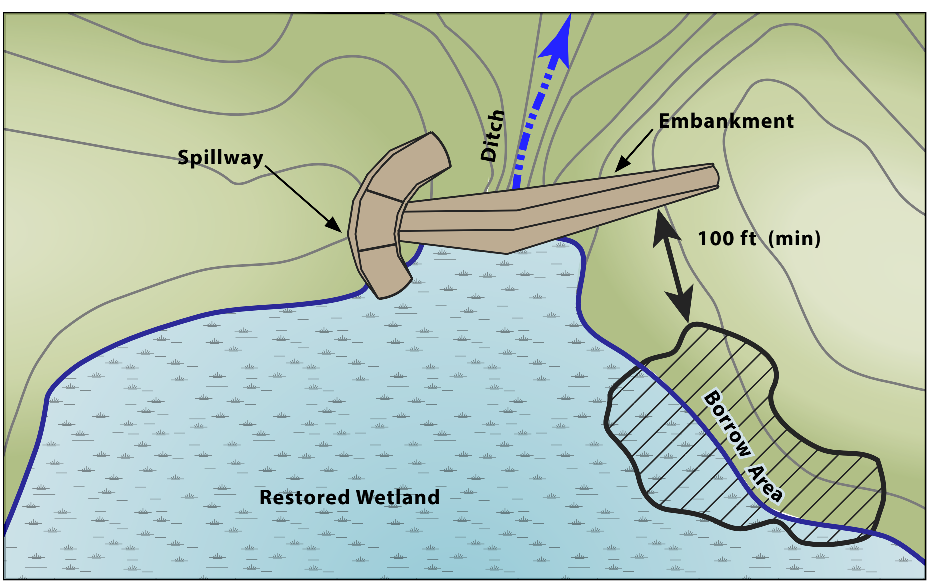


Figure 4.5.7 *Maintaining an Appropriate Buffer Distance Between Borrow Area and Embankment*

- Borrow areas should be finished to have irregular or curvilinear edges with stable side slopes. Finished slopes that are 5:1 or flatter are recommended. Requirements for final grading and topsoiling should ensure the borrow area blends into the site and appears a natural part of the landscape.
- Borrow materials should be located within a reasonable distance from the embankment site as it is usually not feasible to transport borrow materials great distances within a site or from off-site areas. It is often more cost effective to change the design or location of an embankment rather than to pay the high costs of transporting suitable fill material. In some situations, multiple borrow areas may be needed to minimize haul distances (ie. one at each end of a long embankment).

Earthen embankments for most wetland projects will be of relatively low height. This allows for a variety of soil types to be considered for use in their construction. **Table 4-2** provides information on soil characteristics and can be used as a guide to determine the suitability of soils for the construction of most wetland embankments. The information provided considers soil stability, foundation support, compatibility, and permeability. The soil groups in this table are listed in order of suitability and include all soil classes except GW, GP, SW and SP, which are generally not suitable for use. The group symbols shown in the table are from the USDA NRCS Unified Soil Classification System.

To the extent possible, organic soils, other semi-permeable soils, and soils with low stabilities should be avoided in the use of embankment fills. In some situations, however, no other practical alternative will exist and the use of these soils is necessary. Certain precautions and design requirements are needed to address potential issues with surface and tension cracking, decomposition, strength, permeability, subsidence, settlement, burning, and future maintenance. These soils are difficult to compact, especially when wet. They are also more susceptible to wave damage and damage caused by burrowing rodents, in particular muskrats. In addition, a concern with fire exists for embankments constructed with organic materials, especially peats. Limit the use of these poorer soils to areas where shallow water up to one foot in depth will exist against the embankment. Greater depths can be accommodated but will require additional design precautions and considerations.

> Special design precautions are needed when constructing embankemnts with organic soils

When using highly plastic organic clays, dispersive clays, and low-plasticity silts in embankments, a high potential exists for these soils to begin to fracture and crack after they are placed and compacted (**Figure 4.5.8**). These tension cracks can become deep and interconnected, increasing the risk of and problems associated with embankment seepage. The use of these soils requires that certain design precautions and strategies be taken. These include, but are not limited to, proper moisture and density control, use of filters and filter drains, and the select placement and use of available materials. Keeping embankments well vegetated will help to some degree with reducing tension cracking as it helps to maintain moisture in the soil material. Problems can develop, however, during prolonged dry spells or drawdown of wetland water levels.

The use of highly plastic organic clays, dispersive clays, low-plasticity silts, and organic soils in embankment

Figure 4.5.8 *Embankment Soils Fracturing*

Table 4.2 ***Soil Characteristics and Their Suitability for use in Embankment Construction***

	Group Symbol	Soil Description	Embankment Suitability	Permeability and Slopes
GOOD	GC	Clayey gravels and gravel-sand-clay mixtures	■ Stable- adequate for all stages ■ Good foundation bearing ■ Good compatibility	■ Slow Permeability
GOOD	SC	Clayey sands and sand-clay mixtures	■ Stable- adequate for all stages ■ Generally good foundation bearing ■ Fair compatibility	■ Slow Permeability
GOOD	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, and lean clays	■ Stable- adequate for all stages ■ Fair foundation bearing ■ Fair compatibility	■ Slow Permeability
FAIR	SM	Silty sands and sand-silt mixtures	■ Fairly stable - adequate for low stages ■ Fair foundation bearing ■ Good compatibility	■ Moderate permeability ■ Use flat slopes and protect against wave action
FAIR	ML	Inorganic silts, very fine sands, silty or clayey fine sands, and clayey silts of slight plasticity	■ Low stability - adequate for low stages ■ Fair foundation bearing ■ Fair compatibility	■ Moderate permeability ■ Use flat slopes and protect slopes against all erosive forces
FAIR	CH	Inorganic clays having high plasticity and fat clays	■ Fairly stable - adequate for all stages ■ Poor foundation bearing ■ Subject to surface cracking when dried ■ Difficult to compact	■ Very slow permeability ■ Use flat slopes
FAIR	MH	Inorganic silts, micaceous or diatomacaceous fine sandy or silty soils and elastic silts	■ Very low stability - adequate for low stages only ■ Poor foundation bearing ■ Difficult to compact	■ Slow permeability ■ Use flat slopes and protect slopes against all erosive forces
FAIR	OL	Organic silts and organic clays having low plasticity	■ Very low stability - adequate for low stages only ■ Poor foundation bearing ■ Difficult to compact	■ Moderate permeability ■ Use flat slopes and protect slopes against all erosive forces
FAIR	OH	Organic clays having medium to high plasticity and organic silts	■ Very low stability - adequate for low stages only ■ Poor foundation bearing ■ Subject to surface cracking when dried ■ Difficult to compact	■ Very slow permeability ■ Use flat slopes
FAIR	PT	Peat and other highly organic soils	■ Very low stability - adequate for low stages only ■ Poor foundation bearing ■ Difficult to compact	■ Variable permeability ■ Use flat slopes

construction will inevitably require a higher level of monitoring and maintenance. Many of the potential problems with using these materials can be minimized by adding a 6- to 12-inch blanket of mineral soil on the embankment surface. When using these poorer materials, broad embankment top widths, flat side slopes, and upstream/downstream berms may be needed to help address issues with slope stability and seepage.

Embankment Seepage and Stability

Potential issues with seepage and stability need deliberate consideration when designing and constructing earthen embankments. Seepage occurs in varying degrees within every earthen embankment that holds or ponds water. It occurs due to hydraulic pressures against the embankment and the underlying foundation.

Because all embankment fills are permeable to some degree, a seepage or saturation zone will develop within every embankment fill section. The upper limit of this saturation zone is referred to as the "phreatic line". Embankments will be most stable when the phreatic line is contained within the fill section (**Figure 4.5.9**). Problems with seepage can develop when the phreatic line is allowed to exit at some point above the toe of the downstream embankment slope (**Figure 4.5.10**). Problems with seepage can also occur when pores or cracks develop within the embankment fill. This can result from using poor construction materials or improper compaction.

Excessive seepage can erode soil particles from embankment fills.

Seepage losses through an embankment can cause excessive uplift pressures at the downstream toe of the embankment, create problems with slope stability, and reduce soil shear strengths. Embankment seepage can also physically remove and internally erode soil particles from the fill section. The erosion starts first at the discharge end of the leak, causing a local concentration of seepage and erosive forces. The erosion eventually progresses upstream to form a tunnel-shaped passage or pipe through the fill. Eventually, this erosion progresses far enough into the embankment to result in rapid failure. Excessive seepage can affect the wetland's ability to retain hydrology and usually results in the development of wet areas along the downstream toe of the embankment. This may cause undesired impacts to adjacent downstream properties due to prolonged wet soil conditions (**Figure 4.5.11**).

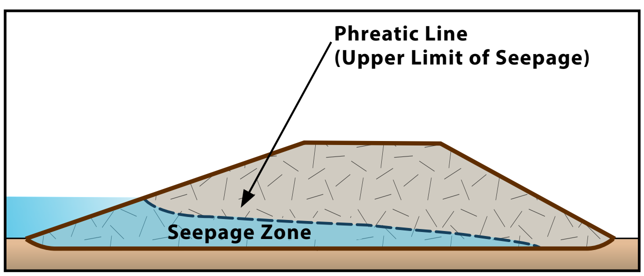


Figure 4.5.9 *Typical Embankment Section Showing Phreatic Line Contained within Fill Section*

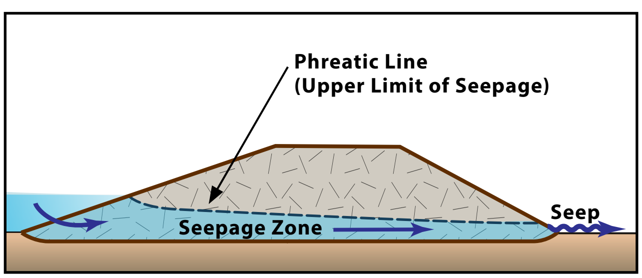


Figure 4.5.10 *Typical Embankment Section Showing Phreatic Line Exiting Above Downstream Toe*

Figure 4.5.11 *Wetness on Downstream Side of Embankment Due to Seepage*

Seepage and other embankment stability issues can be related to poor foundation conditions under embankment fills. These include but may not be limited to:

- Surface of the foundation includes topsoil, rocks, roots, or other debris that are not removed during construction.

- Highly-permeable, deeper foundation soils exist that are not addressed in the design and construction.
- Foundation soils not having sufficient strength to support the weight of the embankment. These foundation soils will exhibit excessive consolidation due to soil compressibility and can eventually fail.

Embankment underseepage is the result of water moving through semi-pervious underlying soils as a result of head differential or water pressure between the upstream and downstream sides of an embankment (**Figure 4.5.12**). Underseepage through the foundation soils may cause excessive uplift pressures on the embankment, potential wetness problems in areas downstream of the embankment, or unacceptable losses of water affecting wetland hydrology. Underseepage issues are primarily a concern when water levels against an embankment will begin to exceed depths of one foot and when working in organic or sandy soils and weak or sensitive clays.

When constructing embankments on organic or other weak soils, there may be issues with compressibility of the underlying soils and subsequent embankment settlement. This is of particular concern when embankments above these soils are to be constructed with heavier soils such as clays, silts, or sands. The rate of settlement of the underlying soils varies and is a condition of several factors including embankment weight and organic content and physical characteristics of the underlying material.

The primary means for controlling seepage both in the embankment fill and the underlying foundation soils involves using quality fill materials, proper foundation treatments, and good design and construction practices. This helps to ensure that the resultant phreatic line will be contained within the embankment fill section. Detailed engineering analysis can be performed to determine the shape and location of the expected phreatic line; however that is usually unnecessary for the scope of embankments constructed when restoring and creating wetlands. Embankments that use quality fill materials, are properly compacted, are broad in width, and incorporate flat side slopes should, in most situations, fully cover and keep the phreatic line below ground and not allow it to exit on the downstream slope.

When site conditions do not allow the use of these simple design strategies and the risk of seepage and internal erosion of embankment soils is high, other methods of addressing the potential for seepage and internal erosion need to be considered. This can include the use of filters, various types of toe drains, or downstream toe berms. A combination of these strategies may be necessary to achieve effective control of embankment seepage. Where the risk for seepage is high and of concern, the design recommendations provided in this Guide need careful review and possible modification. In such situations, it is recommended that additional design guidance on seepage control and an experienced engineer be consulted.

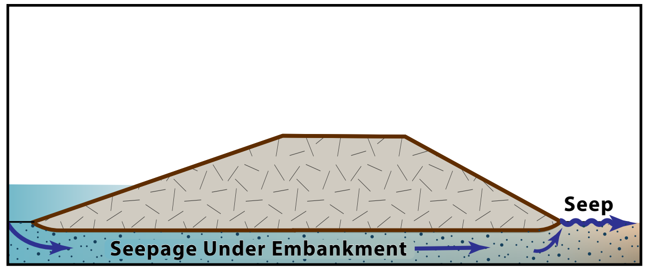
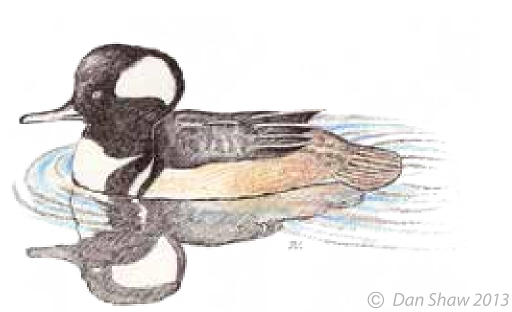


Figure 4.5.12 *Typical Embankment Section Showing Seepage with Wet Conditions Downstream*

General Design Components

After determining the location and type of embankment to construct, the remaining embankment components need to be designed. This includes the stripping depths and foundation work or treatments that will be needed along with the embankment's height, top width, and side slopes. In addition, the specifications, process, and sequence for construction needs to be developed to ensure a successful, long lasting structure.



Foundation Preparation

The characteristics of the underlying foundation soils can affect the design and long term viability of every embankment. Future problems with embankments are likely to occur if poor foundation conditions exist and are overlooked or not fully addressed during the design process.

In most situations, there are practical strategies for designing and constructing embankments to manage for poor foundation conditions. An investigation and evaluation of the embankment foundation soils is necessary. This includes a review of the mapped soils along with simple field measurements of topsoil depths and of other unsuitable materials that may exist in the soil profile.

To provide a stable foundation and address potential issues with underseepage, topsoil and other undesired surface materials must be stripped and removed from the entire area beneath the planned embankment. This simple construction procedure removes plant roots, rocks, debris, and the more-pervious, often organic, topsoil layer (**Figure 4.5.13**). Prior investigation will indicate proper stripping depths and any necessary clearing and grubbing work to be performed. The required depth of stripping will vary and is dependent on the soils and the current land use of the embankment site. For example, if the site was recently cropped or is bare soil, a stripping depth of 0.5 feet will usually be adequate for most locations. On the contrary, if the site is vegetated, stripping depths may need to be increased to as much as one foot or more to remove topsoil and plant roots. Flexibility in the actual stripping depths is needed during construction as depths will likely vary throughout an embankment's length. Stripped topsoil is usually stockpiled and then placed on the finished embankment surface to provide a suitable medium for vegetation establishment. Additional discussion on this occurs in **Section 4-10 Construction Implementation, Topsoil Subcutting or Stripping**.

Some planned embankments will be located on deeper foundations of unstable, permeable soils, or soils that have permeable layers. These foundation soils, if not properly addressed in the design and construction of the embankment, could lead to issues with instability, underseepage, and outright failure. In these situations, comprehensive geotechnical investigations may be needed to determine the suitability of the foundation soils and if any foundation treatments will be needed as part of the design (**Figure 4.5.14**). These investigations should be considered when the scope of the embankment warrants it or where there are known or suspected concerns with the underlying foundation soils with regard to underseepage and embankment stability. The extent of investigations performed should be governed by the project scope and potential foundation issues that are expected or discovered. Additional discussion on the assessment of embankment foundation conditions occurs in **Section 3-3 Site Soils**.

Figure 4.5.13 *Stripping Topsoil at Embankment Site*

Figure 4.5.14 *Soils Foundation Investigation*

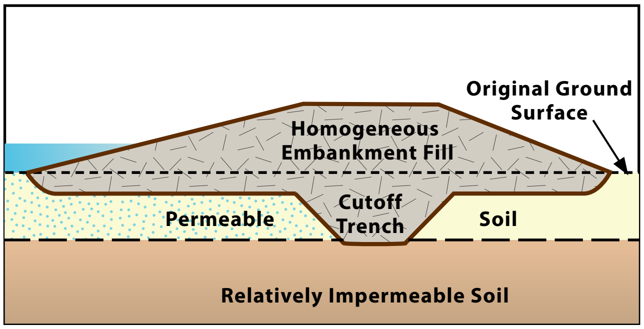


Figure 4.5.15 *Cross Section of Embankment with Cutoff Trench*

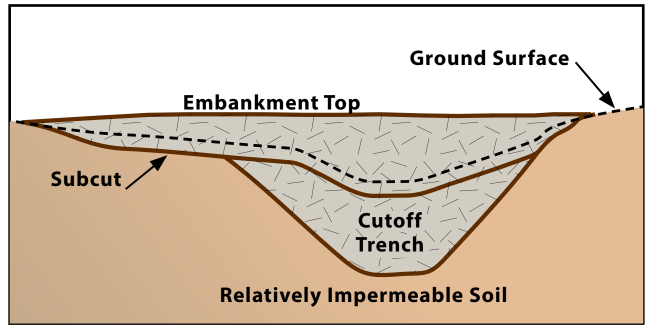


Figure 4.5.16 *Profile of Embankment with Varying Cutoff Trench Depths*

> Embankment Cutoffs or core trenches are commonly used to address poor foundation soils.

The most common and practical design strategy to address issues with poor foundation soils is to construct a cutoff trench under the embankment. A cutoff or "core" trench is excavated in the underlying soils of the embankment down through the unstable or pervious soils and keyed into an underlying layer of a more stable and relatively impermeable soil, typically glacial tills (**Figure 4.5.15**). The excavated trench is replaced with a relatively impervious backfill material that is compacted to appropriate specifications. This strategy can minimize concerns with underseepage and settlement due to compressibility of the underlying soils and allow the use of more suitable, dense fill materials in the embankment construction. The application and effectiveness of this strategy will be limited by the presence of a suitable underlying subsoil layer or stratum and excavation depths necessary to key into it.

The location for the cutoff trench may include the entire embankment length, only certain sections where poor soils exist, or possibly where outlet structures are proposed and additional foundation support is needed. Accordingly, the extent and depth of a cutoff trench can vary throughout an embankment's length (**Figure 4.5.16**). The bottom of a cutoff trench needs to be wide enough to create an effective barrier against seepage and accommodate the construction equipment that will excavate, place, and compact the backfill. A minimum width of four feet is required to accomplish this. Cutoff trenches that are shallow in depth may be more economical to construct with wider bottom widths of eight to ten feet, which can allow the use of dozers and scrapers in their construction. To achieve proper compaction of the fill materials, the side slopes of the cutoff trench should be no steeper than 1:1. The centerline of the cutoff trench shall, under most circumstances, be located at or just upstream of the embankment centerline.

Where deep foundations of organic soils or other unstable soils exist, cutoff trenches are impractical and concerns with the use of heavy clays, silts, or sands in the embankments will exist as the poor foundation soils may not support them. To address potential lateral spreading and vertical compression issues associated with soft or weak foundation soils, a geotextile or geogrid material may be used under the embankment to replace or reinforce portions of the foundation. Otherwise, lighter-weight organic materials may be used with some success for embankment fills that will be low in height. In doing so excessive underseepage and downstream uplift pressures can result. These issues can often be addressed by increasing the length of the underseepage path. This is done by flattening the slopes of the embankment and using a wider embankment top.

Other strategies to address underseepage problems can include constructing downstream toe berms and utilizing toe drains just downstream of the embankment (**Figure 4.5.17**). Note that a combination of strategies may be necessary to achieve effective control of underseepage.

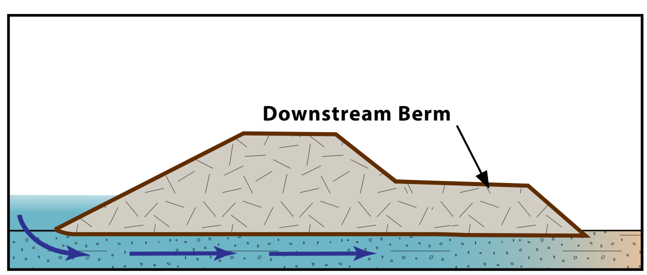


Figure 4.5.17 *Cross Section of Embankment with Downstream Toe Berm*

Foundation soils that are wet or saturated will be difficult to construct upon. While dewatering may provide suitable construction conditions, it is often most practical to postpone construction until soil moisture conditions improve.

Constructing embankments on organic or other unsuitable soils without appropriate foundation or other treatment is not advised. Regardless of what strategies are used to address poor foundation conditions, appropriate engineering design practices must be followed and must begin with a comprehensive investigation of the underlying soils. The design recommendations provided in this Guide need individual consideration for every site. In some situations, additional guidance will be necessary and an experienced engineer or other resource professional should be involved in the design.

Height

When determining the elevation or height for a planned embankment, several factors need consideration, including:

- The elevation of normal wetland water levels against the embankment
- The expected flood stage of the wetland
- Requirements for freeboard or factor of safety
- Allowances for expected wave action
- Allowances for expected settlement of the compacted fills and for compression of the underlying foundation materials
- Other uses or purpose of the embankment such as vehicular travel

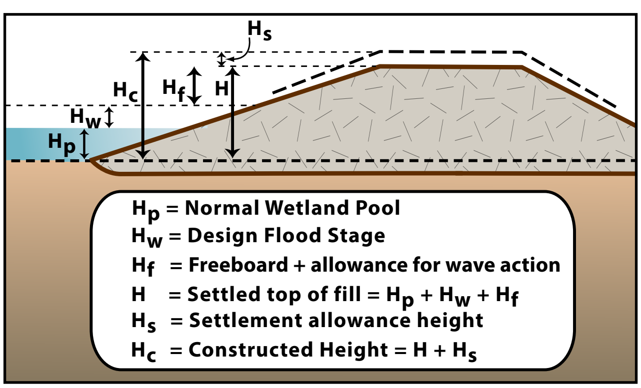


Figure 4.5.18 *Components that Determine Embankment Design Height*

The minimum design height of the embankment (H) above the normal operating or expected wetland pool elevation will be the sum of the design high water or flood stage (H_w), the added height for expected wave action (H_v), if any, and allowances for freeboard (H_f). The constructed height (H_c) should include the required allowances for settlement (H_s). With consideration of the above design criteria, when wetland water depths against an embankment under normal operating conditions are one foot or more, the height difference from the designed embankment top to the wetland's normal water surface should be at least 1.5 feet. With shallower water depths, the height difference from the embankment top to the water surface can be smaller, but should not be less than one foot.

A number of factors need consideration when determining an embankment height.

The **design flood stage** (H_w) is based on an analysis of wetland and watershed characteristics. This analysis determines potential flood stages of the wetland from a design storm event either through flood routing or other methods. Discussion of methods for determining the design flood stage occurs in Section 4-2 Hydrologic Design Analyses.

Freeboard (H_f) is a height allowance that is added to the design flood stage for safety and stability. At minimum, a freeboard allowance of 0.5 feet should be used. Greater allowances for freeboard are needed for larger projects or when downstream safety hazards exist.

Additional freeboard for **wave height allowance** (H_v) should be added for protection from wave action where embankments may be exposed to long stretches of open water (fetch). Consider freeboard for wave action when fetch lengths approach 1,000 feet. In those situations, additional freeboard allowances should be computed separately using an acceptable method that meets applicable design standards. Discussion of additional measures to provide embankments protection from wave action is included at the end of this chapter.

Settlement allowances (H_s) are needed to address consolidation of the compacted fills and compression of the foundation materials after construction is completed. Settlement allowances can be highly variable and depend on several factors including type and moisture content of soil material and method of compaction.

Settlement allowances are typically based on a percentage of the fill height. This should include the depth of fill placed below grade to address foundation issues and concerns. This can include general depths for topsoil stripping as well as additional depths for cutoff trenches.

When foundation conditions and the moisture content of fill materials are near optimal conditions, the following guidelines for settlement should be used.

- When embankment fills are to be compacted with a sheeps-foot, scraper, or other rubber-tired construction equipment, a settlement allowance of not less than five percent of the fill height should be included.
- When embankment fills are to be compacted with tracked equipment an allowance of not less than ten percent of the fill height is recommended.
- Where organic soils are used, settlement allowances of up to 40 percent may be needed.

Top Width

Minimum top widths of ten feet are suggested for all earthen embankments associated with wetland projects. This minimum width will help prevent problems with seepage and can better accommodate construction equipment and occasional vehicular travel. If the embankment may be used as a more-frequently traveled field road or other crossing, the top width shall be increased appropriately for the intended use.

The top of all constructed embankment fills should be slightly graded in each direction from the centerline creating a crown that will facilitate drainage and prevent ponding on top of the embankment. A crown slope of two percent is recommended (**Figure 4.5.19**).

Side Slopes

Properly designed side slopes will ensure stability of the embankment materials and help address long term maintenance issues resulting from embankment erosion due to wave action and embankment seepage.

Embankment designs for all wetland projects should consider upstream side slopes of 5:1 or flatter and downstream side slopes of 3:1 or flatter. In many instances, flatter front slopes on the upstream and possibly even the downstream side of the embankment will provide additional design and performance benefits with regard to addressing potential problems with wave action, less-than-ideal borrow material, seepage, and burrowing muskrats (**Figure 4.5.20**). Slopes that are 10:1 or flatter may be necessary to address these concerns.

Additional discussion on the design of embankments and berms to address these potential problems along with recommended side slopes when constructing with organic soils occurs in Other Considerations at the end of this Chapter.

Figure 4.5.19 *Cross Section of Embankment Showing Slightly Crowned Top*

Figure 4.5.20 *Embankment with a Gradual Front Slope*

Compaction

For embankments to achieve their intended purpose, earthfills used in construction must be properly placed and compacted. Compaction of the embankment soils will increase the density and strength of the embankment and decrease its compressibility and permeability.

In the design of earthen fills, consideration should be given to the expected moisture conditions of the fill and foundation soils at the time of construction along with the specified method of construction. Each soil type will have an optimum moisture content and compaction method at which maximum compaction density and embankment stability will be obtained (**Figure 4.5.22**). Plastic soils, if placed dry, will not compact and will become unstable when they become wet. Any soil that is placed wet or near saturation will be difficult to work with, will not support construction equipment, and may slough or slump excessively when attempting compaction.

> To achieve good compaction, fills must have adequate soil moisture.

When the selected borrow material is either too wet or dry and an alternative borrow source is unavailable, remedial actions are possible. Material that is too wet can be excavated, stockpiled, and left to dry until an adequate moisture condition is achieved. Material that is too dry can have water added prior to, or as part of, its placement.

Soil moisture density tests can be performed to determine the optimum moisture content for placing and compacting soils. However, for the embankment heights associated with most wetland projects, testing

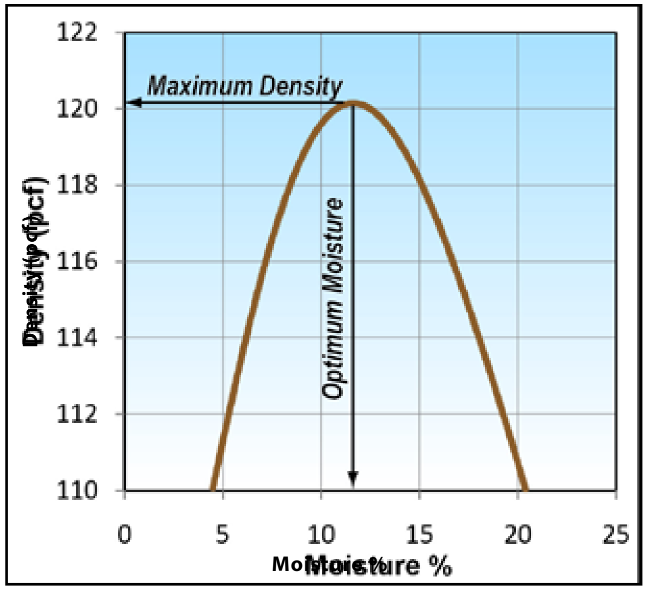


Figure 4.5.22 *Soil Moisture to Compaction Density Graph*

of the soils is not practical or necessary. By specifying and adhering to the following moisture content and construction guidelines, adequate compaction and desired soil densities can be achieved:

- The soil should have enough moisture so that, when formed into a ball, it does not readily separate when kneaded in the hand.
- The soil material does not readily adhere to the treads, tracks, or tires of the construction equipment.
- Construction equipment should only sink a few inches into the compacted soil layer.
- Placed soils are easily blended, resulting in a mass of reasonably homogenous material.

Figure 4.5.21 *Embankment Compaction with Sheepsfoot Roller*

In addition to soil moisture, the thickness of lifts between compaction, compaction equipment used, and the number of equipment passes required, all can affect resulting compaction densities. The prepared construction plans and specifications should clearly indicate what is required as it relates to these items.

Three main types of equipment are used to construct and compact embankment fills: dozers, rubber-tired equipment, and compacting rollers such as a sheepsfoot. Compaction densities that can be achieved from these three types of equipment are listed in **Table 4.3**. As indicated in the table, the use of dozers or other tracked equipment will result in low compaction densities and therefore should only be allowed where low embankment fill heights are constructed, where maximum water depths against the embankments are less than one foot, or where soil conditions prevent the use of rubber-tired equipment or compacting rollers.

To achieve proper compaction densities, the entire surface of each lift of fill should be compacted by at least two passes of the specified construction equipment. With tracked or rubber-tired equipment, this will require that many passes be made to cover the entire surface of the lift (**Figure 4.5.23**).

Whenever possible use compacting rollers such as a sheepsfoot to limit the number of passes and achieve optimum compaction densities.

The loose lift thickness, before compaction, should range between four and nine inches, based on the compaction equipment specified and scope of embankment being constructed. For example, a low height embankment with shallow water depths against it (12 inches or less) can be constructed and compacted with a tracked dozer. However, in doing so, the lift thickness before compaction should be kept to a minimum, between four and six inches. On the contrary, higher embankments with greater water depths should use rubber-tired or sheepsfoot compaction with a lift thickness of nine inches or less.

Figure 4.5.23 *Embankment Compaction with Loaded Tandem Scrapers*

Table 4.3 ***Compaction Densities from Construction Equipment***

Construction Equipment	Average Compaction Density with Optimum Moisture Content
Tracked Dozer	0-20 psi (lb/in2)
Loaded Scraper	100 psi (lb/in2)
Sheepsfoot	200 psi (lb/in2)

Stabilizing the Constructed Fills

Stabilizing constructed embankments with vegetation and other reinforcement or erosion control materials is an important part of the design and construction process. This requires clear, written direction on how the constructed embankment and other disturbed areas will be stabilized and under what timeframes the work needs to be completed. This includes requirements for:

- Final grading of the constructed embankment, borrow areas, and other disturbed areas.
- Topsoiling of the finished surfaces, where required, to prepare a suitable medium for seeding.
- Selecting an appropriate seed mix and application rate for the identified areas.
- Identifying the optimum dates in which seeding can occur.
- Determining an appropriate stabilization method to support the seeding (mulching, erosion control blankets, riprap etc.)

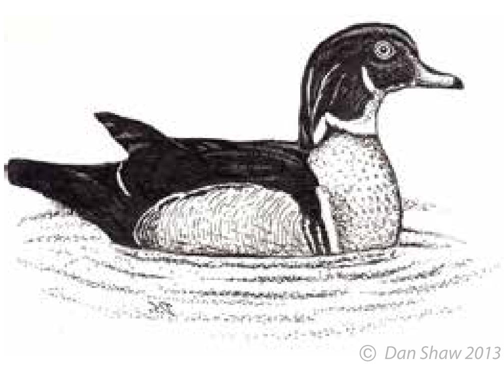
Specify the required stabilization work in the pollution, sediment, and erosion control plan or construction specifications. This includes requirements for stabilization timeframes after the construction activity has either temporarily or permanently ceased. For larger projects, compliance with this timeframe may require that stabilization methods such as seeding and mulching occur in several stages.

Additional discussion on stabilizing construction areas may be found in **Section 5-4 – Establishing Upland Vegetation, Stabilizing Construction Areas and Upland Soils**.

Figure 4.5.24 *Placing Mulch on a Constructed Embankment*

Other Design Considerations

Embankment designs should always account for the potential for damage or failure from other, less obvious factors including, but not limited to, wave action, muskrat damage, and problems with seepage. To address these concerns, additional provisions may need to be incorporated into the design of each embankment. Because these provisions increase the cost of construction, the tendency is to not consider them important enough to include in the design. However, the cost to address these concerns up-front, as part of the initial construction, will be much less expensive than the cost of any repair work needed later. In addition, funds tend to be more readily available and working conditions much better during the initial establishment of a project than they will be later, should repair work be needed.



Protection from Wave Action

Wave action against embankments and other constructed slopes can cause significant damage and be costly to correct. Embankments associated with large, deeper-water wetland systems and wetlands susceptible to prolonged flooding will be subject to the greatest potential for wave damage. However, even small, shallow wetlands are susceptible to wave damage under the right conditions, especially during the first few years after their construction before protective vegetation establishes in the wetland and on the embankment slopes. Embankments constructed with low-plasticity soils or organic materials will be more susceptible to damage from wave action than those constructed with other, more tightly bonded soils.

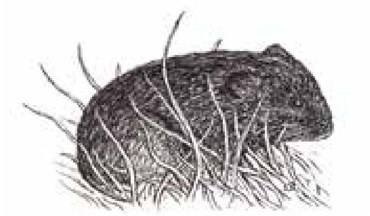
Several strategies are available that can address potential problems from wave action. They include:

- If existing vegetation exists upstream and adjacent to the planned embankment, make every attempt to preserve it. After hydrology is restored, this existing vegetation may provide wave protection while the embankment slope vegetation is being established. Plan ahead on stripping methods (locate topsoil on the downstream side of embankment) and methods to obtain and haul borrow to the embankment site (avoid driving over the buffer

Figure 4.5.25 *Embankment Damage from Wave Action*

area). Depending on the type and extent of existing vegetation, the buffer may only be temporary and other options to protect against waves will be needed.

- Use flat slopes in the construction of the upstream embankment slope. Slopes approaching 8:1 or flatter will provide the greatest protection.
- Seed and mulch the embankment as soon as construction is completed in an attempt to stabilize and protect the constructed embankment. Where possible, consider staging or even delaying the restoration or introduction of hydrology to the wetland to allow vegetation to establish on both the embankment and in wetland areas along it.
- Construct a wave berm in front of the embankment. The berm should be constructed to be at or just above the planned wetland water surface and should be at least ten feet wide (**Figure 4.5.26**). Wider berms will provide greater protection and should be considered when feasible and practicable. Wave berms can also provide some protection against potential muskrat damage. Wave berms can be constructed with random material, preferably excavated material from another project component (cutoff trench, shallow scrape, excess topsoil, etc.). Durable hydrophytic vegetation suitable for the planned hydrologic condition should be established on the wave berm.
- Where deeper water conditions would otherwise exist in front of an embankment or where a wave berm is not practical or desired, any effort to raise the wetland bottom immediately adjacent to the embankment will be of benefit. Adding fill to create a zone of shallower water in front of an embankment will provide more suitable conditions for the establishment of emergent wetland vegetation that in turn can provide a very suitable natural buffer to protect the embankment slope from wave damage. Using fill material excavated for some other purpose on the project will be most economical for this strategy.



- Occasionally, better protection against wave action is needed than can be provided by the methods discussed above. Additional protection to embankment slopes and berms can be provided by erosion control blankets, turf reinforcement products, or rock riprap (**Figure 4.5.27**). Use appropriate design sources and installation methods when using these materials and protection strategies.

Controlling/Minimizing Animal Damage

Embankments and other earthfills adjacent to wetlands are attractive to a variety of burrowing animals including: muskrat, beaver, fox, coyote, badger, and even gophers. The heights and relatively steep side slopes of these earthfills in comparison to other wetland shoreline areas provide favorable conditions for burrowing and den construction. Tunnels and dens can cause surface collapse, piping, and even failure of the earthen structure; the result can be a loss of wetland hydrology and unintended downstream impacts. Embankment repair work as a result of animal activity can become a costly, annual event.

Figure 4.5.26 *Embankment Protected with Wave Berm*

Figure 4.5.27 *Embankment Slope Protected with Riprap*

Figure 4.5.28 *Muskrat Damage to Embankment*

> Rodents, in particular muskrats, may be the single greatest threat to the integrity of earthen embankments.

Muskrat and other burrowing animals can quickly inhabit restored and created wetlands and will tunnel and create dens within constructed embankments if given the opportunity (**Figure 4.5.29**). For new projects, constructed embankments may provide the only opportunity for den habitat until emergent vegetation to construct the more typical muskrat house is established. When surface waters, such as an open ditch or wetland, exists adjacent to and downstream of the embankment, muskrat tunneling activity within the embankment often seems greater and is probably due to their desire to create tunnels that connect the two surface water systems.

Beavers are another threat to the integrity of earthen embankments. Beaver are normally lodge builders, if there is an adequate supply of desirable trees they can use for material and as a food supply. However, they do occasionally create dens by tunneling into constructed embankments. Wetland restoration done on open land with little or no adjacent tree growth may at first be less appealing habitat to a beaver. But as the site matures over time, the natural regeneration of trees such as

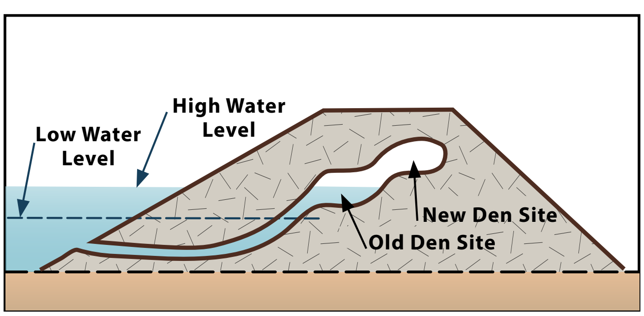


Figure 4.5.29 *Typical Muskrat Den in Embankment*

willow and cottonwood along the edges of the wetland restoration could create the best quality habitat for the beaver. Though it can be time consuming and costly, minimizing tree growth in a landscape setting adjacent to a wetland restoration where trees were not prevalent before can be used as a tool to discourage beavers from habituating a site. Beaver are most likely to inhabit wetlands that are restored adjacent to their primary habitat, like wooded river and stream corridors or other flowages and lakes.

Several strategies can be used to reduce, delay, or prevent animal burrowing. In reality, however, no practical solution exists to make an embankment completely "animal proof".

While on-going maintenance will always be necessary; the use of the following design and construction strategies can minimize those future maintenance efforts:

- Avoid using organic soils in the embankment fill. Rodents can easily dig and tunnel through these soft, less cohesive soils. The use of well-compacted mineral soils can be a deterrent to tunneling.
- Use flat slopes in the construction of the upstream embankment slope. Slopes approaching 8V:1H or flatter will provide the greatest protection.
- If possible, avoid locating embankments adjacent to a downstream water source such as ditches or other wetlands. If an embankment will be constructed adjacent to a downstream water source, flatter embankment back slopes are recommended.
- Avoid situations where water depths of six inches or more will exist in front of an embankment. Avoid excavation work adjacent to and upstream of the embankment. Where possible, consider filling in open ditches and raising the ground area immediately adjacent to the embankment. This is best accomplished by placing and constructing fill along the front of the embankment to create a wide berm or shelf. See wave berm discussion under protection from wave action on previous page.
- Construct a vertical barrier of rock aggregate or other impenetrable material within the front portion of the embankment. To be effective, the top of the barrier should be at least 12 inches in elevation above the normal wetland elevation and be extended to and flush with the embankment surface.

The depth or bottom elevation of the barrier will be dependent on the scope and location of the barrier within the embankment and should at least extend to the wetland bottom elevation along the embankment (**Figures 4.5.30 and 4.5.31**). Aggregate material, if used, should be crushed rock approximately two to four inches in size and placed in a trench that is a minimum of 12 inches wide. Line the trench with a non-woven geotextile blanket when concerns exist with possible encroachment of fined grained embankment soils into the rock trench.

- Place a fence barrier within the front portion of the embankment. A variety of fencing materials can be used, however, the mesh opening size needs to be small enough to block the passage of an adult muskrat. This requires the dimensions of the mesh opening to be no larger than 1¾ inches. A heavier-gauge galvanized or vinyl-coated fence material will provide the greatest protection and longevity. The following list of fencing materials are recommended for use when attempting long-term control of muskrat and beaver activity in earthen embankments:
    - 1 ¼" x 1 ¼" Galvanized or PVC Vinyl Coated Chain Link Fence, 9 Gauge
    - 1" x 2" Galvanized Welded Wire Mesh, 14 Gauge

These fencing materials come in rolls in a variety of different lengths and widths. The roll width should be governed by the amount of vertical protection desired and the installation method. The amount of vertical protection needed will often vary along the length of the embankment. It may require more than one roll width or the use of more than one row of fence to cover those areas where the embankment is greatest in height.

Figure 4.5.31 *Construction of Aggregate Barrier*

It will be most economical to place the fence barrier within the constructed fill on a partially constructed, steeper slope; less fence material will be needed than if placed on a flatter, finished slope. For example, placing an eight-foot-wide roll of fence on a partially constructed slope that is at a 1.5:1 grade will create a vertical barrier that is about 4.4 feet high. For many embankments, that is all that is needed for protection. The same eight-foot fence placed on 5:1 finished grade will only provide about 1.5 feet of vertical protection. In most situations, that will be inadequate and requires necessitating the use of a wider fence or multiple rolls of fence. An overlap of at least six inches is recommended when multiple rows of fence are used.

The top edge of the fence should be placed at a fixed elevation at least one foot in elevation above the planned wetland surface or just below the embankment top and as close as possible to the finished embankment surface (**Figures 4.5.32 and 4.5.33**).

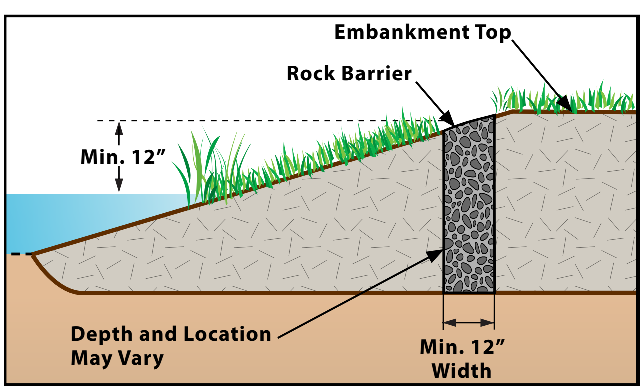


Figure 4.5.30 *Vertical Aggregate Barrier in Embankment*

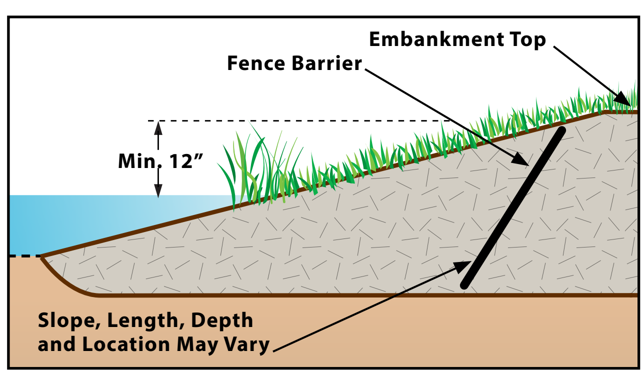


Figure 4.5.32 *Typical Rodent Fence Design Layout*

As an alternative, fence barriers can be installed vertically within the embankment. Construction costs will however likely be higher than with placing the fence on a partially constructed, steeper slope as described above. Vertical installations are more common when retrofitting an existing embankment that is experiencing excessive animal damage and is need of repair.

Constructing Embankments Across or Adjacent to Surface Ditches

Embankments constructed across or adjacent to open surface ditch systems will need additional protection. The presence of an open ditch system either upstream or downstream from the embankment can present additional long term maintenance issues for the project. Issues with embankment stability, seepage, and muskrat burrowing activity tend to be greater when open ditch systems are abutting an embankment.

For embankments constructed across an open ditch, it is recommended that, whenever possible, portions of both the upstream and downstream ditch be filled in beyond the extent of the embankment. At minimum, 10 lineal feet of both the upstream and downstream ditch system should be filled, with greater distances being more beneficial. The upstream ditch fill will keep deeper water areas away from the embankment and help address potential problems from wave action and muskrat damage. The downstream ditch fill will increase the base width of the embankment and help prevent problems with embankment seepage and sloughing of the downstream slope. Additional discussion on this topic occurs in the Blocking and Filling Surface Drainage Ditches **Technical Guidance Document** located in **Appendix 4X-1**.

Figure 4.5.33 *Installation of a Rodent Fence in Embankment*

Embankments constructed adjacent to functioning ditch drainage systems should be located and designed to prevent or minimize seepage or hydrologic losses and to maintain a stable ditch bank and slope. Certain setback distances or foundation treatments must be employed to address seepage and potential drainage impacts of the ditch. Where possible, design for broad embankment top widths and flat slopes. This will help limit wetland drainage impacts of the ditch system and address requirements for future access to allow ditch maintenance and spoil placement. Additional discussion on this topic occurs in the Ditch Bank Improvement **Technical Guidance Document** located in **Appendix 4X-1**.

Constructing Embankments in Floodplains

Embankments constructed in floodplains are likely to experience occasional flooding and overtopping. This requires embankments with broader top widths and flatter slopes.

When constructing embankments in floodplains, there is great potential to impact flood levels of the riparian source. A comprehensive hydrologic assessment of flood flows will likely be needed as part of the design. Permits for floodplain work and a hydrologic assessment will likely be required as part of the permit review and approval process.

Long term maintenance of floodplain embankments is critical. Prolonged and excessive flood flows over the embankment put it at great risk for damage or failure. Floodwaters can also damage or destroy the vegetation, making an embankment susceptible to erosion and requiring frequent maintenance and replanting. Wooded floodplains provide an undesired source of seed for tree growth. Shading from tree growth near embankments can limit the development of a suitable, protective stand of herbaceous vegetation on the embankment, leaving it susceptible to damage from flood events. In addition, the development of tree roots within embankment fills can lead to increased seepage and potential structural failure.

An experienced engineer should be involved in the design of most embankments that are planned in floodplain areas.

4-6 Sediment Removal, Scrapes and Other Excavations

Figure 4.6.1 *Typical Scrape/Sediment Removal*

An overview of the following list of strategies is discussed in this chapter of the guide with more specific and detailed information provided in Technical Guidance Documents that are located in Appendix 4 and referenced accordingly.

- **General Considerations**
- **Excavations in Drained and Altered Wetlands**
  - *Sediment Removal*
  - *Wetland Scrapes*
  - *Soils as a Borrow Source*
- **Excavating to Create Wetlands**
- **Design Considerations**
  - *Depth*
  - *Slopes*
  - *Shape*
- **Construction Requirements**
  - *Site Preparation*
  - *Removal and Placement of Excavated Materials*
  - *Topsoiling*
  - *Stabilizing Excavation and Spoil Placement Areas*
- **Other Considerations**

Soils are basic to the overall function of every wetland and their protection, restoration, or establishment should be a priority for every restoration or creation project. Wetland soils serve as a medium for plant growth, support invertebrates and invertebrate egg banks, and provide chemical and biological processes that are necessary for a healthy, functioning ecosystem. Underlying wetland soils can form an impervious barrier to retain water or function as a pervious stratum that allows groundwater exchange.

This chapter of the Guide discusses design and implementation strategies for the excavation of soils within wetland areas that are being restored or created. The application of this information must be consistent with the scope of the project. The design principles discussed and presented are applicable in small to moderate scope projects where comprehensive and costly engineering efforts and analysis are typically unnecessary. For sites with more complicated geotechnical issues and those that currently or previously contained rare and natural wetland plant communities, the information presented provides a general understanding of overall design features. More demanding site investigations and design methods associated with those projects may be beyond the scope of this Guide.

General Considerations

Excavations are commonly used to create shallow wetlands and ponds. These excavations occur within low-lying upland areas or upland areas adjacent to existing wetland areas. Excavations are also performed within drained and altered wetlands and can be a key element of their restoration. Excavations as part of a wetland restoration may be done for a variety of reasons, such as:

- Removing soils that have been placed in shallow wetlands.
- Removing sediment that has accumulated over time due to erosion of adjoining upland areas.
- Removing topsoil that is laden with nutrients and pesticides.
- Removing monolithic stands of hybrid cattail, reed canary grass, or other undesired vegetation.
- Improving wetland habitat by enhancing wetland depths and providing microtopography.
- Restoring the historic water storage capacity of small, depressional wetland basins.
- Obtaining borrow material for a specific construction purpose such as ditch fills or embankments.

Excavation activities can influence the functions, appearance, cost, and overall success of a project.

If the planned wetland project is to include excavation, consider doing an assessment and analysis of the site's soils as part of the project design. All site assessment efforts should be consistent with the project scope. For example, when soils from a drained wetland are intended as a borrow source for constructing a simple ditch plug or fill, limited investigation of that soil for construction suitability can probably occur at the time of construction.

In contrast, when soils from a drained wetland are desired for constructing a larger earthen embankment where significant quantities of high quality soil material are needed, a comprehensive investigation and evaluation of those soils is needed. This can include specific and detailed geotechnical explorations, sampling, and testing of physical characteristics of the soil properties.

To avoid problems and improve the likelihood for success, the project designer should have at least a general understanding of site soils and their physical properties along with associated broader geological issues of the site. In some situations, it may be necessary to utilize experienced geologists or soil scientists in the site assessment process. Additional discussion on assessing site soils and site hydrology occurs in **Section 3 - Site Assessment and Evaluation**.

Figure 4.6.2 *Excavation to Remove Undesired Cattail*

Excavations in Drained and Altered Wetlands

The composition, structure, and function of soils within most drained and altered wetlands are, in many cases, severely impacted by years of human activities within these wetlands and their watersheds. Impacts may include the mixing of soil layers through tillage, the application of pesticides and nutrients, and drainage through ditching and tiling. Soils in the surrounding watershed may also have eroded and settled within the wetland as sediment. Upland soils have been purposely placed in many wetlands in attempts to improve the property for other uses. Many small, shallow, depressional wetlands around the state have been lost in this manner.

Consider the overall goals of the project when deciding whether to excavate soils from a drained or altered wetland. When the primary goal of a project is to restore the natural or historic wetland type, excavations should be limited to removing sediment or other upland soils from the wetland, removing or blocking drain tile, or filling surface drainage ditches. For other projects, there may be a desire to improve or modify historic wetland functions for a more defined current project purpose, such as enhanced diversity of wetland vegetation and wildlife. In such cases, a limited amount of excavation in portions of the former wetland area may be desired. This could occur as part of an overall sediment removal strategy. Usually, excavations are completed with some other project purpose in mind, such as removing undesired vegetation like hybrid cattail or reed canary grass or to obtain fill from more effectively drained wetlands for another construction purpose.

The extent that excavations within drained and altered wetlands are performed is usually a function of the purpose for the excavation activity as well as the conditions of the site at the time of construction. When the purpose of the excavation is for the removal of sediment, other wetland fills, undesired vegetation, nutrient and pesticide laden topsoil, etc., the scope of the excavation work could include the entire area or footprint of the former wetland. When the purpose is for improved or enhanced wildlife diversity or to obtain fill or borrow for some other construction activity, the extent of excavation or disturbance may be minimal and limited to a specific area of the wetland. Regardless of the reason, the hydrologic condition of the site at the time of construction often dictates the extent of excavation work that can be accomplished. Sites that are only partially drained or altered are often too wet to even consider many of the excavation strategies discussed. For that reason, scheduling excavations within these wetlands may only be possible during the driest months of the summer or possibly only during years with below-normal precipitation.

Figure 4.6.3 *Sediment Removal from Partially Drained Wetland*

Excavating and removing soils from a drained wetland as part of its restoration or for wetland creation can be an expensive construction strategy. Decisions on whether or how much to excavate will be a function of project goals and available funding.

Sediment Removal

Many shallow depressional wetlands have been degraded not only by drainage but also from years of sediment accumulation. Intensive land cultivation practices along with other soil-disturbing activities within these wetlands and their watersheds has led to increased sedimentation and, in some cases, complete elimination of low-lying temporary, seasonal, and even semi-permanent wetlands. Filling has occurred through plowing or tillage of sloped areas adjacent to wetlands where, over time, gravity has moved these soils to the lowest spot in the landscape. This is most evident or noticeable where higher adjacent areas are void of topsoil, with clay subsoil being exposed at the surface. Wind and soil erosion also contribute to the sedimentation process. Features of the surrounding watershed, such as soil types, slopes, land use, and hydrologic conveyance systems such as ditch, tile, and storm sewer outlets may

Figure 4.6.4 *Sediment Being Removed from Wetland Edge*

Where sediment accumulation or other wetland fills have occurred, the restoration or exposure of the original, native wetland soil can be an important design and construction strategy. If done correctly, removal of sediment and other fill materials can expose and allow germination of the remnant native vegetation seedbank and invertebrate egg banks. It has been found that sediment depths as little as just a few inches, if not removed as part of restoration, can have an adverse effect on invertebrate and seedling emergence.

have had a direct impact on past sediment inputs from erosion. Some wetlands have also had soil and other undesirable materials purposely placed in them as a result of a drainage project, development activity, or simply to make them farmable.

Sediment resulting from erosion of upland soils often accumulates along the edges and in bottoms of wetlands (**Figure 4.6.4**). Sediment depths tend to vary throughout a wetland . The deepest accumulations will usually be at the slope locations along the wetland edge of layer basins or in the middle of smaller basins (< 1 acre). In some locations, the depth of sediment as a result of these inputs can be up to three feet thick or more.

Many wetlands have a history of tillage and soil disturbance that has mixed upland sediments with their native wetland soils. This further reduces the functions of the wetland soils and removes much of the microtopography that once existed. Related to this is the use of chemicals (e.g. nitrates, phosphates, pesticides, and herbicides) on these drained and altered farmed wetland soils and their surrounding upland watersheds. Nutrient-laden wetland soils and sediment can quickly become dominated by a monoculture of hybrid cattail or reed canary grass when restored.

The accumulation of sediment and other fills in natural basins removes much of the seasonal storage volume and flood retention benefits they once provided. Removal of sediment can restore this important wetland function to the landscape.

Despite its effectiveness, removing sediment from a wetland through excavation is expensive and should only be considered when it becomes valuable relative to the restoration goals of the project. Studies suggest that for the cost, the most functional benefit is achieved when removing sediment from depressional wetlands no larger than 1.5 acres in size. Removing sediment from larger wetlands is often cost prohibitive. An alternative is to consider the resources available to the project and target or focus on removal areas where maximum functions and values will be attained.

> When attempting to restore historic functions, depths of sediment and other fills should be thoroughly investigated.

Determining accurate depths of sediment deposition can be a difficult task, even for experienced resource professionals. The location and depth of sediment deposits will vary within each wetland basin. The assessment of sediment locations and depths often requires extensive explorations, measurements, and analyses. At minimum, this includes assessing soil texture and color. It can also include using more extreme measures such as testing for effervescence using hydrochloric acid or oven-drying the soil for a more accurate color test. For additional information on the methods and procedures to perform soils exploration and assessment, refer to **Section 3 – 3 Site Assessment and Evaluation, Site Soils**.

A lack of soils assessment or poor construction oversight can result in only the partial removal of sediment deposits or the unintentional removal of desired, underlying wetland soils. Either of these scenarios would limit, if not erase, the effectiveness of this restoration strategy. For these reasons, it is important to involve soil scientists and/or biologists in the design and construction process. It is also important to train and use an experienced construction contractor who has the appropriate equipment for this type of work. Low ground pressure dozers between 90 and 140 HP provide the greatest flexibility in removing sediment layers with limited compaction of the underlying wetland soils.

Note that, in some situations, attempts to remove sediment may actually increase the potential for colonization of invasive species such as hybrid cattail. Understand the implications of any soil disturbance activity and be aware of conditions within the wetland and its immediate watershed, as well as the time of year, when conducting the work. Utilizing the knowledge of local resource professionals who have experience with this strategy can be very beneficial and increase the likelihood for success.

Wetland Scrapes

Excavations in drained and altered wetlands as part of their restoration are often referred to as scrapes. While scrapes are often associated with sediment removal as discussed above, they are also frequently done to enhance or improve wetland depths and microtopography, to increase diversity and aesthetics, to provide more suitable habitat for targeted plant and animal species including waterfowl, and to provide better animal access to deeper, open water conditions. Assuming favorable construction conditions, scrapes for enhanced habitat are usually performed away from shorelines or wetland edges where bottom elevations are lowest. This provides better security for wetland wildlife and can minimize construction costs since less material needs to be removed to achieve desired wetland water depths. Scrapes with irregular edges and undulating bottom depths will provide the best results (**Figure 4.6.5**).

Figure 4.6.5 *Wetland Scrape with Irregular Edges*

Wetland scrapes are also performed within drained and degraded wetlands for other reasons, including removing undesired plant communities or removing nutrient- and pesticide-laden topsoil. Reed canary grass or hybrid cattail, for example, can often be more efficiently and effectively removed from a project site through scraping and removal of the entire plant and its roots than through chemical treatment. If this strategy is warranted, cutting or burning the vegetation first will make the removal process easier and more efficient. Find a location to spread the scraped material where conditions will not allow the undesired vegetation to reestablish in the wetland.

Soils as a Borrow Source

When excavations or scrapes within drained or altered wetlands are planned, consider how you will dispose of the excavated materials. It will be economically beneficial if the excavated material can be used in another part of the project. When deemed suitable, excavated soil from wetland areas can function as borrow materials for the construction of certain project features such as embankments or ditch plugs. Discussion on the suitability of soil materials for embankments and the construction of borrow areas occurs in **Section 4-5 Earthen Embankments, Construction Materials**. Otherwise, the material may be suitable for other purposes such as the construction of wave berms, loose fill areas, or to fill in open ditch systems that are being abandoned (**Figure 4.6.6**).

Figure 4.6.6 *Excavated Sediment Being Placed as Loose Fill on Adjoining Property*

The options for reuse are greater when excavating within wetland areas that are well drained and where the soils are workable and not too wet. When working in altered or partially drained wetlands, the use and placement of excavated wetland soils needs greater attention from both a permitting perspective as well as a functional one. These soils are usually wet and their use as a construction material will be limited. The placement of these excavated materials within the partially drained wetland area will not be allowed unless the activity is deemed a necessary part of the restoration strategy, such as a ditch fill.

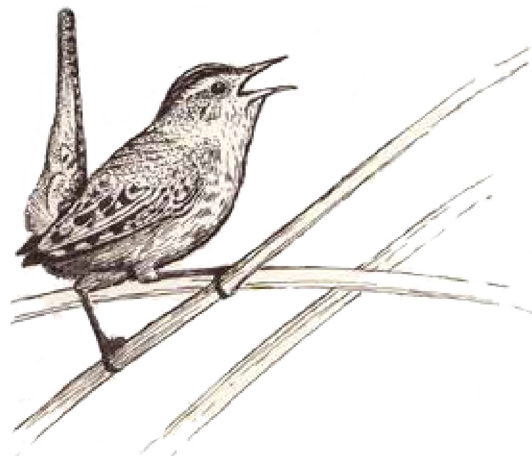
When there is no identified use for the excavated wetland soils, they should either be hauled off site or, when possible, placed on adjoining upland areas, preferably in areas that currently lack topsoil such as hilltops. Topsoil placed on adjoining uplands should be evenly spread and adequately stabilized to prevent it from eroding and being redeposited as sediment back into wetland areas.

Properly constructed and finished borrow excavations can improve certain wetland functions upon successful restoration of wetland vegetation and hydrology.

Excavating to Create Wetlands

Although there has always been some interest in creating wetlands for the purpose of improving wildlife habitat, other more regulatory-driven processes have increased the demand for wetland creations in the state. This includes creating wetlands to help control non-point source pollution, treat stormwater and wastewater, and to meet other regulatory mitigation requirements through the completion of on-site wetland replacements or wetland banking efforts. Functional success of created wetlands is limited when compared to most restorations. Challenges include, but won't be limited to, establishing and maintaining proper hydrology and developing a suitable soil substrate for the wetland.

Most created wetland projects include some type of excavation activity. While hydrology is considered the principal element that needs to be established, it is just as important to develop a functioning soil substrate that can provide a suitable medium for establishing wetland vegetation and developing other important biological and chemical conditions unique to wetlands.



Achieving success with these two important elements for planned creation projects will require extensive geological evaluations and site monitoring.

Establishing hydrology in a created wetland occurs through one of several methods. The most common is to excavate in upland areas immediately adjacent to existing wetlands, thereby increasing the size of the wetland. The success of this strategy, from a hydrology standpoint, is usually quite high as the extents of the water table and site hydrology are already known. These excavations must not compromise functions of the existing wetland or impact other wetlands in the immediate area. Excavations are also conducted in areas with high water tables where the planned excavations are deep enough to reach the water table and provide the necessary hydrology for the created wetland.

There is a growing trend to convert gravel and mining sites to functional wetland areas upon completion of the excavation or mining activity. In most cases, hydrology is already available for these projects, as these excavations usually extend well below the water table. Developing a suitable soil substrate for wetland vegetation establishment becomes the main challenge. The ability to temporarily dewater the site while establishing a substrate and vegetation will greatly improve working conditions and success rates.

Another, less predictable method to establish wetland hydrology in a created wetland system requires excavation in non-wetland areas with the addition of a compacted substrate that effectively seals the wetland bottom, reducing its permeability and limiting hydrologic losses. The permeability of the existing subgrade will need a comprehensive geotechnical analysis. Two common methods used to reduce subgrade permeabilities are mechanically compacting the existing subgrade or introducing and compacting a clay layer from a suitable borrow source. Consider compaction requirements, material suitability, placement depth, and thickness along with the use of a suitable substrate for plant establishment when designing this type of created wetland system. The design of these systems is not fully addressed in this Guide; more extensive literature and research should be referenced when it is being considered.

Design Considerations

The following design strategies relate to most excavations within drained and altered wetlands.

Depth

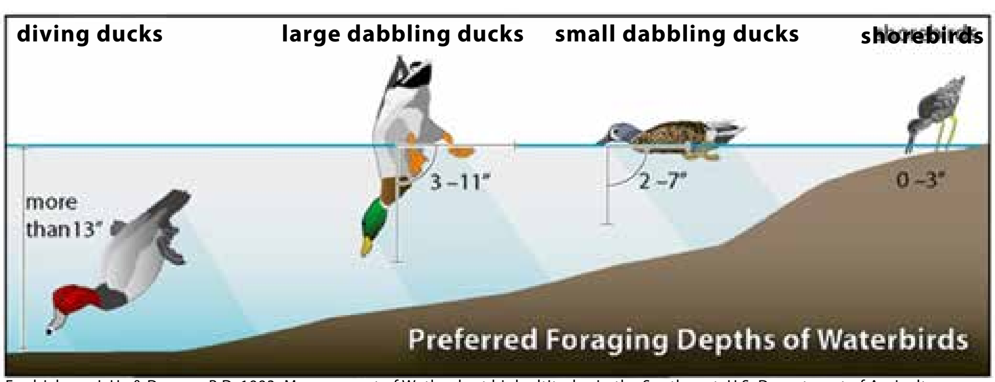
Excavation depths will be governed by several factors; the most important may be the purpose for which the excavation is being conducted. If the purpose is for sediment removal, then the depths will be limited to that necessary to remove the sediment but not the original wetland soil. If the purpose is for removal of undesired existing vegetation or nutrient-laden topsoil, then excavation depths should be sufficient to ensure that an adequate depth or thickness of topsoil that includes the undesired plants, seeds, or soil materials is removed. If the purpose is for obtaining borrow as a construction material, depths may be dictated by the quantity and quality of material needed but also limited by material suitability and moisture content. If the purpose is for improving wildlife habitat, excavation depths will be limited to that which is necessary to achieve successful outcomes for the targeted species.

Regardless of purpose, excavations should be designed to incorporate a variety of depths with final grading work resulting in an undulating bottom.

For maximum wildlife benefits, provide for an interspersion of vegetation and open water with average depths ranging from 6 to 18 inches(**Figure 4.6.7**). Deeper excavations can result in larger areas with open water wetland communities. Whether this is beneficial or detrimental to the wildlife depends on the project goals and the targeted wildlife species. Deeper water areas of three to four feet or more can provide open areas void of emergent vegetation, which is often desired as habitat for animals that require a reliable source of water when rearing their young, such as waterfowl. However, deeper water areas can harbor and provide over-wintering habitat for undesirable fish species, such as fathead minnows, bullheads, or rough fish that might be introduced to the wetland.

Geologic explorations should be conducted before performing any excavations.

Excavation depths may be limited by geological conditions of the site. For example, in surface water controlled wetlands, excavations could penetrate through an impervious bottom substrate into a more pervious underlying soil layer. This pervious soil can function as a drain. Underlying pervious soils are found in many wetland types, from wetlands with glacial till bottom substrates to those with organic soils. Wetlands currently drained by open ditches also need a comprehensive geological evaluation to determine if the excavated ditch has already penetrated through an impervious bottom substrate into a more pervious underlying soil. If so, a complete



Fredrickson, L.H., & Dugger, B.D. 1993. Management of Wetlands at high altitudes in the Southwest, U.S. Department of Agriculture, Forest Service, Southwest Region, Washington, D.C.

Figure 4.6.7 *Preferred Foraging Depths for Waterbirds* filling of the ditch will likely be required to reseal the wetland bottom. Additional discussion on landscape setting and wetland hydrology occurs in **Section 3 – 4 Site Assessment and Evaluation, Site Hydrology**.

Slopes

Design and construct side slopes of excavated areas to achieve maximum wetland functions and benefits. Functions are enhanced by incorporating a variety of slopes into the design. Wetland soils will be prone to erosion and slumping if constructed with slopes that are too steep. Most animal species will benefit from excavations that incorporate gradual side slopes. Finished slopes of wetland scrapes and sediment removal areas should be 10:1 or flatter, with some slopes as gentle as 16:1 or more.

Shape

To improve wildlife habitat features and general aesthetics of the project, incorporate curvilinear features or irregular edges to better mimic natural wetland conditions and provide for greater biological diversity and function. Historic photos and soil maps may provide some help with determining the best shape for any planned excavations. Consider a variety of shapes and sizes if more than one excavation is planned.

Construction Requirements

To ensure that design objectives for each excavation component are met during the construction process, the prepared construction drawings and specifications must provide detailed views and explicit instructions on how to construct and finish the excavation work. Specifically, they should identify the following:

- Purpose for the excavation activity.
- Timing of planned excavation work with respect to project features that will restore or create wetland hydrology (i.e. tile blocks, ditch plugs, etc.).
- Required surface preparation work (clearing, grubbing and topsoil stripping).
- Requirements for using or disposing of excavated materials.
- Size, shape, elevations (depths), and slopes of the excavation.
- Requirements for stabilization before, during, and immediately after construction.
- Methods that will be used to verify quantities, qual ity, and completeness of work.
- Method for payment and process used to measure payment quantities.

Figure 4.6.8 *Shorebirds Using a Restored Wetland*

Site Preparation

The requirements for preparing planned excavation areas vary depending on the purpose of the excavation. The preparation work can include marking or staking the construction limits, clearing and grubbing of woody vegetation or other debris from the site, and stripping topsoil from the excavation limits.

Removal and Placement of Excavated Materials

Materials should be excavated and hauled to the designated placement areas or off site. Depending on the site conditions, it may be important or required that the excavated material be entirely removed from the wetland area. Attention to excavation and haul methods will be necessary in these situations. Ensure spoil placement does not impede or divert watershed flows original to the wetland.

> Ensure that spoil placed on adjoining uplands has no opportunity to erode and wash back into the wetland.

Excessive use and travel of construction equipment on both wetland and adjacent upland areas may result in undesired compaction of site soils. This is detrimental to overall soil structure and may impede efforts to establish high quality vegetation on the site. The construction plan should address this and require that equipment use be limited where possible and that compacted soils be loosened as part of any finishing operations.

Topsoiling

When working in drained and altered wetlands, it may be desired to salvage and reuse the existing soil surface layer or topsoil before excavating the underlying soils. Topsoil that is original to the wetland should be high in organic matter and may contain remnant native plant seeds and invertebrate egg banks. Where this condition occurs, the topsoil material should be stripped, stockpiled, and later spread over the finished excavated surface. Because salvaging and spreading topsoil over large excavation areas can be time consuming and expensive, the excavation work may be completed in stages, moving the topsoil from a new area onto an area that has already been excavated (**Figure 4.6.9**). This strategy allows the majority of topsoil on the project be moved only once, not twice as normally associated with most topsoil salvaging operations.

Figure 4.6.9 *Topsoiling of Excavated Scrape Area*

When wetland topsoil contains sediment, seeds, or plants from invasive species, or is laden with nutrients and chemicals such as phosphorous, consider, where feasible, removing the topsoil from the wetland.

Most wetland creations require that a suitable topsoil substrate material be located and transported to the wetland site. The methods to develop or secure suitable substrate materials and the depth and density at which they should be placed are important aspects of the project design.

Potential sources of substrate or topsoil could be from upland or other wetland sites located on the project or nearby. Each has its own advantages and disadvantages. Topsoil from upland areas will likely contain seedbank material that will not survive in prolonged saturated conditions, therefore allowing planted or volunteer wetland plant species to establish without competition. Conversely, topsoil from wetland areas may contain viable seedbank materials that are diverse in numbers and well adapted to saturated conditions. However, they may contain aggressive, undesired invasive seed species. The selection of donor material from known, quality sites can greatly influence the success of wetland functions restored as part of a project.

Stabilizing Excavation and Spoil Placement Areas

Finishing work includes final grading and spreading of topsoil and other excavated materials. Completed finish work should achieve the side slope, shape, and depth of the excavation as required in the construction plans. For most excavations, it will not be necessary or desired to finish the excavation to a smooth surface. A semi-rough, undulating bottom with varying microtopography will provide the most beneficial habitat conditions

Figure 4.6.10 *Finished Grade of Wetland Scrape*

and wetland functions for the site (**Figure 4.6.10**). The exception to this might be when excavations are conducted in shallow areas where aesthetics and appearance are important to the overall project goals.

The excavated area should be finished and, when required, spread with salvaged topsoil or, in the case of wetland creations, a suitable substrate that will promote the successful germination and establishment of wetland vegetation. The depth or thickness of the topsoil or substrate should be as indicated in the construction plans.

Stabilizing excavation and spoil deposition areas needs prompt attention during and immediately after construction. Provide clear requirements in the design, construction drawings, and specifications on how disturbed areas should be stabilized and under what time frames the work needs to be completed. Consider expected water depths and timing of when water will occur in the excavation. For example, water may appear in the bottom of many excavated areas immediately or within days after construction is completed. Depending on water depths, these conditions may not be suitable for planting or seed germination. Unless water levels can be controlled, seeding the outer edge and shallower areas within the excavation along with supplementing plantings of root or containerized wetland plants in areas with deeper water may be the only viable option for successful vegetation establishment.

When possible, mulch the side slopes of excavated areas as well as spoil deposition areas. This will help stabilize these critical areas and may prevent or limit the reintroduction of sediment into the wetland from adjoining areas.

Other Considerations

All planned excavations, in particular those in partially-drained and altered wetland areas, regardless of their purpose, need to adhere to local, state, and federal laws and regulations. Obtain all necessary approvals, permits, exemptions, etc., as soon as possible in the design process.

4-7 Other Design Strategies

Most often, wetland restoration or creation projects are straightforward and can be successfully accomplished with a practical approach to design and implementation. When completed, these projects can provide significant benefits to the local area and watershed. However, some projects will present challenges with regard to adverse impacts to adjacent properties or other infrastructure. This includes potential impacts to private lands, public lands, transportation systems, and utilities.

This chapter of the Minnesota Wetland Restoration Guide discusses items that are beyond the scope of more typical restoration strategies such as drainage system modifications or the construction of embankments and wetland outlets. Instead, information and associated design strategies are presented for situations that are occasionally encountered or desired when restoring and creating wetlands. This information varies from design and construction strategies used to protect adjacent properties or other infrastructure from wetland impacts to those used to improve habitat features for select wildlife species.

Discussion on the following topics occurs in this chapter of the Guide.

- **Adjacent Land Impacts**
- **Transportation Systems**
- **Utilities**
  - *Above Ground Utilities*
  - *Below Ground Utilities*
- **Public Access**
- **Nesting Islands and Peninsulas**
- **Artificial Structures for Nest Sites and Loafing Areas**

Adjacent Land Impacts

A project owner's legal rights and responsibilities with respect to development, drainage, water management, and land use under local and state laws can be complicated. Nonetheless, when restoring and creating wetland habitats, have some understanding of these issues and follow program policies or seek legal advice when difficult or questionable situations arise.

Notwithstanding a landowner's legal rights, approach every project with the mindset that off site impacts to non-project lands or properties should be avoided. Impacts related to land use, drainage, or flooding will be of most concern for neighboring property owners as well as local permitting authorities that regulate the implementation of many wetland restoration projects in the state. When it is not feasible or possible to avoid these impacts, easements, agreements, or other appropriate authorizations or permissions should be obtained from the adjoining property owner or affected party. This may require negotiations and discussions of project options, for which some general understanding of associated legal rights and responsibilities is necessary. Adverse impacts on these adjoining properties may be avoided through the use of certain design and construction strategies. These strategies, where feasible and practicable to implement, can be an important part of landowner negotiations as projects are being planned.

Unfortunately, the boundaries of many drained wetlands are not always consistent with property boundaries. The restoration of those wetlands may require the involvement of more than one property owner (**Figure 4.7.2**). The best approach to restoring these wetland sites is to ensure that the entire area of the drained or altered wetland is included or acquired as a part of the project or, at the very least, appropriate permissions or land rights are obtained from owners of the affected properties. These can include flowage easements, drainage agreements, permits, or, in some cases, simple written permissions or notifications.

When required acquisitions, permissions, or authorizations for drainage, flooding, or other impacts are unattainable, the project may not be restorable. Further analyses of the site may show that the restoration plan can be modified to avoid impacts to those adjoining properties. These modifications can include restoring and managing wetland hydrology at lower elevations or implementing design and construction strategies that will protect the adjacent property from impacts. These modifications may result in a wetland restoration that does not fully meet defined project goals, land owner desires, historical water levels or site conditions, or simply one that is not feasible or practicable for the site. Regardless, discussion and cooperation with adjoining property owners is necessary when attempting the restoration of wetlands under these conditions.

Construction strategies to protect adjacent properties from wetland restoration impacts can include: constructing a confining embankment, re-routing, diverting, or even installing new drainage systems, or through simple grading work to raise the elevation of the adjacent property. The methods and strategies used to construct earthen embankments are discussed in **Section 4-5 Earthen Embankments**. Modification of existing drainage systems to protect both private and public drainage rights is discussed in **Section 4-3 Drainage Systems Modifications** and in **Section 4-9 Construction Related Laws, Regulations and Permits**.

The strategy of performing grading work to raise the elevation of an adjacent property to protect it from hydrologic impacts may be a feasible and practicable solution when cooperation between property owners exists and where protection of anticipated impact areas is desired. This strategy is usually limited to adjacent land areas that are relatively small in size with feasibility be-

Figure 4.7.2 *Drained, Depressional Wetland Split by Property Line*

Figure 4.7.3 *Fill Placed and Graded to Protect an Adjacent Property*

ing governed by the scope of the project (**Figure 4.7.3**). Depending upon the land use within the planned fill area and soil characteristics of the fill material, the area being impacted may need to have its topsoil stripped, stockpiled, and reused on the finished graded surface. If the adjacent land is in agricultural crop production, timing the fill placement to coincide with the spring or fall season may avoid the necessity of negotiating a payment for crop damages. The source of borrow material for the fill, its location, placement elevation, anticipated allowances for settlement, and grade are essential elements of the design. When combined with other on-site excavations such as sediment removal or other wetland scrapes, this strategy can be cost effective, assuming haul distances are reasonable and the material being excavated is suitable for its purpose.

When utilizing this strategy, extend the fill into the project area at least 10 feet to allow for a buffer or travel lane along the outer edge of the project boundary (**Figure 4.7.4**). The buffer can filter runoff from the adjacent property, which might otherwise contribute nutrient-rich sediment to the wetland.

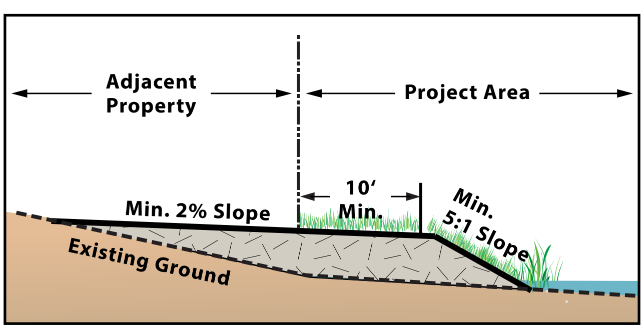


Figure 4.7.4 *Typical Fill Cross Section*

Transportation Systems

Occasionally, a planned wetland restoration or creation project will abut or impact an existing road, driveway, railroad, or trail. The success of these projects often relies on the ability to negotiate a design solution that protects those features from impacts. The authorities or owners of these transportation systems may be supportive of efforts to restore and create wetlands but want assurances that public safety will not be compromised and their road, driveway, railroad, or trail will not be negatively impacted by the project. Meet with the owners or authorities of transportation systems early in the planning and design process to avoid delays or problems with future approvals or permits for any work that may be planned to those systems or within their right-of-ways. Allow ample time to discuss the project, its impacts, and to negotiate a design concept agreeable to all parties.

Design and construction strategies are available to address potential transportation system impacts. These impacts can include seepage, flooding, rodent damage, or wave damage, all of which can affect the stability and integrity of the transportation system. In many situations, the planned hydrologic condition will be rather insignificant and may be acceptable with no other improvements needed. This is often the case when the expected project will result in saturated or very shallow water conditions within the system's right-of-way. In other situations, measures to protect the transportation system and its right-of-way may be needed. This usually occurs where deeper, more permanent water would exist within the right-of-way or where elevations of the transportation system are quite low with respect to planned wetland elevations. The design work involved in analyzing the site and developing a plan for these projects may require assistance from an experienced engineer since detailed hydrologic, hydraulic, and geotechnical assessments are needed.

One strategy that is used to avoid transportation system impacts is to construct an earthen embankment within the project property and just off of the right-of-way. This would be done to isolate wetland hydrology within the project area, preventing it from impacting the right-of-way or the transportation system. This

Figure 4.7.5 *Embankment Being Constructed to Protect Adjacent Road*

option is not always feasible or practicable and likely requires that alternative drainage for the right-of-way area exists (**Figure 4.7.5**).

In many situations, it will be more economical and beneficial to perform construction work within the right-of-way to provide the transportation system with the necessary level of protection. When authorized, this work can include filling and re-grading the right-of-way, constructing a berm against the road or flattening its side slope (**Figure 4.7.6**). The general strategy of each of these options is to place fill within and raise the elevation of the right-of-way area to minimize or prevent hydrologic impacts to the transportation system. The design and construction methods chosen are governed by the type and elevation of the transportation system, planned water depths or elevations against it, width of the right-of-way, and availability of suitable fill material.

In other, more extreme, cases, the transportation system itself may need to be raised or possibly even moved to facilitate the planned wetland project (**Figures 4.7.7** and **4.7.8**). For cost reasons, this strategy is likely limited to gravel surfaced roads, driveways, or

Figure 4.7.6 *Earthen Berm Against Road Slope*

trails and where the wetland resource is of significant size or value and the feasibility of such work can be justified. When it is planned to raise a road, driveway, or trail, there may be additional work required within the right-of-way to protect the transportation structure, as discussed above. Obviously, this strategy requires significant coordination and cooperation with the road authority or owner of the transportation system both during the design and construction processes.

A culvert or subsurface drainage tile that passes through or under the bed of the road, driveway, railroad, or trail may need to be modified or removed as a component of the restoration. This could occur independently or in conjunction with the strategies discussed above. This strategy often includes modifying the entrance to an existing road culvert, moving a culvert, or installing a new culvert to an elevation that controls hydrology of the restored wetland (**Figure 4.7.9**). These strategies are discussed in more detail in the **Technical Guidance Documents** *located in* **Appendix 4-xx** of the Guide.

Figure 4.7.7 *Road Bed and R-O-W Being Improved as Part of a Wetland Restoration*

Figure 4.7.8 *Improved Road Bed – Post Construction*

Figure 4.7.9 *New Culvert Thru Road as Wetland Outlet*

Utilities

Utilities that exist within or adjacent to a planned project create additional design challenges. Utilities can be located either above or below the ground and include electrical power, telephone, other communication or transmission lines, and various types of pipelines and conduits. During the planning process, identify the type and location of any utilities that exist within or adjacent to a project. Notify the state's Gopher State One Call system to request identification and marking of these utilities, in particular those that are below ground and unseen. Note that the One Call system does not locate private facilities such as natural gas farm taps, natural gas or propane gas pipelines to buildings, private water systems, private data communication lines, underground sprinkler systems, invisible fences, etc. The owners of these specific utilities will need to be contacted directly for assistance. Remember that some landowners may forget or be unaware of privately-installed hazards such as buried pipes, wires, and storage tanks. Work on their property can lead to potential litigation if construction activity causes leaks, damage, or personal injury. Discuss the potential for these outcomes with the landowner well ahead of construction.

For most utility structures, easements exist that can limit or prevent certain activities or land uses that would impact or prevent access to a utility for inspection and maintenance. Because of this, any planned restoration or construction work that can affect a utility must be discussed with the utility owner early in the planning process. Depending on the situation, a permit or some type of written permission may be needed from the utility owner before a project can proceed. In limited situations, it might be determined through negotiations that the best protection strategy will be to relocate the utility out of the planned wetland area. It is more common, however, to negotiate for certain construction strategies that will minimize or avoid wetland impacts to the utility. Permits or permissions may be granted provided that design or construction strategies will protect the function of the utility and access to it.

Discuss potential impacts with utility owner early in the design process.

Negotiations will need to identify the responsible party for conducting and paying for any necessary protection strategies. In many cases, the utility company will move the utility out of the wetland area or provide protection measures, all at their own costs. In other situations, there is an expectation or requirement that the project proponent will be responsible for these items. The decision on this will be influenced by the type of utility, protection measures needed, type of project, and, most importantly, the terms and conditions of any recorded easement or right-of-way documents for the utility.

Discussion on some of the available protection strategies for the more common utility situations follows.

Above Ground Utilities

Above ground utilities such as electric, telephone, and transmission lines will occasionally exist within planned wetland areas. Requirements for avoidance, access, and protection of the poles and towers that support these utility systems are usually needed. The best outcome for these discussions will be to have the utility moved out of the wetland area. When that is not possible or feasible, it may be necessary to consider some form of protection for the poles and towers that support the above ground systems.

Figure 4.7.10 *Utility in a Drained Wetland*

Protection strategies include placing a concrete pad, collar, or other durable product around utility poles to prevent their exposure to water or protect them from potential ice damage (**Figure 4.7.11**). Another strategy is to place and compact earthfill around poles both for protection and to create a dry, functional area or pad for future maintenance work. Where this strategy is used, the poles or tower legs may need to be treated or wrapped to protect them from excessive moisture prior to placing fill around them. In addition, the construction plan may need to provide for a functional access road to the pole or tower (**Figure 4.7.12**). The requirements of the pad, access road, and treatment of the pole or tower legs will be dictated by the utility owner and provided as a condition of their permit.

Underground Utilities

Underground utilities require special attention as part of a planned wetland restoration or creation. Certainly caution will be needed with all planned excavations near underground utilities. However, not all underground utilities will be impacted by the project activities or outcomes. For example, buried electric, telephone, and other communication lines may only need protection or modifications at above ground access points such pedestals and hand holes (splice points). In contrast, underground conduits and pipelines often require extensive protection measures because of the risk for floatation and the need for future access to the utility line for monitoring and maintenance. These can be difficult issues to overcome and often prevent the

Figure 4.7.11 *Sleeve Protection of Utility Poleland*

Figure 4.7.12 *Earthen Pad and Access Road to Utility Tower*

restoration or creation of wetland areas containing these types of utilities.

When addressing underground conduits and pipelines, it is very important to discuss the restoration or concept plan with the utility owner as early as possible in the planning process. The extent of hydrologic impact will be important to the negotiations. In some situations, a limited amount of hydrologic impact may be acceptable to the utility owner. In other situations, it may be feasible and acceptable to design and construct an earthen berm or graded fill above the utility that prevents it from floatation and provides reasonable access to it for inspections, monitoring, and repairs. Concrete weights or collars can also be considered but their high cost often precludes their use.

Good planning and communication are key elements to developing functional, sustainable, and successful wetland projects. This is especially true when negotiating potential impacts and protection strategies with owners of adjacent properties, transportation systems, or utilities. Early and frequent communication with the owners of utilities throughout the planning, design, and construction process will increase the likelihood for project approvals and success. It may prove beneficial to incorporate drawdown capability as part of the wetland's outlet, whenever possible. This could aid in providing better access to the site when maintenance or repairs are needed. Assuring access can be the difference when seeking a permit from any of these entities.

Public Access

The question of public access often arises when restoring wetlands on private lands that abut public roads. In Minnesota, a wetland is lawfully accessible if there is a public access, or if public land or a public road right-of-way abuts the surface of the water, or if you have permission to cross private land to reach the surface of the water. A wetland is open to recreational use over its entire surface if it is capable of recreational use and if it is lawfully accessible. In general, a wetland that is deep enough to float a canoe is capable of recreational use, including hunting.

Figure 4.7.13 *Underground Pipeline*

This issue has caused concern with many private landowners along with hesitation or refusal to undertake certain wetland projects. Project managers must understand state trespassing laws and what rights or options these landowners may have to protect their properties from public use. Minnesota Statute 103G.235 does provide private landowners some protection in these situations. This statute allows landowners the right to prevent access to restored or created wetlands on private lands that abut public land or a public road right-of-way if they properly post their property. Depending on the situation, posting open water wetlands can be difficult and will require regular oversight and maintenance. More importantly, it can be difficult for the general public to discern the difference between a restored or created wetland versus existing public waters wetlands, which cannot be posted when they abut public lands or public road right-of-ways.

When working with road authorities to provide protection to roads as part of the project design and construction, it may be possible, as previously discussed, to extend any road right-of-way fills out beyond the road right-of-way into the private property. In addition to providing protection to the road, this simple design strategy can also allow posting of the private property and prevent public access to certain restored or created wetlands.

A similar issue exists when restoring wetlands that are owned by more than one landowner. Permission to access the wetland by one landowner may allow access to the entire wetland water surface. This topic should be discussed among the landowners involved to avoid future conflicts.

Every situation is unique and application of the discussed state trespassing law, landowners rights, and design strategies may require further clarification from a DNR Conservation Officer or other Peace Officer who enforces trespassing law.

Nesting Islands and Peninsulas

In limited situations, island construction as a part of a project may create resting, courting, nesting, and brood habitat for waterfowl that is safe from predators. Island construction is especially beneficial in areas where other nesting cover is limited. Island construction is rarely done, however, and is only suitable for a limited number of projects. Island construction should only be considered if certain criteria can be met or obstacles overcome that may limit their success or long-term sustainability.

The most important factor in constructing an island is to locate it far enough from land, with deep enough water in between, to discourage predator access.

Therefore, the limiting factor to planning and constructing an island is the size and depth of the wetland. Unfortunately, those same factors that are necessary to limit predator access are also the demise of most constructed islands. Wave action from open water wetland systems tends to erode and destroy constructed islands, some within just a few years after they are constructed.

Designing and constructing islands to withstand the forces of wave action is essential to their longevity.

Islands can be expensive to construct if earthfill needs to be transported from a distant borrow area. The volume of material needed is quite large considering the depth of water around any functional island. Using natural land forms or microtopography within a drained wetland basin or surplus excavated materials from other grading or construction components can reduce the costs.

Consider the following criteria and management techniques when planning, designing, and constructing nesting islands.

- Islands should be located a minimum distance of 300 feet from a land-based shoreline.
- The water depth between the island and shoreline should at some point be deep enough to limit the growth of emergent vegetation such as cattail. This will typically require water depths of at least 3 ½ feet.
- Islands can be constructed from earth, rock, or a combination thereof. Avoid the use of organic soils or peat in their construction.
- The size of an island can vary; a minimum recommended size is 0.1 acres.
- To be successful for nesting, the height or elevation of the island needs to be above any potential flood stage.
- The side slopes of the island should be at least 8:1 or flatter to allow for some protection from wave action. Rock rip rap protection may be needed to protect the island from erosion.
- Choose a seed mix that will provide a dense cover to protect the island from erosion and cover the nest sites from aerial predators.
- If an island is constructed of rock material, top dress it with mineral soil to provide a medium to support vegetated cover.
- To be successful for nesting, the established vegetation will likely require occasional management strategies such as burning and woody species control.

Peninsulas are land forms that jut out from a wetland's shoreline. Peninsulas provide a more irregular shape and to increase the edge length of a wetland. Wetlands that have an irregular shoreline that includes points, peninsulas, and bays are more attractive to waterfowl and other wetland species. Peninsulas are also constructed to create suitable areas for recreation opportunities such as wildlife watching and hunting.

Many of the same criteria for constructing islands will apply to peninsulas. How far a peninsula extends into the wetland basin is a design preference based on water depths, availability of materials, and funding. A peninsula extending from the shoreline at least 20-30 feet with some deep water habitat around it is desirable. A peninsula built too far into an open water wetland can be subject to wave action and erosion.

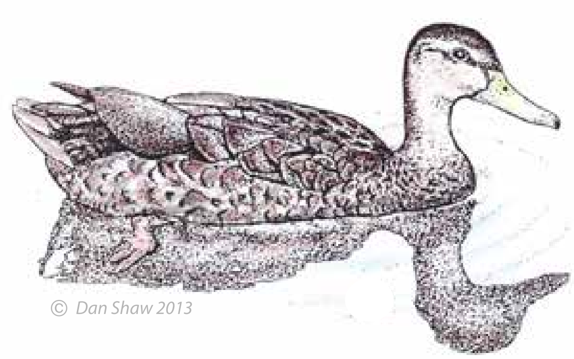


Figure 4.7.16 *Wood Duck House*

Artificial Structures for Nest Sites and Loafing Areas

The functional values of wetlands can be enhanced by providing safe nesting sites for waterfowl and other wildlife species. This is best achieved when large blocks of undisturbed grass cover are adjacent or in close proximity to the wetland. When adequate upland grass cover is not available, limited areas for nest sites are vulnerable to predators. To offset this problem and to supplement whatever cover is available, artificial nesting structures can be installed. These nesting structures should only be used where adequate brood water will exist after hatching.

The use of constructed houses, nest boxes, and other nesting platforms are commonly used to create nesting habitat for cavity and tree nesting birds like Wood Ducks, Common Mergansers, Hooded Mergansers, Common Goldeneyes, and Buffleheads. The boxes can be placed in trees or posts over the water.

Several other nesting structures can be constructed and placed on and near wetlands to benefit different types of waterfowl. These include "hen houses" and "nesting rafts". The hen house is a structure that consists of a three-foot long nesting tube made from welded wire mesh. The tube is formed from a double layer of the wire mesh with straw or course grass placed between the wire layers (**Figure 4.7.17**). This structure is attached to a post located over the water. Nest success with these structures is reported to be very high. Nesting rafts are floating structures that are used for nesting and loafing by a variety of waterfowl species.

Predation on all types of artificial nesting structures is a persistent issue, so their construction and placement can be critical to nesting success. To learn more, readers are encouraged to utilize resources and publications available through private conservation organizations and government agencies regarding these structures. They will include detailed instructions and plans for their construction and placement, which, if followed, improve their success.

In addition to nesting areas, waterfowl and other wetland wildlife species desire secluded areas for loafing and resting. These areas can be incorporated into a wetland restoration or creation project with simple

Figure 4.7.17 *Constructed "Hen House"*

planning and foresight. Loafing areas can be provided with an artificially-made and anchored raft. It can more easily be done with rocks, logs, and larger tree branches incorporated from areas of the project (**Figure 4.7.18**). Trees located on the site that were already cleared and grubbed during construction of the wetland are particularly handy. These materials should be placed strategically at the edge of the wetland and in the shallow water to provide rest areas. Extending larger branches and trunks at least partially into the water itself encourages their use by turtles and other aquatic species. Trees placed in water areas should not extend more than four feet above the water surface, otherwise they may become suitable perches for raptors.

Figure 4.7.18 *Constructed Loafing Area*

4-8 Construction Plan Development

Arguably, the most important and rewarding component of a wetland restoration or creation project is its construction. Before any actual construction work begins, however, a significant amount of planning and design work should have already been completed. The outcomes and requirements of the planning and design process need to be clearly and accurately conveyed in sufficient detail to allow contractors and others involved in the project's implementation to fully understand the project requirements. This primarily occurs through the preparation of construction plans, specifications, and other construction related documents.

This chapter of the Guide focuses on the preparation of construction plans and other construction documents and includes discussion on how they can be used to best achieve construction success and meet the intended goals established for the project. The following related components are discussed:

- **The Construction Plan**
  - *Project Scope and Plan Considerations*
  - *Plan Content and Drawings*
  - *Plan Format*
- **Construction Notes**
  - *Considerations for Use*
  - *Sequencing and Phasing Considerations*
- **Construction Specifications**
- **Construction Contracts**
  - *Bid Information*
  - *General Conditions*
  - *Drawings and Specifications*
  - *Special Provisions*
- **Measurement and Payment**
  - *Payment on a Per Job Basis*
  - *Payment on a Time and Materials Basis*
  - *Payment using a Unit Price Bid Schedule*

Figure 4.8.1 *Construction Plan Development*

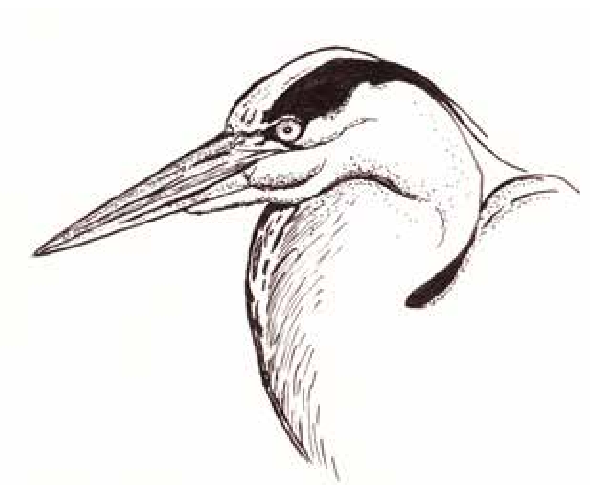
The Construction Plan

Project Scope and Plan Considerations

The amount and extent of information that is incorporated into a construction plan will vary, depending upon the scope and complexity of the work required to construct the project. Small, less complex projects generally require little construction work; therefore, the design and plan requirements may be kept to a minimum. With larger projects, the opposite is likely to be true and comprehensive construction plans will be needed to accurately depict the required work. Regardless of the project size or complexity, the planned work needs to be shown and described so both owner and contractor can fully understand the requirements. The clearer, more comprehensive and detailed the construction documents, the greater the likelihood for project success.

> Construction plans need to clearly show and describe the required work for the project.

Ideally, two things should occur before significant resources are spent in preparing the construction plan. First, the designer should have explored all the possible design alternatives for the project and considered the outcomes of each as it relates to the project goals. Second, a concept plan that identifies wetland locations, types, elevations, and the locations of construction components such as excavations, embankments, outlet structures, drainage system modifications, etc., should already have been drafted, reviewed, and approved. Comments and concerns that are received as a result of concept plan reviews should be considered, as appropriate, for inclusion into the construction plan.



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Construction plans are presented by both graphic drawings and narrative methods and outline the type, scope, quantity, and quality of work to be accomplished.

A plan can serve many purposes, including:

- Graphically represents the required construction information to everyone involved in the construction project.
- Facilitates project permits, reviews, and approvals.
- Identifies the quantity and quality of the work to be completed.
- Is used to verify and approve the work that is performed by the contractor.
- Provides a means for the owner/developer to take legal recourse should the final product not meet project specifications.
- Becomes a useful reference when developing and implementing an operation and maintenance plan.
- Becomes a useful and important reference should repair or replacement of the construction components ever be needed.

Plan Content and Drawings

To ensure that specific design objectives are met during the construction process, the construction drawings should provide detailed views and specific instructions on how to construct and install all project components. The drawings should accurately convey clear, legible, and comprehensive design details. They should display quality in both organization and format.

A construction plan contains three sections (**Figure 4.8.2**):

- A title sheet (cover sheet)
- A grading plan (plan view)
- Additional sheets showing construction details, notes, and requirements.

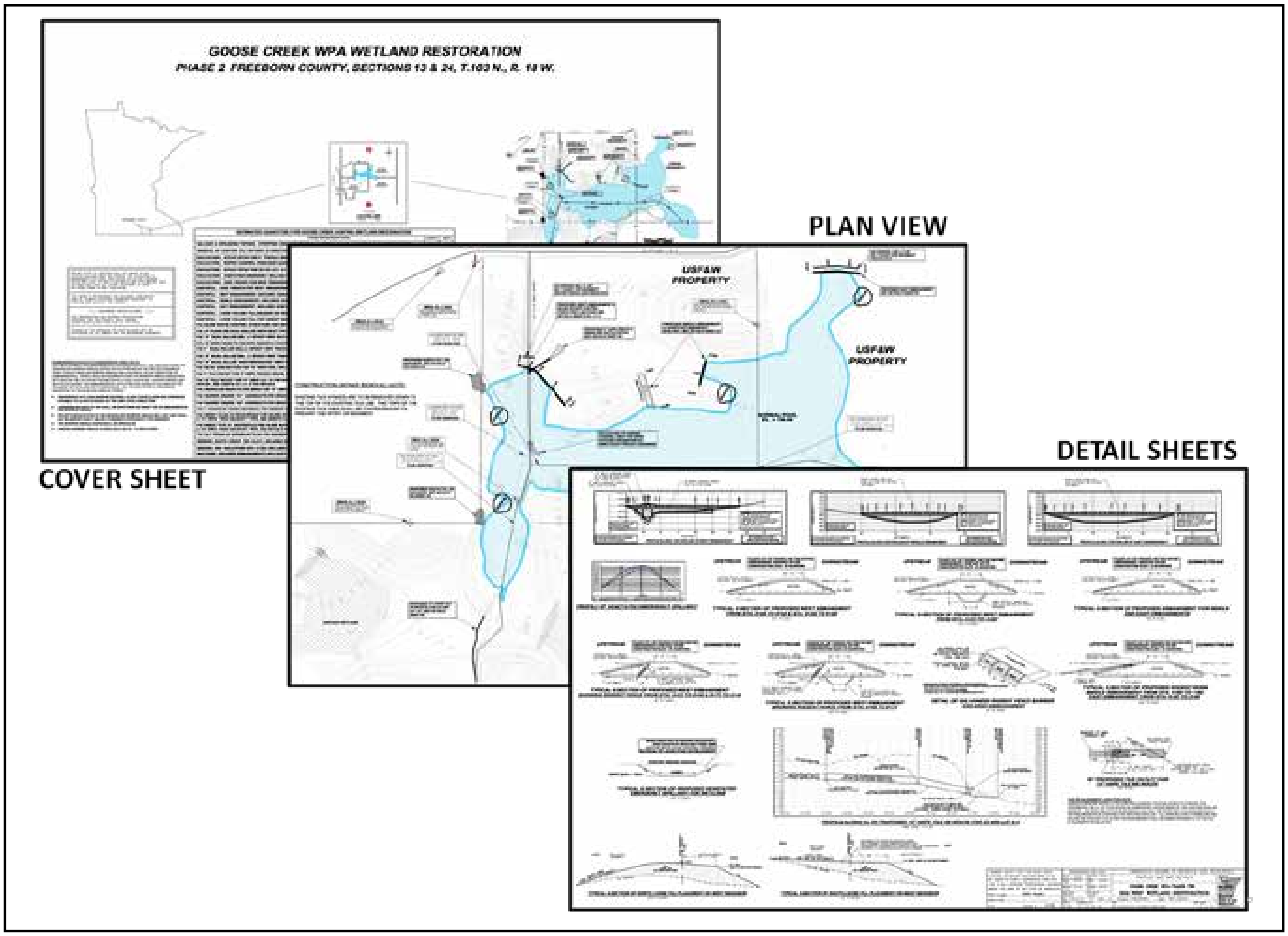

Figure 4.8.2 *Typical Sections of a Construction Plan*

The amount of detailed information contained within these three sections of the construction plan should be commensurate with the complexity and scope of the project. This information will include, at minimum, any of the following components as appropriate for the project:

- Project title
- Location map
- Access route(s)
- Construction limits
- Utility rights-of-way and contacts (when known)
- Utility notification requirements (Gopher State One Call)
- Table of estimated quantities
- Project control points and descriptions (bench marks)
- Grading plan
- Construction erosion control measures and re-quirements
- Construction sequencing and phasing requirements

- Excavation/stripping limits, depths and slopes.
- Location of borrow excavation areas.
- Locations, lengths (stationing), top widths, elevations, slopes for embankments and other earth fills along with any required foundation and site preparation work (cross section and profiles).
- Locations, types, sizes, grades, dimensions, elevations, materials and other requirements for outlet structures, pipes, drainage tile, etc.
- Requirements for stabilizing the site (seeding, mulching, etc.).
- Construction notes, details, and specifications, as appropriate.
- Types, sizes, amount, and quality of materials to be used.
- Location, elevations, grades, tolerances.
- Requirements for fabricating, placing, installing, and finishing the structure.
- Backfilling requirements, compaction specifications, and settlement allowances.
- Final grading and stabilization methods

Plan Format

A construction plan should be prepared on sheet sizes that are appropriate for the scope of the project allowing for design details to be shown in a neat and uncluttered manner. The scale of the drawings, details, and views must be selected to insure clarity of detail and must also consider the manner in which copies of the plan will be reproduced. While there can be some benefit to providing a construction plan on standard letter size paper, the scope and amount of detail needed for most wetland project construction plans will require at least 11 x 17 or larger sized plan sheets.

Because of the detail that needs to be provided, the topographic map that was prepared for the project is typically used as the basis for developing the construction grading plan or plan view. In limited situations, aerial photos may be used. In doing so, however, it can be difficult to clearly convey the requirements for construction, especially for larger, more complex projects.

All plan sheets should include a title block that identifies the project name, sheet number, sheet purpose or description, and signature(s) when applicable. Construction plans can be specifically developed for an individual job or, when appropriate, through the use of applicable standard drawings and forms. Standard drawings or details should be used to the extent possible to provide uniformity and efficiency, but not to the extent that poor quality or incomplete drawings are used.

The Minnesota Board of Water and Soil Resources (BWSR) has developed standard design drawings that apply specifically to strategies and components associated with restoring and creating wetlands. These drawings are available in both CAD and PDF formats and are located in Appendix 4-YY.

Construction Notes

Considerations for use

Design details within a construction plan often need written information to state what is required and how it is to be accomplished. This information is provided through written construction specifications. However, specifications can be more effective if stated as supplemental notes on the drawings rather than in a separate specifications packet. This should be considered only if the information can be more conveniently and effectively conveyed to the user as a note rather than as a specification. When preparing construction details, notes on the drawings will have the same effect as written specifications in defining the type and quality of materials to be furnished and in defining the scope of work.

The designer must use good judgment in deciding where written instructions and requirements should be located for maximum effectiveness. Notes on the drawings should be brief and limited to those required for complete and accurate interpretation of the design and specifications (**Figure 4.8.3**). Great care must be taken to avoid a conflict between the construction notes and specifications.

Sequencing and Phasing Considerations

Planning and scheduling construction activities in a well-thought-out manner can be a major factor in ensuring project success. All elements of the construction operation must be clearly understood so that implementation occurs as intended and in harmony with other project activities, in particular the vegetation establishment.

Any sequencing, scheduling, or staging requirements should be clearly stated within the construction plan. To the extent practicable, these sequencing and phasing requirements are best conveyed on the construction plans through the use of construction notes and details. Items to consider when identifying sequencing and phasing requirements can include:

- Identifying operations that will minimize site disturbances in an attempt to control construction-related erosion and sediment pollution.
- Sequencing construction operations for components in a logical manner to allow them to be completed before hydrology is returned to the wetland.
- Scheduling of construction and vegetation establishment operations to allow seeding of the site to include recently completed or disturbed construction areas. Coordinate with vegetation planners and designers of the project to ensure the implementation plans and schedules do not interfere, but work well together to improve the chance of project success.

Construction Specifications

Construction specifications are written to support the construction drawings. They should provide specific instructions on how construction is to be performed and what materials are to be used in the process. The following construction related items are typically addressed in the specifications:

CONSTRUCTION REQUIREMENTS

EMBANKMENT:

- SUBCUT DIMENSIONS ARE MINIMUMS, DEPTH AND WIDTH MAY VARY BASED ON SITE AND SOIL CONDITION. ENGINEER MAY DIRECT WHEN NECESSARY TO EXCAVATE TO DIFFERENT DIMENSIONS THAN WHAT IS SHOWN IN TABLE ABOVE.
- CLAY CORE DIMENSIONS ARE MINIMUMS, HEIGHT, WIDTH, AND SIDE SLOPES MAY VARY BASED ON SITE, SOIL CONDITION, AND MATERIAL AVAILABILITY.
- RANDOM FILL DIMENSIONS ARE MINIMUMS, HEIGHT, WIDTH, AND SIDE SLOPES MAY VARY BASED ON SITE, SOIL CONDITION, AND MATERIAL AVAILABILITY.
- SETTLEMENT ALLOWANCE IS CALCULATED FROM BOTTOM OF CLAY CORE SUBCUT TO DESIGN ELEVATION OF RANDOM FILL.
- EMBANKMENT COMPACTION SHOWN IN TABLE IS THE MINIMUM COMPACTION REQUIRED.

Figure 4.8.3 *Typical Construction Notes*

- Clarification of the technical and workmanship requirements for the project.
- Definition of the required types and quality of the materials that are to be used.
- Specifications for construction tolerances, installation methods, and procedures.
- Specifications to be met from the methods of testing performed for the various construction operations.
- Definition of the required methods of measurement and the basis for payment for specific construction components.
- Provide additional or supplemental directions that are not shown on the drawings.

As with the construction plan, the amount of detailed information contained in the construction specifications should be commensurate with the scope and complexity of the project. For small, simple projects, the construction and material specifications may be incorporated as

Construction specifications in some form should be provided for every construction project.

text within the construction plan, avoiding the need to prepare a separate specifications document. Exercize good judgment when attempting to incorporate specifications into the construction plan as they can clutter the drawings, affecting the ability for the required work to be effectively communicated.

For most construction projects a separate construction specifications packet is prepared as a supplement to the construction plan. As most specification requirements will remain consistent from project to project the use of a standard specifications packet is common to ensure consistency and efficiency as projects are administered. In doing so, it will be important to reference the applicable specifications for the project or individual work items. This is usually done within the bid documents or directly within the construction plan.

Ideally, construction specifications will be specific and relevant to the requirements of each construction project; they are more likely to be read and adhered to and will be more easily enforced.

Construction Contracts

Construction contracts are written and executed between the owner of the project and the contractor hired to build the project. Contracts are developed and executed to specify what work will be performed, how and when it will be performed, what quantities and materials are needed, who will be responsible for providing them, and what specifications are to be used when performing the work. Construction contracts are intended to be legal documents in that the contract terms and conditions are binding and enforceable.

Construction contracts are not often utilized for smaller, less expensive construction projects, or projects that are conducted on private lands. In those situations, construction plans, specifications, and a bid document may be all that is needed for successful project implementation. As projects get larger and more costly, if working conditions or time constraints are of a concern, or if the work is planned on publically-owned lands, then the use of a contract is warranted and, in some cases, it may be required.

Construction contracts can exist in many forms, from documents that are quite simple to those that are complex and lengthy. The larger, more complex the wetland project, the more carefully thought out and detailed the components of the construction contract need to be. The body of a construction contract will consist of five main components:

- Bid Information
- General Conditions
- Drawings
- Construction Specifications
- Special Provisions

Bid Information

The bid information includes a notice or invitation for bids, information for bidders on general project requirements, information on the project owner and engineer, information on the bid process, and the bid proposal form or bid schedule for prospective contractors to complete and submit to the owner. The bid proposal form or bid schedule form provides the basis for payment as it lists all items of work for which payment will be made and defines the method of measurement and payment for each work item listed.

General Conditions

The General Conditions or Provisions contain the administrative and technical requirements of the contract. Standard or "boiler plate" General Provision documents are used as the language tends to remain consistent from project to project. The General Conditions document should address the following items:

- Performance Security - Bonding Requirements
- Notification of Utilities
- Liabilities
- Insurance Requirements
- Contractor's Requirements and Responsibilities
- Owner's Responsibilities
- Engineer's Responsibilities
- Work Schedule
- Provisions for Site Access
- Start and Completion Dates
- Extensions for Completion Date
- Construction Inspections
- Plan Modifications

- Protection and Restoration of Property
- Penalties and Liquidated Damages for Unmet Deadlines
- Payment Process

Drawings and Specifications

The construction drawings and the construction specifications address and contain the technical details and requirements of the project.

Special Provisions

The Special Provisions are prepared on a project specific basis and contain administrative and technical instructions unique to the project.

Construction contracts are written to cover a wide range of construction-related issues. However, even in the largest projects, a certain amount of good faith and understanding between the contractor and the owner/developer/engineer is necessary, as it is not practicable for the construction contract to cover every possible construction-related item.

Measurement and Payment

Regardless of whether a project will be completed under a formal contract or through a simple agreement, some basis for determining how much contractors will charge for completing the specified work is needed before the actual construction work begins. Three methods for bidding and paying for a project are discussed below. The appropriateness of each method will generally be determined based on the scope of work associated with the project.

Job "Plan Quantity" Basis

Measuring and paying by the job is the most straightforward method of payment. One lump sum amount is bid for the planned work. The limitations are that this method of payment does not easily allow for plan or quantity changes that would affect construction costs. This method of payment is recommended only for small, uncomplicated, and relatively inexpensive projects where cost overruns or unexpected plan changes are unlikely.

Time and Materials Basis

Bids can also be based solely on the time and materials required to complete a project. Use of this payment method should be limited to small or relatively straightforward projects where no complications are anticipated during the construction work.

This payment method is most preferred by contractors in that they feel more secure in bidding on this type of work and will often do the work at a cheaper price than they would through other methods of payment. The reason for this is that they will not lose money on a job that takes longer to complete than anticipated due to unexpected site conditions or poor weather. However, it does require close oversight of the construction work to ensure that the actual hours worked and material quantities used are accurately measured and billed.

> A good relationship and great deal of trust must exist between the owner and contractor when using this method of payment.

Different hourly rates will apply to different pieces of construction equipment. Determining these rates and keeping track of equipment time can be a challenge, especially when several pieces of equipment will be operating simultaneously.

It can also be difficult to accurately compare bids if the contractors bidding on the job propose to use different equipment. Equipment that is larger and more efficient will usually cost more per hour to operate, however they will complete the job faster than smaller, less-efficient equipment.

Under this method, materials and supplies needed for the project should be billed to the owner at the contractor's cost. Copies of product invoices should be included with the contractor's invoice when submitting for payment.

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Unit Price Bid Schedule

Paying for construction work through the use of a "unit price" bid schedule or form is the most common and practicable method used. A unit price bid allows for the measurement and payment of specific construction and material quantities. It allows maximum flexibility during construction as any variation in project quantities are reflected in the final payment. This method of payment usually requires that actual constructed quantities be measured at time of completion. Arrangements with the contractor should be made ahead of time as to how that will occur as certain items, if construction is allowed to continue, will not be measurable (e.g. volume of an excavated core trench).

A unit price bid schedule or form shows the estimated quantities of work, the unit of measurement that will be used, and it provides space for entry of the contractor's unit bid price for each of those items (**Figure 4.8.4**).

The preparation of the bid schedule or form requires close cooperation of the responsible design engineer and contracting officer, if any. Operating procedures should include provisions for administrative review of the prepared bid schedule or form in the early stages of its development as well as upon its completion. If a construction contract is used, the administration of the contract will be directly affected by the manner in which the bid schedule is organized.

Considerable judgment based on design, construction, and contracting experience is required to identify and divide specific work items for inclusion into the bid schedule or form. An attempt should be made to keep the number of bid items to a minimum, yet be comprehensive enough to allow the contractor to make reasonably accurate estimates of the cost of performing specific work items. The practical extent to which the work should be divided into unique bid items must be judged in light of the quantities and scope of work involved. All items that involve significant quantities of work or specific methods of construction should be designated as separate bid items. In addition, the identified bid items should include those items necessary that will result in a fair and equitable treatment of the contractor and project owner(s). It should also be clearly noted if any of the required materials for the job will be provided by someone other than the contractor. For example, the owner of the project may have or will provide certain materials that the contractor will only need to install.

Items that are either not conventional for measurement or have quantities that are fixed and not subject to variation may be designated for payment on a lump sum

BID FORM

Project Name: *Ed Jones Wetland Restoration* Project No: *2008-007* *30-Sep-2009*

CONTRACTOR INFORMATION

Contractor/Company Name: Business Phone No.: Cell Phone No.:

Address: City/State/Zip Code: Contractor Signature:

Item / Spec. No.	*Description of Bid Item*	*Pay Unit*	*Estimated Quantity*	*Unit Price*	*Sub Total Cost*
1	Mobilization (not to exceed 5% of total bid price)	L.S.	1.0		
2 *2.210*	Salvage and Spread Topsoil (P)	C.Y.	87.0		
3 *2.220*	Excavation - Spillway (P)	C.Y.	34.0		
4 *2.220*	Excavation - Shallow Scrapes/Sediment Removal (P)	C.Y.	145.0		
5 *2.230*	Earthfill - Embankment (P) (CV) *(Includes volumes for subcut area and settlement allowance)*	C.Y.	300.0		
6 *2.391*	Tile Investigation	L.F.	100.0		
7 *2.391*	Tile Block/Removal	L.F.	200.0		
8	F & I Outet Structure - Basin #1 *(See Bill of Materials Sheet X)*	L.S.	1.0		
9 *2.430*	F & I Geotextile Underlayment for Rock Riprap, MnDOT Type 4 (P)	S.Y.	67.0		
10 *2.410*	F & I Rock Riprap - Angular, MnDOT Class 3 (P)	C.Y.	6.5		
11 *2.250*	Seeding - Native Construction Mix 32-241 *(Embankment tops and other disturbed upland areas)*	Acre	1.5		
12 *2.250*	Mulching (P) *(Embankments and spillways)*	Acre	1.0		

TOTAL $

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Figure 4.8.4 *Unit Price Bid Form*

or job basis within the bid schedule. A simple outlet structure or pipe end section are examples of construction items that could be bid on a lump sum basis.

Other unconventional and difficult-to-measure items that are subject to some variation may, when appropriate, be designated for payment on an hourly basis within the bid schedule. Simple excavation work and tree removal are examples of construction items that could be bid out by the hour.

Examples of various pay units include, but are not limited to: lump sum, job, cubic yard, square yard, cubic feet, square feet, lineal feet, ton, gallon, hour, acre, and staked quantities. The units of measurement used in the bid schedule must be compatible with the measurement and payment clauses defined in the construction specifications.

Items involving an insignificant quantity of work or work that is logically related to another pay item can be considered a subsidiary item or an item whose pay is to be considered incidental to another bid item. These incidental work items are not listed in the bid schedule or form and must be designated and described as such on the construction plans and in the construction specifications. For example, the excavation of a borrow area to obtain soil material for construction of an earthen embankment would typically not be considered a pay item but rather be included in the costs or be incidental to the cost of constructing the embankment.

4-9 Construction Related Laws, Regulations and Permits

Figure 4.9.1 *Construction Site Excavation*

The topics covered in this chapter of the Guide include discussion of current local, state, and federal laws, regulations, and permit requirements that are required as part of implementing wetland restoration or creation projects.

- **Wetland Protection Laws**
- **Other Environmental Laws and Permit Considerations**
- **Drainage Laws and Regulations**
  - *Public Drainage Systems*
  - *Private Drainage Systems*
- **Other References**

When restoring and creating wetlands, those involved in the implementation and construction process have a responsibility to manage and promote the appropriate use of the state's resources for the benefit of its present and future residents. There are a number of federal, state, and local laws and regulations that exist to ensure this occurs. Construction activities associated with restoring and creating wetlands are subject to many of these laws and regulations. Most relate to the use of surface and subsurface water but also to construction site stormwater management, soil erosion and sediment control, public safety, and historic preservation. Project managers need to be familiar with applicable federal, state, and local laws, regulations, and ordinances. They also need to be aware of on-going changes to these regulations as they occur frequently and may supersede information presented in the Guide.

Where permits or other approvals are needed, the process to obtain them can be lengthy. Make plans to seek them early in the planning and design phase so as not to cause delays with project implementation.

Wetland Protection Laws

When restoring partially drained wetlands, it is sometimes necessary for planned construction activities to occur within existing, albeit altered wetland areas. For example, earthen ditch plugs or embankments often need to be constructed across areas of partially drained wetland as part of a planned wetland restoration. Fortunately, wetland regulations recognize that these minor impacts will be for the greater good and in most situations do not require replacement or mitigation for them. Nonetheless, permits, approvals, or exemptions, are still needed for these wetland impacts through the applicable federal, state, and local wetland regulatory laws.

In limited situations, replacement or mitigation for these impacts may be needed. This generally occurs when the wetland is being restored for replacement or mitigation purposes. This situation needs to be discussed with appropriate regulatory authorities early in the planning and design process.

Construction work that will occur in effectively-drained or non-wetland areas will not likely be subject to these wetland protection laws.

In Minnesota, the primary wetland protection laws to consider when performing construction to restore and create wetlands are:

- Federal Clean Water Act, Section 404 and Section 401
- Minnesota Wetland Conservation Act
- Minnesota Public Waters

A general description of these laws and considerations for addressing them is provided in **Table 9.1**.

Figure 4.9.2 *Wetland Partially Drained by Open Ditch*

Table 4.4 *Wetland Protection Laws Affecting Construction Activities*		
Protection Law	**General Description**	**Considerations**
Federal Clean Water Act-Section 404	Under Section 404 of the federal Clean Water Act and Section 10 of the Rivers and Harbors Act, the U.S. Army Corps of Engineers (COE) regulates the discharge of dredged or fill material into "waters of the United States". COE regulations define these waters to include certain wetlands as well as ponds, streams, lakes, and other special aquatic resources. In general, land alteration activities in any area falling under the broad category of "waters of the United States" must be authorized by a COE permit	The COE has developed "general permits" that may cover wetland impacts associated with wetland restoration projects. It will be important to coordinate the planned activities early in the process with the local COE project manager. It is recommended that written confirmation be requested from the COE that the project is not under their jurisdiction, is authorized by a COE general permit, or some other type of authorization provides compliance with federal wetland and water rules.
Federal Clean Water Act-Section 401	Section 401 of the Clean Water Act provides the COE with authority to regulate and permit for water quality protection standards related to pollutant discharges into waters of the United States.	Section 401 water quality certifications are issued by the Minnesota Pollution Control Agency (PCA) as part of the Section 404 permit process. Projects that are regulated by Section 404 general permits do not need 401 water quality certifications as they have been determined to be "pre-certified".
Minnesota Wetland Conservation Act	The Minnesota Wetlands Conservation Act (WCA) provides protection of wetlands not protected under other existing wetland laws. Regulatory authority for WCA is found in Minnesota Statutes Section 103G. Wetlands that fall under WCA jurisdiction cannot be drained or filled (or excavated under specific circumstances), wholly or partially unless replaced by restoring or creating wetland areas of at least equal public value under an approved replacement plan. The WCA is administered by a local governmental unit (LGU), usually a Soil and Water Conservation District, County, City, or in a few instances a township.	An application to the LGU is needed for construction activities that are planned in partially drained or altered WCA regulated wetlands. Most wetland restoration activities conducted in wetlands can be approved by the WCA LGU without mitigation or replacement through a "No-loss" determination under MN Rules Chapter 8420.0415, item D. Communicate with the LGU early in the planning process and seek guidance on impacts to wetland areas. When required, project approval needs to be given prior to conducting any implementation work. Enforcement actions can be expensive if work that is conducted in wetlands turns out to be noncompliant with WCA rules. In addition to LGUs, the local SWCD can provide assistance in determining wetland permitting needs.
Minnesota Public Waters	The Minnesota Department of Natural Resources (DNR) administers the permit process to allow work in Public Waters at the state level. The DNR's authority to require such permits is established in Minnesota Statutes Section 103G. Public Waters are a subset of lakes, wetlands, watercourses, or altered natural watercourses that meet certain criteria. Although most Public Waters Wetlands are natural, undisturbed systems, some are also partially drained and altered and can be considered for restoration.	A DNR permit will likely be required for any work that will occur below the Ordinary High Water Level (OHWL) in a Public Water. Wetland restoration or creation projects adjacent or connected to a Public Water may also require DNR approval. To determine if a particular wetland is a Public Water, refer to the Public Waters Inventory (PWI) maps that can be found on the DNR website. If a project has the potential to affect a Public Water, coordinate with the DNR's local Area Hydrologist. The Area Hydrologist can provide written confirmation of the need for a permit. In some cases, the DNR will waive their permitting authority to the local government unit as discussed in the following section on the Wetland Conservation Act.

Other Environmental Laws and Permit Considerations

Other permits or approvals may be necessary for planned land-disturbing activities associated with construction of wetland restoration and creation projects. These relate to the protection of the state's water resources and regulation of planned land alterations, ensuring environmental compliance, public safety and well being, and the protection and preservation of historic resources.

Following is a list of other, more typical permits and approvals that may be needed when performing construction to restore and create wetlands. A general description of these laws and regulations and considerations for addressing them is provided in **Table 9.2.**

- National Pollutant Discharge Elimination System
- Watershed Districts and Water Management
- Local Zoning Regulations and Ordinances
- Transportation Systems and Utilities
- Dam Safety
- Cultural Resources

Table 4.5 *Other Environmental Construction Laws and Permit Considerations*		
Regulation	**General Description**	**Considerations**
National Pollutant Discharge Elimination System	The Minnesota Pollution Control Agency (MPCA) administers the National Pollutant Discharge Elimination System (NPDES) in Minnesota. The MPCA issues permits to construction site owners and their operators to minimize the potential of water pollution by excessive storm water runoff during and after construction and until permanent erosion control practices are in place. While some exemptions for the NPDES program exist for conservation-related activities, many wetland restoration and creation projects will require an NPDES permit.	As part of this permitting process, the owner or operator must develop a storm water pollution prevention plan (SWPPP). The SWPPP must explain how storm water runoff will be managed on the site and how any potential pollution from soil erosion will be minimized. Spot checking of temporary or permanent practices is done to determine that they were correctly installed and are being properly maintained.
Watershed Districts and Watershed Management Organizations	Watershed Districts and Water Management Organizations have permitting authority over the use and management of surface and subsurface drainage systems. Their permitting authority also includes the use and management of water resources, construction, and certain other land-disturbing activities within their jurisdictions.	It will be important to understand locations and boundaries of these local units of government and to adhere to their rules and permitting requirements as they can influence project outcomes.
Local Zoning Regulations and Ordinances	County, city, or township authorities have local zoning laws that may regulate activities associated with typical wetland restoration and creation projects. Conditional use permits and letters of approval are commonly used to gain approval for these activities.	The local government authority should be contacted early in the planning and design process to determine what ordinances exist and if permits will be needed.
Transportation Systems and Utilities	The planned activities associated with some wetland restoration and creation projects may impact public roads, railroads, or their rights-of-way. They may also impact existing above or below ground utilities including; electric, telephone, fiber optics, cable television, other transmission lines and their associated posts or towers, and underground pipelines that carry various gas and liquid products. Whether there is a direct impact through construction or an indirect hydrologic impact, permits or other approvals from the appropriate transportation authority or utility will be needed.	Contact appropriate transportation system and utility authorities early in the planning and design process for any wetland restoration or creation project. Not all planned activities will be allowed; some discussion and negotiation as to what can be done will often be necessary.
Dam Safety	Projects can include the restoration or creation of a large wetland basin. These projects may include the construction of larger dams that impound large volumes of water. If a project falls under the definition of a "dam", it will be regulated by the state. The DNR oversees and regulates the state's Dam Safety Program. This program regulates the repair, operation, design, construction, and removal of public and private dams within the state. The Dam Safety Program has the following responsibilities: ■ Provide minimum standards for safety, design, construction, and operation of dams. ■ Provide engineering review of proposed dam projects. ■ Issue dam safety permits through a Public Waters Permit. ■ Inspect and analyze publicly and privately owned dams to ensure their structural integrity, safety, and that they are responsibly operated and maintained.	State dam safety regulations apply only to structures that pose a potential threat to public safety or property. State dam safety rules do not apply to dams that are so low or retain so little water as to not pose a threat to public safety or property. Dams less than six feet high, regardless of the quantity of water they impound, and dams that impound 15 acre-feet of water or less, regardless of their height, are exempt from state dam safety rules. Other exemptions may also apply depending on potential for loss of life due to failure or misoperation. Dam safety review is conducted as part of the Public Waters Permit program. Additional information of the Dam Safety Program can be obtained on DNR's website.
Cultural Resources Review	The preservation and protection of cultural resources will be an important aspect and consideration for every project. Section 106 of the National Historic Preservation Act of 1966 requires federal agencies to evaluate the impact of all federally funded or permitted projects on historic properties, including archaeological sites, through a process known as Section 106 Review. Minnesota state law requires state agencies to submit development plans to either the Minnesota State Historical Preservation Office (SHPO) or the Minnesota Indian Affairs Council for review when there are known or suspected archaeological sites in areas that are planned for disturbance. It also requires that state agencies consult with the SHPO before undertaking or licensing projects that may affect properties on the Network or on the State or National Registers of Historic Places.	Not every planned activity will be a cultural resources concern. In fact, most activities conducted within drained and altered wetlands will not be. Upland buffer areas, on the other hand, are more likely to contain cultural resources, especially those areas adjacent to larger, drained wetlands. All projects should have a cultural resources review and determination early in the planning and design process to allow time for appropriate actions to be taken when resource impacts are suspected or identified. The SHPO has state-wide jurisdiction, except within the boundaries of tribal lands that will have their own Tribal Historic Preservation Office.

Figure 4.9.3 *Sediment and Erosion Control Practice*

Note that this is not a complete list of environmental laws and regulations that require permits or approvals. Certain projects will also require permits or authorizations for impacts to threatened and endangered species, an environmental assessment worksheet (EAW), or other regulatory or compliance measures.

Drainage Laws and Regulations

Many wetland restoration projects will involve to some degree the manipulation of a public or private drainage system as part of restoring site hydrology. Drainage systems can provide positive benefits to agriculture and urban landscapes. The misuse or mismanagement of these drainage systems can affect public safety and welfare and can become a point of contention for neighboring landowners. Plans to manipulate drainage systems can have possible legal implications and therefore require appropriate legal procedures be followed and related approvals and permits secured, where necessary.

> Drainage systems have inherent legal rights that are governed by state law.

When manipulating a drainage system, comprehensive site investigations and analyses need to be completed. Depending on the situation, it may be necessary to prepare engineering reports and plans to support the proposed project and demonstrate that there will be no adverse offsite impacts resulting from its completion.

In Minnesota, both public and private drainage systems exist. While their general use and appearance may be similar, the legal process to manipulate these systems is quite different and thus they will be discussed separately.

Minnesota's public drainage systems are governed by state law through Minnesota Statutes Chapter 103E, Minnesota's Drainage Law. The oversight of Minnesota's drainage law lies primarily with the following entities, often referred to as the "Drainage Authority":

- County Board of Commissioners
- Joint County Drainage Authority
- Watershed District Board of Managers

Watershed districts can have permitting authority over the use and management of private drainage systems, as well. The legal process and permitting requirements for manipulating both public and private drainage systems is discussed below.

Public Drainage Systems

In Minnesota, Drainage Law exists for the oversight and management of public drainage systems. According to Drainage Law, approval from the Drainage Authority will be required if a planned wetland restoration project will impact a public drainage system.

These planned impacts can include blocking, filling, or abandoning all or a portion of a drainage system, realigning or diverting a drainage system to avoid a wetland, and to impound drainage system waters as part of a planned restoration project. Depending on the specific actions to be taken, requests to modify are initiated through a petition to the Drainage Authority. Drainage systems have inherent legal rights which are often governed by state law. Various sections of drainage law may apply and will need to be appropriately addressed to allow the planned activity.

The following two sections of Minnesota's Drainage Law are most often referenced when planning to ma-

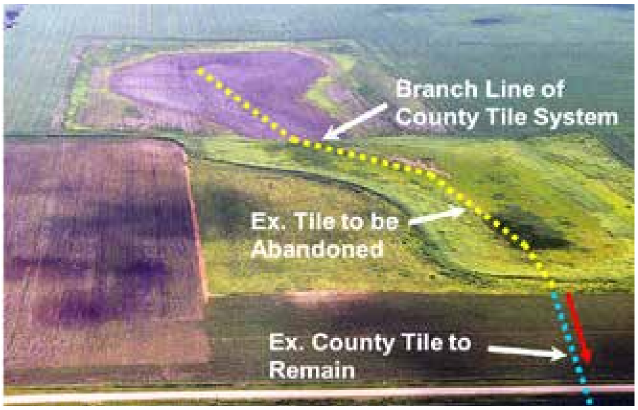

Figure 4.9.4 *Partial Abandonment of Public Drainage System*

nipulate a public drainage system as part of a wetland restoration:

- Section 103E.806 - Partial Abandonment of a Drainage System
- Section 103E.227 - Impounding, Rerouting and Diversion of Drainage System Waters

These sections of law are as described as follows:

Section 103E.806, Partial Abandonment of a Drainage System recognizes and allows parts of existing drainage systems to be abandoned if it can be demonstrated that the section to be abandoned will no longer be a public benefit and will not serve a substantial useful purpose to properties remaining on the drainage system. This is a common situation for many wetland restoration projects that are located at the beginning or upstream end of a public drainage system. Upon a successful request to partially abandon a public drainage system, the responsibility of the drainage authority for that part of the system ends.

Example: *A depressional wetland basin is drained by a branch line of a county tile system. The upper end or beginning of the branch tile and the land area it benefits (drains) are located within the property being secured to facilitate the restoration of this drained wetland. The restoration plan would include the construction of an appropriately designed tile block on the county tile system at the wetland's outlet (***Figure 4.9.4***). A petition to the drainage authority to partially abandon the reach of branch tile that exists within the property area being purchased would be applicable to this situation.*

Section 103E.227, Impounding, Rerouting, and Diversion of Drainage System Waters allows the construction of water-resource-related projects such as the restoration of wetlands on existing public drainage systems. The use of this section of law is applicable to projects where the restored wetland(s) will be located within the extents of an existing drainage system. In other words, a functioning reach of the public drainage system will exist both upstream and downstream of the restored wetland.

Example 1: *A depressional wetland basin is drained by a county tile system. The tile extends upstream of the wetland basin and provides drainage benefits to properties upstream of the project (***Figure 4.9.5***). The wetland will be restored by blocking the tile and installing a structure at the wetland's outlet. Engineering investigation and design shows that the upstream reach of county tile has enough grade (vertical relief) so that the upstream properties that*

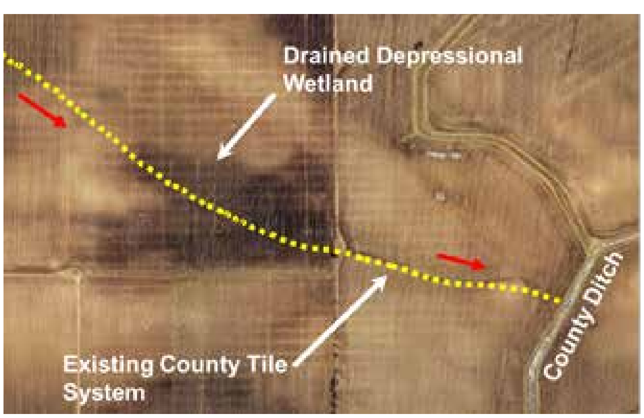

Figure 4.9.5 *Wetland Drained by County Tile System*

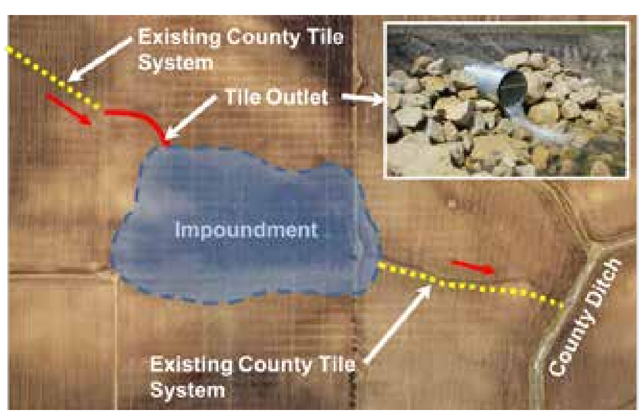

Figure 4.9.6 *Wetland Restored Within County Tile System*

*benefit from the tile system will not be negatively affected by the planned restoration. A petition to the drainage authority to impound water on the drainage system through the construction of a tile block, outlet for upstream tile and outlet structure along with abandonment of the existing county tile within the impoundment area would be applicable in this situation (***Figure 4.9.6***).*

Example 2: *A county ditch system flows through and drains a shallow wetland. The ditch extends upstream from the wetland and provides drainage benefits to properties upstream of the project. Engineering investigation and design shows that the upstream reach of county ditch is too flat in grade and cannot be outletted into the planned wetland restoration without impairing upstream drainage benefits. The restoration plan then requires a diversion of the upstream ditch system around the planned wetland restoration (***Figure 4.9.7***). A petition to the drainage authority to re-align or divert the county ditch drainage system around the planned wetland project along with the abandonment of the county ditch within the wetland basin would be applicable in this situation.*

The process to modify or abandon all or portions of a public drainage system for restoration purposes begins with preparing and obtaining signatures on a petition that will be filed with the Drainage Authority. Check with the local drainage administrator or county auditor for any specific requirements that relate to preparing and submitting a petition. In some cases, it may be necessary to seek legal counsel in the preparation of these documents as they need to comply with the requirements of Section 103E of state law. Upon acceptance of the petition, hearings are scheduled at which time the project is discussed and a decision is made by the Drainage Authority as to whether or not allow the proposed change to the public drainage system.

Figure 4.9.7 *Typical Rerouted County Ditch System*

Actions taken on either of these two sections of Minnesota's drainage law will not release project properties from any existing drainage liens or future drainage assessments

Private Drainage Systems

When restoring drained wetlands in Minnesota, it is most common to encounter drainage systems that are privately owned. Many of these private drainage systems are jointly owned and maintained by a group of landowners. Many jointly-owned systems have written, recorded drainage agreements and easements that need legal consideration if modifications are planned. Depending on the situation and specific language of these legal documents, they may need to be either amended or vacated for the drainage system to be legally modified or abandoned. Again, it may be necessary to seek legal counsel in the review of these recorded documents to determine the legal implications of the planned restoration activities.

In addition, local permits are often required when private drainage systems are planned to be manipulated and are within the jurisdictional boundaries of a Watershed District or Watershed Management Organization. Understand the rules and permit requirements of these governmental units, as they do vary.

Other References

Included in **Appendix XXX** is a checklist that can be used for individual wetland restoration or creation projects that summarizes the findings and decisions of the project as they relate to the most common construction related permits and regulatory requirements.

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4-10 Construction Implementation

Figure 4.10.1 *Project Site Construction*

The construction of a wetland restoration or creation project is an accumulation of the site investigation, surveying, planning, and design efforts that have been completed. Although not the final step, the construction process provides the last opportunity to set in place the foundation on which project goals will be accomplished to satisfy the expectations of the landowner, agency, and program.

The information in this chapter of the Guide discusses the process involved to implement a construction plan for a wetland restoration or creation project. It includes discussion of what activities are needed prior to the actual start of construction up through the finished work. Also, it includes discussion of pre-construction work items such as; securing all necessary construction related permits, identifying project utilities, and providing for discussion of construction staging and sequencing. Specific construction-related information is provided, including methods to mark and layout the required construction components and strategies to consider during the construction process. Finally, information is provided on the process to inspect and certify the completed work, allowing for final stabilization and contractor payments.

An overview of the following list of strategies is discussed in this chapter of the guide with more specific and detailed information provided in Technical Guidance Documents that are located in Appendix 4 and referenced accordingly.

- **Contractor Selection**
  - *Hiring Options*
  - *Bid Timing*
  - *Pre-Bid Meeting*
- **Pre-Construction Project Considerations**
  - *Permits and Notifications*
  - *Identifying and Marking Utilities*
  - *Construction Sequencing and Staging*
  - *Cultural Resources*
- **Pre-Construction Meeting**
  - *Purpose*
  - *Agenda Items*
  - *Inspection Plan*
  - *Defining Roles and Responsibilities*
- **Layout and Staking**
  - *Identifying and Marking Construction Limits*
  - *Project Control*
  - *Staking Specific Construction Components*
- **Implementing Construction Components**
  - *Scope of Work*
  - *Site Examination*
  - *Initiating Pollution, Sediment and Erosion Control Measures*
  - *Clearing and Grubbing*
  - *Topsoil Stripping*
  - *Excavation Work*
  - *Earthfills/Embankments*
  - *Drainage System Modifications*
  - *Outlet Structures*
  - *Geotextile and Rock Riprap*
  - *Final Grading and Site Stabilization*
  - *Site Cleanup*
- **Construction Inspection**
- **Project Modifications**
- **As-Built Plans and Construction Certification**
- **Reviewing Contractor Invoices and Making Payments**

Contractor Selection

Construction work on wetland restoration and creation projects can be highly specialized, requiring specific construction equipment and operators who have the experience to implement the project. The success of a project can largely be attributed to the quality of the work performed in its construction. That quality is a reflection of the contractor's ability to follow the construction plans and adhere to the project specifications. Using correct materials, establishing proper grades and elevations, and implementing appropriate construction strategies and procedures will be important aspects of the construction process.

Hiring Options

Contractors are selected and hired by one of several methods. The method chosen often depends on the scope of the project and who is doing the hiring.

In many situations, contractors are hired through a simple selection process. This occurs for smaller-scope projects or when contractors are being hired by private landowners. Aside from the simplicity of this hiring method, it has advantages in that the project owner can seek and hire a specific contractor with the experience and equipment necessary for the project. Owners are encouraged to seek input and ask for references from local resource professionals when bidding and determining qualifications of potential contractors. Owners should also attempt to get bids from more than one contractor before making a hiring selection.

> Considering the potential variety of construction strategies used to restore and create wetlands, it will be important to select a qualified contractor for each project.

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For work on most public- or government-owned land and when public entities or agencies are hiring the contractor, the selection is done through a formal bidding and contract process. Using this method, the lowest-qualified bidder typically is awarded the project. This process can limit the opportunity to hire a contractor based on their experience and ability. To help ensure a qualified contractor is selected under this type of hiring process, the construction plans, specifications, and other contract documents need to be as comprehensive as possible and must clearly identify what is to be accomplished and expected from the contractor. The clearer the construction documents are in defining the requirements of the project and the conditions or specifications under which it is to be completed, the less likely it will be that an unqualified or inexperienced contractor will bid on the project or be accepted for it.

Bid Timing

The time of the year to solicit bids can be an important consideration. Soliciting bids during the construction off-season, late winter into early spring, provides contractors with more time to thoroughly review the project details and plan accordingly for pending work. This leads to more accurate bids that are often lower in price than if they were bid during or late into the construction season. In addition, more contractors may be willing to bid on projects during this time period than when they are busy with other work. The downside of bidding at this time will be that contractors may be unable to properly assess the site which for some projects, could influence bid prices.

> Contractors often give better prices when bidding in late winter or early spring.

Pre-Bid Meeting

Prospective contractors interested in bidding on a project may be unfamiliar with or inexperienced in using the planned materials or type of work to be performed. Inexperienced contractors who bid on wetland restoration or creation projects may have reservations about the project, project conditions, or about specific project components. As a result of these uncertainties, they might submit inflated bid amounts to protect themselves or they may inadvertently under-bid a project because of unfamiliarity with the work. Conducting a pre-bid meeting allows interested contractors to ask questions and provides an opportunity to have the project's goals, construction requirements, and the plans and specifications explained to them. If possible, the meeting should include an on-site review of the project. Pre-bid meetings will increase contractor familiarity with the site and scope of work and, hopefully, will promote reasonable and financially-competitive bids. When doing so, there may be an advantage to have the planned construction work partially or fully staked at the site to aide any of the prospective contractors in their understanding of the work to be performed. As long as all the prospective bidders are given the same information, it is both legal and advisable to provide as much information and assistance as possible prior to the bid deadline. Investing time and effort now will result in more uniform bids that are easier to compare and less controversial to execute later.

Pre-Construction Project Considerations

Permits and Notifications

Before any construction work begins on a project, all necessary permits must be obtained and required notifications made. It is the responsibility of the owner and the contractor to ensure this is done. The requirements for these items should have been discussed during the pre-construction meeting; there should be no surprises if proper planning and communication have occurred.

The project inspector should review the list of permits and notifications with the contractor to ensure everything is in order and, when required, site postings of these permits, exemptions, and notifications are done. Additional discussion on permits, regulations, and authorizations occurs in **Section 4-9 Construction Related Laws, Regulations, and Permits**.

Figure 4.10.2 *Site Utilities Marked*

Identifying and Marking Utilities

It is the contractor's responsibility to have all utilities within or close to the project area marked before beginning any construction work. The contractor is responsible to use the current State of Minnesota "Gopher-State-One-Call" notification system to have the utilities located. The contractor is also responsible to contact and coordinate with those utility companies when their presence has been requested or is necessary for construction that is near or that affects their utility.

The Gopher-State-One-Call ticket should be in the contractor's possession and the inspector should obtain a copy of the ticket or note the relevant information from it for the construction file.

Construction Sequence and Staging

Every effort should be made during the construction operations to minimize the potential for soil erosion to occur and be deposited as sediment in undesirable areas. The most effective way of accomplishing this is by staging the construction activities into smaller areas to limit the extent of exposed soil on the site. This may require that stabilization activities be conducted in multiple stages as individual areas are stabilized.

In addition to staging construction activities, there is also a logical sequence for all of the construction operations that should be considered. Proper planning and scheduling of the construction sequence can be important, depending on the project scope. If a sequencing plan is not provided as part of the construction plan, it should be discussed with the contractor at the beginning of the construction operations. A sequencing plan should consider the following:

- Erosion and sediment control measures
- Dewatering needs (maintaining drainage throughout construction)
- Site access needs
- Use of site materials (excavated material for borrow, salvaged pipes, etc)
- Proper disposal of undesirable material such as brush, trees, stumps, and rocks

Two examples help illustrate the importance of this:

Example 1: Relates to the timing of manipulating, blocking or removing existing drainage systems as part of a restoration. If done too soon in the construction process, hydrology could prematurely be restored to a site. This can affect the ability to complete remaining portions of the project, causing construction delays or changes. Where possible, the blocking or disabling of an existing drainage system should be one of the last construction items to complete.

Example 2: Relates to the timing of vegetation establishment for a project. If the site seeding is done in advance of the construction, disturbed areas will need to be reseeded and stabilized as part of the construction operations. If the site seeding is to be done well after construction is completed, the construction plan will need to include requirements to seed and stabilize the constructed features. The seeding plan for the rest of the site may have to contend with restored or created hydrology in wetland areas. Ideally, the timing can be such that site seeding is done immediately upon construction completion. The timing for it will be critical to allow stabilization of the constructed features to occur under optimum conditions.

When construction activities or areas are sequenced and staged, the construction plan may require that the establishment of vegetation or other temporary or permanent erosion controls be installed in stages. This requirement needs to be clearly communicated throughout the entire construction process as it will likely add extra costs to the project.

Cultural Resources

Cultural resources may be discovered during construction, especially when working along the edge of former and existing wetlands. In the event of such a discovery, work that might adversely affect the historic artifacts should cease immediately. The engineer or project manager must be notified so appropriate actions can be taken that are consistent with state and federal laws. Additional discussion on the preservation of cultural resources occurs in **Section 4-9 Construction related Laws, Regulations, and Permits**.

Pre-Construction Meeting

Purpose

The purpose of the construction plan, specifications, and other construction documents is to clearly define the requirements of the project and the conditions under which it is to be completed. Regardless of the project's complexity, a pre-construction meeting should be held upon selection of a contractor to ensure everyone fully understands the existing site conditions and the requirements for the project. A pre-construction meeting provides the project engineer and project manager the opportunity to convey these requirements and construction expectations fully to the contractor. All parties involved in the project should attend the meeting including the project engineer, manager, planner, other consultants, the contractor and the owner(s) of the project. If possible, all or a portion of the meeting should be held on-site to better address specific site issues.

For smaller-scope projects, this meeting can be rather informal and probably occur on-site at the beginning of construction. For other projects, a meeting that is held in advance of construction will be of benefit to all involved parties. This meeting will allow review and discussion of implementation procedures along with the specifications and requirements for any materials that are needed and who is responsible for providing them. For projects being completed for mitigation purposes, invite the regulating authority overseeing the mitigation or banking project. This will ensure that all parties involved, including the contractor, fully understand the goals and objectives for the project and the expected construction requirements to achieve them.

Figure 4.10.3 *Pre-Construction Meeting in Progress*

Agenda Items

There are many project-related items to discuss during the pre-construction meeting. The project engineer usually facilitates the meeting and should plan ahead to prepare a comprehensive agenda. The agenda should cover items from plan content, anticipated site conditions, specification requirements, sequencing considerations, inspection requirements, permits, payment process, and site cleanup and close out. The agenda and any notes recorded during the meeting could become valuable documents should problems develop during construction. Any claims made by the contractor, owner, or anyone else involved in the project of not being aware of certain requirements can be nullified if, during the pre-construction meeting, those requirements were discussed and documented. A sample agenda for a Pre-Construction Meeting is included in **Appendix 4-X.**

Inspection Plan

The project engineer or manager should prepare an inspection plan that is commensurate with the scope of the project and meets agency, program, and practical requirements. The purpose of the inspection plan is to clearly define the expectations and requirements of the project inspector(s). The inspection plan should identify the main components of the project's construction, the schedule and scope of inspection requirements (i.e. does a specific construction component require periodic or continuous inspection), and the type of record keeping that is needed to ensure compliance with the specifications and permits. Review the inspection plan during the pre-construction meeting so everyone involved in the construction process, most importantly the contractor, is aware of the inspection requirements, allowing them to plan accordingly. A sample Inspection Plan is included in **Appendix 4-X**.

Defining Roles and Responsibilities

Pre-construction meetings are held to cover a wide range of issues related to the project's implementation. Perhaps most importantly, a pre-construction meeting establishes a line of communication between the owner, contractor, and the engineer. To limit problems, it will be important to establish a clear understanding of the respective roles and responsibilities of all involved parties in the construction process.

Layout and Staking

The information on the construction plan is transferred to the site through the layout and staking process. Construction stakes are placed to locate specific construction components and to identify the lines, grades, cuts, fills, and elevations specified in the plans.

Even the simplest restoration project requires some amount of layout and staking.

The process of laying out and staking project components should begin in part before any of the actual construction begins and then continue throughout the construction process.

The methods used to stake a project will be dependent upon the complexity of the work to be performed and the preferences of the contractor. Review the staking and marking procedures with the contractor as there can be some variability in this process.

Identifying and Marking Construction Limits

For some projects, it will be necessary to mark the limits of construction. This will include marking the boundaries of construction areas and, in some situations, may also include marking areas that are to be protected from disturbance. These areas should be clearly marked, fenced, or flagged to ensure they are visible and should be reviewed onsite with the contractor before any construction work begins.

Many construction areas will have vegetative cover at the time of construction. This vegetation, particularly tall grasses, can present challenges when staking as

Figure 4.10.4 *Layout and Staking Process*

stake visibility can be an issue. It is also a problem for some certain grading and excavation activities, as working with vegetation-laden topsoil is difficult and often results in less-than-desired finished results. To help remedy this problem, cut and remove vegetation within the construction limits before setting construction stakes and starting construction. Limit the vegetation removal to the required construction areas only. This requires some planning to ensure it gets accomplished before construction begins. The cutting and removing of vegetation is a project function that can be performed by the landowner on private land projects. This should be a discussion item during the pre-construction meeting.

> Cut and remove existing vegetation from planned construction areas prior to staking.

Project Control

When laying out, staking, and constructing a project, reestablish the project control so that all construction work is consistent with the original site survey and project design. It will be most critical to re-establish proper vertical control. However, depending on survey equipment and methods used to layout and stake the project, the reestablishment of horizontal control may also be necessary.

For vertical control, first check and verify for accuracy the project benchmark or control point from which other benchmarks will be set. When permanent project control points are not close by or otherwise easily accessible, it is strongly recommended you establish additional temporary benchmarks or construction hubs nearer to specific construction areas (**Figure 4.10.5**).

Consider setting construction hubs at elevations relative to a construction component. For example, setting a construction hub at an embankment's design elevation , or some even number relative to it, can simplify the construction checking process and reduce the chance of errors.

> Well placed construction hubs can aide construction efforts

Staking Specific Construction Components

Many of the different construction components utilized in the design of wetland restoration and creation projects will have specific staking needs. Following are suggested methods to stake project components that are common to many wetland projects.

Figure 4.10.5 *Temporary Construction Hub*

Earthen Embankments

Earthen embankments can be staked using a variety of methods. At minimum, stakes should be set at the beginning and ending of the embankment profile to show the starting and ending limits of the fill. These stakes are referred to as Beginning of Project (BOP) and End of Project (EOP) and should be identified as such. To protect these stakes, set offsets for them that will be safe from construction activity. Offset stakes are placed a set distance from and perpendicular to the embankment centerline. An offset distance of 50 feet is recommended. These stakes should be marked accordingly as BOP and EOP offsets with the offset distance noted.

Longer, more complex embankments may require that additional stakes be set along the embankment's centerline at intervals (stations) matching the stationing shown on the construction plan profile. The station number, fill height, and top width are recorded on these centerline stakes. It is often preferred and sometimes necessary to also set perpendicular offsets to these centerline stakes. Locate the offsets a safe distance where they can remain undisturbed throughout the stripping and earthfill operations. Be mindful of placement locations and extents for stripped topsoil or excavated core trench materials when locating offset stakes. For example, if stockpiles of excavated materials will be placed upstream of the embankment footprint, put the offset stakes on the downstream side of the embankment.

A cutoff trench, when required as part of the embankment, is staked to correspond with the centerline stationing of the embankment and as shown in the construction plan. The extents and depths of the core trench should also be indicated on both the embankment centerline and corresponding offset stakes.

Toe slope stakes or flags will benefit embankment construction

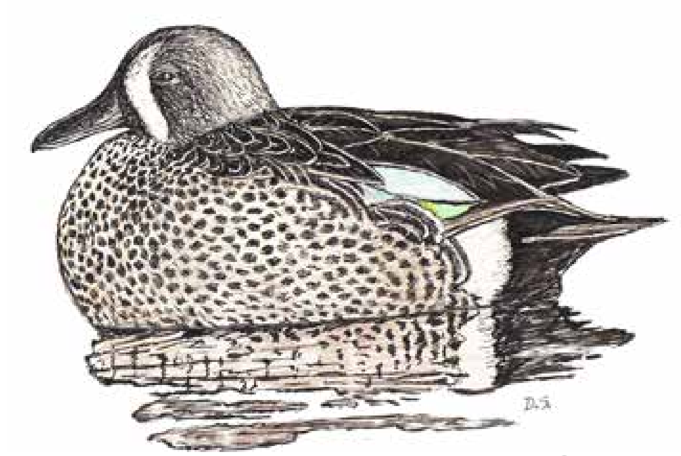
It may be beneficial, especially for longer embankments and those with varying heights, to also set embankment toe slope stakes. This will aid in determining where both the front and back slopes of the embankment will intersect the existing ground surface and more precisely marks the limits for the embankment subcut or stripping operations. Toe slope stakes are offset by two to four feet from the actual toe; this way they can be maintained during the course of construction. For many projects, wire flags can be used to mark the toe slope offsets.

A sample staking plan for a simple embankment and vegetated spillway outlet is provided in **Figure 4.10.6**

Excavated Ditches and Spillways

Ditches and spillways to be excavated are staked in a similar manner as earthen embankments, except that centerline stakes indicate cut amounts instead of fill amounts. Centerline stakes in these excavated areas are difficult to maintain during construction, so establish centerline offset stakes and mark ditch or spillway edges with stakes or flags.

In addition, when staking the control section of a spillway, all four of its corners should be marked with offset stakes or flags. As construction of the spillway's level control section nears completion, set construction hubs at grade in each of the four corners to help ensure accuracy of the finished elevation.



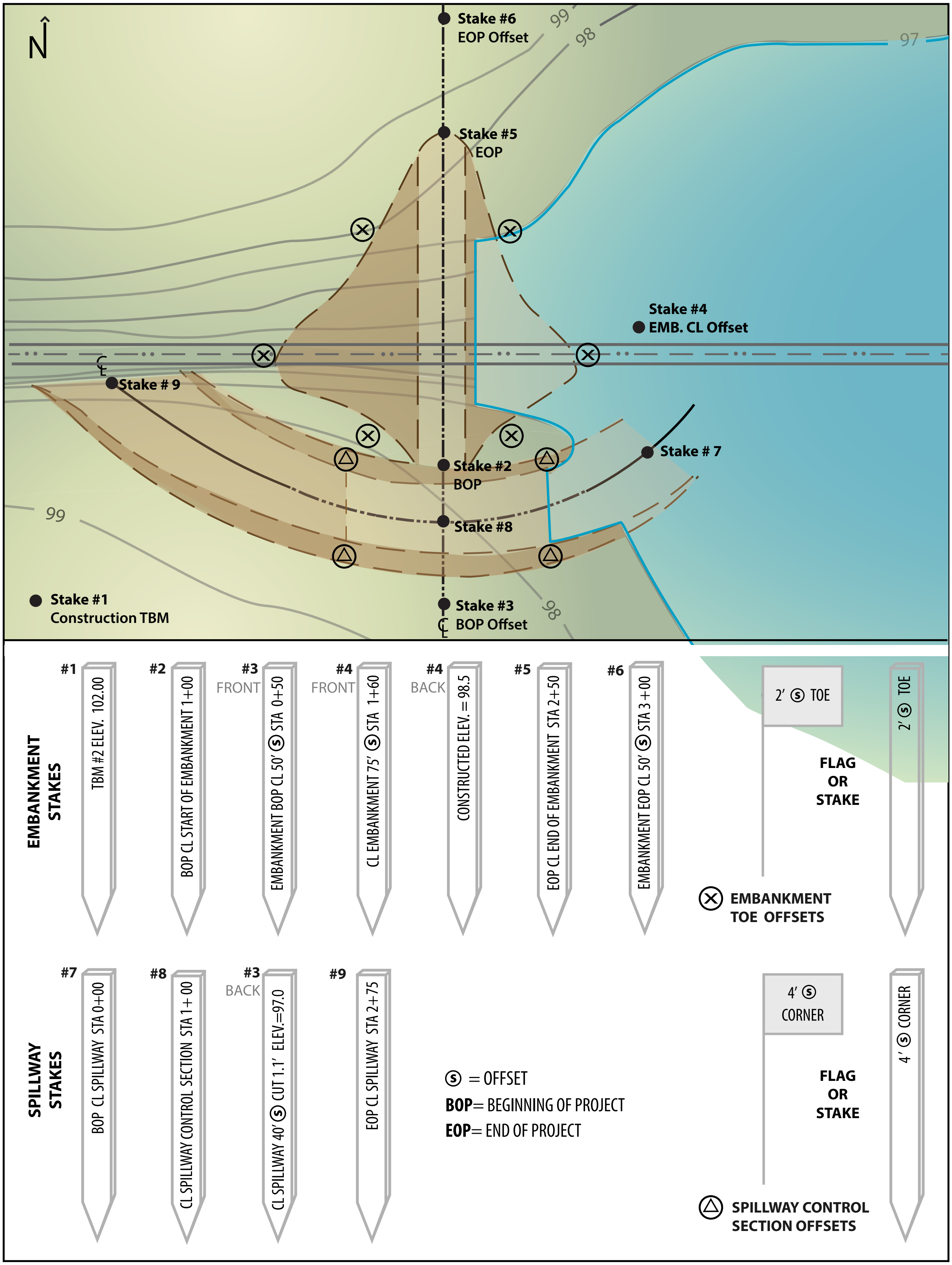


Figure 4.10.6 *Sample Staking Plan for an Embankment and Vegetated Spillway*

Tile Blocks/Removals

The staking of tile blocks prior to construction can be difficult as the exact location of the tile system to be blocked is often unknown. It is more practical to mark the search or investigation limits for the tile with the required removal lengths noted. When tile locations are known or are discovered through investigations, the location and limits of the tile removal as per the plan requirements can be marked with stakes or flags at each end of the required removal length (**Figure 4.10.7**).

Outlet Structures

The staking needs for pipes, conduits, and other outlet structures will vary with each site and with each type of outlet to be constructed. It is difficult to accurately locate these project components before construction begins, as their locations are often dependent on other constructed project features, such as an earthen embankment. Communicate with the contractor as to what is needed for staking and when it needs to be completed.

Figure 4.10.8 *Sediment Protection of Functioning Tile Inlet*

Maintaining the required elevations and grades for these structures is important and becomes a fundamental aspect of the staking process. The use of construction hubs set at the required grades for these features is necessary to accomplish this. Allow some flexibility with the layout of the structure, as it can, and usually will, deviate a little from what is shown in the construction plan. Important features of the structure need to be measured, staked, and

Figure 4.10.7 *Tile Block Location Marked with Flags*

adjusted as they are being constructed to best fit the conditions and topography of the site. The project engineer or a representative should be present during this stage of construction.

Staking Other Areas

Other project components should be appropriately marked and staked to accommodate plan requirements and contractor needs. This can include, but not be limited to, borrow areas, by-pass tile alignments, and surface tile outlets.

Implementing Construction Components

Scope of Work

All construction implementation activities should be completed as shown on the construction drawings and as specified in the construction specifications prepared for the project. Unless specifically noted otherwise in these construction documents, the contractor shall provide all materials, labor, transportation, tools, and equipment necessary to construct the project. The contractor should provide everything necessary and reasonably incidental to execute the work and be commensurate with good construction practices.

Site Examination

Before equipment starts moving at the site, the contractor should perform a thorough review of the project. At this time they should familiarize themselves with all existing conditions and limitations pertaining to the work. The project site should have already been staked, flagged, and otherwise marked for construction and ready for the contractor's review.

Initiating Pollution, Sediment and Erosion Control Measures

To prevent or minimize environmental impacts from the construction operation, the contractor must apply temporary erosion, sediment, and other pollution controls both before construction begins and during the construction process. This includes minimizing the area and time that site soils are disturbed and installing the required erosion and sediment control measures. All erosion and sediment control measures or construction site best management practices (BMP's) should be implemented as appropriate and as identified on the drawings, in the construction specifications, or in a Stormwater Pollution Prevention Plan (SWPPP), if prepared for the project.

The extent of the required temporary erosion and sediment control measures will vary from project to project but will include the following:

- Preparing Access/Haul Roads
- Establishing Perimeter Controls
- Protecting Construction Slopes
- Protecting Tile and/or Culvert Inlets and Outlets
- Protecting Other Receiving Waters
- Limited Areas of Construction Disturbance – Sequencing

Construction areas, if not properly protected, can further degrade the wetlands being restored or possibly even contribute sediment to other downstream water resources. Silt fence is one of the more commonly used sediment control measures and it, along with other sediment control BMP's, should be installed and maintained as specified in the SWPPP or project plans and specifications.

> All construction activities have the potential to produce sediment from erosion of exposed on-site soils.

Sediment is not the only construction site pollutant that can affect downstream receiving waters. The improper storage of chemical pollutants such as fuel, lubrication or transmission fluids, contaminated wash water, soaps and cleaning detergents, fertilizers, and herbicides are also of concern. The use of liquid-tight storage containers, tanks, or barrels should be required and these storage units should frequently be inspected. Potential problems can be minimized or avoided entirely by locating these stored materials on flat gradients and as far away from potential receiving waters as practical.

The use of, location, and maintenance of temporary sanitation facilities should be addressed. For short-duration construction projects, sanitation accommodations can be made without too much difficulty. For longer-duration projects, or if otherwise required as part of a grading permit, portable self-contained chemical toilets should be considered. If used, locate these portable units away from any receiving waters or connections to receiving waters to minimize the risk of contamination in the event of leakage.

Figure 4.10.9 *Clearing and Grubbing of Planned Embankment Area*

The main sources of air pollution at a construction site will be from vehicle emissions, dust, and the burning of brush or slash. The extent to which these become problems will correspond to the location of the project and the potential impact these pollutants will have on neighboring properties or businesses. Weather conditions also play a role. All burning activities must adhere to state and local permitting requirements. Firebreaks or other fire-control measures must be installed before beginning any burning activity to minimize a hazard. If a neighbor might be affected by dust, smoke, or fumes, prior notice of the planned disturbance, along with an indication of how long it is expected to last, will go a long way towards reducing complaints and possible construction delays.

Clearing and Grubbing

When necessary, the clearing and grubbing of woody vegetation and other materials will be one of the first construction activities to be performed. The extent of materials to be removed shall be as indicated in the construction plan or determined on-site in consultation with the contractor. If clearing or grubbing operations are done carefully and properly sequenced, the impact on the environment from site erosion will be minimal. If done carelessly, these activities could lead to an increase in erosion, requiring additional erosion and sediment controls to be installed and adding to the costs of the project.

> Clearing and grubbing will likely be the first construction opperation performed.

Prior to the start of clearing and grubbing, the project engineer or inspector should review the limits and requirements with the contractor. At this time, discussions should occur regarding the following items:

- Scheduling or staging of activities
- Methods to mark and protect construction stakes, trees, buildings, fences, or other facilities
- Items to be removed such as trees or fences
- Tree and/or stump removal requirements
- Methods of construction and location for disposal
- Burning permits and fire control

With any restoration project, clearing and grubbing activities associated with preparing a site can be expanded to include the removal of other undesirable vegetative species. This includes non-native and invasive plant species that have been determined to be detrimental to the success of a project. If left in place and unchecked, they will compete with and threaten the survival of native plant species that currently exist or are to be established. The methods of removal will be specific to the conditions of the site and the species of concern. It can include any combination of the following items:

- Mechanical Removal
- Hand Clearing (sensitive or difficult areas)
- Application of Herbicide
- Soil Removal

Figure 4.10.10 *Stripping Topsoil Under Planned Embankment*

Topsoil Stripping

To limit the amount of soil exposed to erosion, only strip topsoil from areas planned for immediate construction .

Before the construction of certain project components can occur, existing topsoil and vegetation will need be removed and possibly stockpiled for later use (**Figure 4.10.10**). It is important to ensure that topsoil is stripped to the extents and depths specified on the construction plan or in the construction specifications. Failure to do so could lead to future problems such as issues with water seepage under the constructed fill.

Topsoil that is suitable for salvaging and re-use should be stockpiled where it won't interfere with other construction operations and should be located as far as practical from receiving waters. Stabilize soil stockpiles in accordance with the required erosion and sediment control measures of the plan.

Excavation Work

Excavations associated with wetland restoration and creation projects are performed for a variety of reasons, including the construction of core trenches, borrow areas, spillways, structure installation, ditches, diversions, and for wetland scrapes and sediment removal. Excavations should be performed to the lines and grades shown on the drawings and as staked in the field. Bottom widths, side slopes, depths, and grades should all be inspected as final grading of the excavated component is being completed.

Topsoil from planned excavation areas should always be removed, stockpiled, and, when required, re-used to prepare the constructed area for seeding. This is especially true for excavations within drained wetland areas, as wetland topsoil may contain remnant wetland seeds desirable for germination as part of the restoration plan.

Material from planned excavations, if deemed suitable by the engineer or field technician, can be used as a borrow source for the construction of some earthfills. Material not identified for use on the project shall be properly disposed of as waste material. Waste material can sometimes effectively be used to fill in ditches within the project that are being abandoned or even to construct wave berms in front of embankments.

EarthFills/Embankments

Various types of earthfills are needed to restore and, sometimes, create wetland projects. The primary use of earthfill is for the construction of embankments and berms needed for water retention. The use of suitable earthen materials and the proper placement and compaction of those materials affects the long-term viability of a project. The requirements for these construction variables should be specified in the engineering plans and specifications and should be adhered to during the course of construction.

Figure 4.10.11 *Earthen Embankment Under Construction*

All embankment sites must be properly prepared prior to placing any fill materials. The preparation work includes the clearing and grubbing of woody vegetation or other debris from the site and the stripping of topsoil from the entire embankment construction limits and identified borrow areas. It might also include any necessary foundation treatments including the excavation of a core trench as required in the design. It may also include temporary dewatering of the core trench or embankment foundations soils to facilitate proper construction conditions.

Prior to the placement and compaction of embankment fills, the entire constructed or prepared subgrade should be scarified to ensure proper bonding with the embankment fills.

In-field testing of compacted earthfills may be specified to determine if the required compaction densities are being achieved during the construction work. Perform routine inspections of the construction operations to ensure that the contractor is following the required methods of construction and compaction. Also check the moisture content of the soil material being used to construct the earthfill. Desired compaction densities can only be achieved with optimum soil moisture conditions. Material that is too wet or too dry will not allow for proper compaction. The construction specifications should address the soil moisture requirements and they should be closely monitored during construction. In some cases, construction activity may need to be stopped to allow for earthfill borrow conditions to improve or to locate alternative borrow areas, if the desired compaction densities cannot be achieved with current materials. Refer to **Section 4-5 Earthen Embankments, General Design Components** for additional discussion on this topic.

Simple test to determine adequacy of compaction: a tile probe or similar sized metal rod will not easily be pushed into properly compacted mineral soils.

Earthfills should be constructed to the lines and grades shown on the drawings and as staked in the field. The final embankment grading should incorporate a slight crown to provide for drainage of the embankment's surface. Elevations, grades, top widths, side slopes, and crown slopes should all be inspected while final grading of the constructed earthen component is being completed.

Figure 4.10.12 *Construction of Tile Block/Removal*

Drainage System Modifications

When restoring wetlands drained by subsurface tile drainage systems, a variety of construction methods and requirements are utilized to manipulate the subsurface drainage systems. Extensive investigations may be needed during construction to locate drainage tile and then determine if the construction plan, as designed, is applicable to the actual situation. Often, drainage tile locations, elevations, grades, sizes, and sometimes even their extents are not known as the project is being designed. This often leads to design adjustments during construction to achieve the project's intent. The engineer or representative must be present during the investigation operations to work with the contractor in making critical project decisions upon locating and gathering information about the drainage tile system. When there is some uncertainty of drainage tile locations, the construction plan and associated bid documents should provide for some amount of investigation work to be performed.

Paying for drainage tile investigation by the lineal foot of excavation or by the hour worked allows flexibility and variability that is often needed for this work.

When removing drainage tile as part of a planned tile block, the tile fragments, whether made of concrete, clay or plastic, must be removed from the excavated trench and to the extent possible, removed from the excavated spoil prior to placing and backfilling the trench. Before backfilling, block and seal the exposed tile ends as specified in the plan or specifications. The method used to backfill and compact the excavated trench for tile removal can be critical to the success of this strategy, especially when the tile block occurs under constructed embankments, spillways, or other surface flow areas.

Backfill placed and compacted in the tile removal trenches will settle; provide appropriate allowances for settlement.

When the project requires the installation of an underground conduit for diversions or drainage systems alterations, the services of an experienced drainage contractor will be required. All pipe joints and connections must be constructed according to the plan and made watertight when necessary. When surface outletting upstream drainage tile into the project wetland or other downstream areas, ensure the outlet is stabilized in accordance with the project plan.

Outlet Structures

The construction requirements associated with the installation of outlet structures varies and is dependent on the type of structure, materials used, and conditions of the site at the time of installation. A variety of construction materials can be required including: concrete, fiberglass, geosynthetics, rock, and various types of metals and plastics. They can include pre-manufactured structures or those that are to be fabricated or constructed by the contractor. Outlet structures vary in size from simple tile inlets to large drop structures.

Each outlet structure should have specific and detailed plans and specifications prepared for it that address required materials, fabrication, sizes, dimensions, and installation requirements. These specifications and requirements must be adhered to during construction.

Figure 4.10.13 *Compacting Around Outlet Pipe*

Inspect the following items closely during the construction and installation of any outlet structure:

- That correct materials are used and that they are in good condition and not damaged.
- That accurate sizes and dimensions of structure components are provided.
- That proper installation techniques are used that follow both written and manufacturer specifications.
- That proper equipment is used in the installation that meets or achieves the required specifications.
- That material is properly bedded, as specified.
- That proper backfill material is used and that placement and compaction specifications are met.
- That designed or required elevations are achieved.
- That final grading meets plan requirements.

Regardless of the type of outlet used, the above items must be properly addressed to ensure that materials and installation methods meet or exceed plan and specification requirements. In addition, plan adjustments must occasionally be made in the field during construction to achieve the design intent for the project. Considering the importance of the outlet structure to the project and that the majority of project failures are related to these structures, it is critical that the engineer or representative be present during the entire installation process to oversee the work performed and to work with the contractor in making any necessary plan adjustments.

Geotextile and Rock Riprap

Many wetland restoration and creation projects will utilize rock riprap underlain with geotextile or other suitable filter as both a temporary and final measure to help protect and stabilize many components of the project, including but not limited to:

- Wetland outlet structures
- Spillways
- Embankment slopes
- Check dams and sediment blocks

Ensure that geotextile or other filter material meets the required material specifications and that the site is properly prepared before it is installed.

The placement method, thickness, type, and gradation of rock riprap material can be critical to the design of the project. Understand what type of rock is required in the plan as it can be specified as either field stone or angular crushed quarry stone. With either source, the rock must adhere to the gradation specification.

Figure 4.10.15 *Placing Topsoil on Constructed Embankment*

Place the rock carefully on the underlying geotextile or filter material to prevent puncture of the material or damage to any adjacent structure. Hand-rearranging of the rock may be required to achieve the desired size distribution, fill any voids, protect a structure, and leave a reasonably smooth appearance of the finished work (**Figure 4.10.14**).

Inspect all riprap upon delivery to ensure required type and gradation are met.

Figure 4.10.14 *Rock Riprap at Wetland Outlet*

Final Grading and Site Stabilization

Final grading includes smoothing rough-graded areas associated with any earthwork and preparing the areas for seeding. The areas should be graded fairly smooth and void of rocks, tree roots and branches, and large clumps of soil that would make site stabilization difficult. As a final step in the grading process, topsoil salvaged from earlier construction operations should be spread on the surface and used as a medium for establishing vegetation (**Figure 4.10.15**). The final grading should leave the site ready for stabilization by seeding, sodding, or other methods as specified in the plan with minimal raking, dragging, or disking being needed.

The pollution, sediment, and erosion control plan or construction specifications should provide an allowable timeframe for stabilization of areas that have been final graded. For larger projects, compliance with this timeframe may require stabilization methods such as seeding and mulching to occur in several stages. Seed specifications, application rates

Stabilize construction areas as soon as possible upon completetion of final grading.

and methods, mulch requirements, and time of the year as provided in the construction plan and specifications should be followed to ensure that a healthy vegetative condition becomes quickly established in these areas.

Site Cleanup

The contractor is responsible to see that the worksite is kept in an orderly condition at all times during the construction period. All areas should be properly restored and stabilized with permanent erosion control measures in place and functioning before the work is accepted.

Arrangements need to be made with the contractor to remove all silt fence and other temporary erosion and sediment control devices upon successful stabilization of the site's vegetation. Silt fence left in place is unattractive and can pose a barrier to small animals that will use the site.

Construction Inspection

All construction work should be subject to periodic, if not frequent, inspection to ensure that the work is completed in accordance with the construction documents prepared for the project. A good construction inspector needs to be knowledgeable, able to ensure that the construction drawings and specifications are adhered to, able to effectively communicate with the contractor and the engineer, and able to develop and document necessary project modifications. The level of inspection required will vary with the scope of the project, method of construction and contracting, and experience of the contractor.

Good communication and a certain amount of trust between the engineer or project inspector and the contractor is essential for every construction project. However, even the best contractors may misunderstand or misinterpret the plan drawings and specifications or, more likely, will encounter unforeseen or unexpected site conditions. In addition, mistakes, oversights,

Figure 4.10.15 *Checking Construction Work*

incorrect construction methods, use of improper or defective materials, and potential design problems may be encountered. These issues need to be identified, discussed, and quickly resolved to prevent further problems with the project. When these situations occur, having the engineer or other project inspector readily available for advice or direction can save the contractor considerable time and expense and limit construction delays.

The uses of improper, unsuitable, or damaged construction materials, inadequate topsoil stripping, poor or inadequate compaction work are examples of construction components that are difficult to detect unless they are observed as they are installed or constructed. If not identified and corrected, inadequacies may only become evident weeks, months, or even years after completion of the work, usually after a failure to some degree has occurred. These are preventable problems that can be avoided through regular inspection of the contractor's work. An inspection plan if prepared can provide further clarity with inspection roles and requirements.

The inspector should be in frequent contact and should keep the engineer informed about all aspects of the project construction. Any issues that cannot be immediately resolved by the inspector should be reported to the engineer as soon as possible so a solution or remedy can be determined.

Construction supervision is a responsibility of the contractor and should not be confused with the duties of the project inspector. The inspector's role is to ensure that the contractor adheres to the construction plans and the construction specifications. The contractor has a number of roles and responsible including:

- The purchase and processing of specified materials.
- Understanding and performing the work in accordance with the plans and specifications.
- The coordination of work done by others (i.e. subcontractors).
- Quality control and job site safety.
- Being responsible to inspect and maintain any temporary erosion control practices.

The inspector should create a comprehensive written record or diary as well as photographs of daily construction activities in case disputes develop over time or quantities used. These written reports and photographs are invaluable when reviewing billable hours, progress, and plan changes. Completeness, timeliness, and clarity of the documentation are important. Items to document include date, weather conditions, starting and ending times, work that was accomplished, items of concern, equipment used, personnel on-site, etc. In addition, the inspector should keep and document in the form of survey notes all work used to set construction stakes and temporary benchmarks and when checking and certifying completed construction components.

Project Modifications

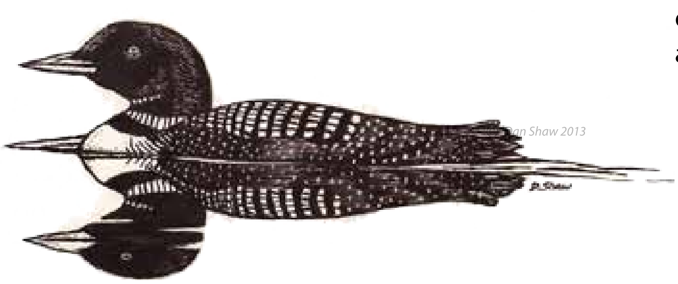
The scheduling of the various construction activities for a project should be determined well before the start of the construction work. During the course of construction, however, some minor changes and adjustments to the planned sequencing and phasing activities may be needed due to site and weather conditions, time of season, or contractor preference. These changes and other scheduling requirements must be discussed and agreed to between the contractor and the inspector or engineer. This requires the engineer to be available when needed so prompt decisions can be made to avoid project delays. As stated previously, communication and flexibility are essential for a construction project to be successful.

Aside from scheduling changes, the requirements of the construction plans and specifications may need to be modified or changed due to unexpected site conditions or project-specific issues that are encountered. If changes are needed during the course of construction, the engineer or project manager should coordinate with the owner and contractor the changes and associated cost adjustments. Change orders are used to accommodate, document, and approve modifications to a construction project including adjustments to project quantities and the addition or subtraction of certain construction items.

As-Built Plans and Construction Certification

Upon completion of all construction components, a set of as-built drawings should be prepared under the direction of the engineer. Each sheet of a set of the construction plans should be labeled "AS BUILTS" and should identify specific changes, omissions, and final elevations and grades. All changes, markings, and notes should be recorded in red ink or pencil.

The detail or scope with which specific changes are noted depends on the effect of the change on the function or performance of the constructed component. Changes can be shown on the as-built drawings by redlines, dimensions, angles, stations, elevations, or as notes. The as-built drawing should also state or verify the materials used along with their source and the supplier or manufacturer's name.



All as-built drawings and prints must be carefully checked. All field notes, diaries, and other records must be reviewed to ascertain that all changes have been properly recorded. Completed as-built drawings should be certified by the engineer or other qualified individual in accordance with program, agency, or company procedures.

> As-built drawings will be the primary reference for the future maintenance, repairs, and compliance of constructed features.

Reviewing Contractor Invoices and Making Payments

The final step in the construction process is making payment to the contractor for the services performed. This includes reviewing the contractor's bid and making necessary adjustments to it for plan or quantity changes that were made and noted during the course of the construction process. This is best accomplished if both the contractor and the project inspector kept accurate notes and records on a daily basis during construction, allowing for them to compare those notes and, hopefully, be in agreement with the final quantities to be invoiced. It is much easier to negotiate final quantities with a contractor before they prepare an invoice than after. See also Section 4-8 Construction Plan Development, Measurement and Payment.

Construction payments will be made much easier by having detailed and accurate bid documents, keeping good records and notes during construction, and establishing a regular line of communication between the owner, contractor, and the engineer or project manager. Unfortunately, issues with invoiced quantities, unapproved expenditures, partial payment requests, and program payment procedures will occasionally exist. Having good negotiating skills, experience with construction management, and a thorough understanding of applicable program rules and processes are a definite asset in these situations.