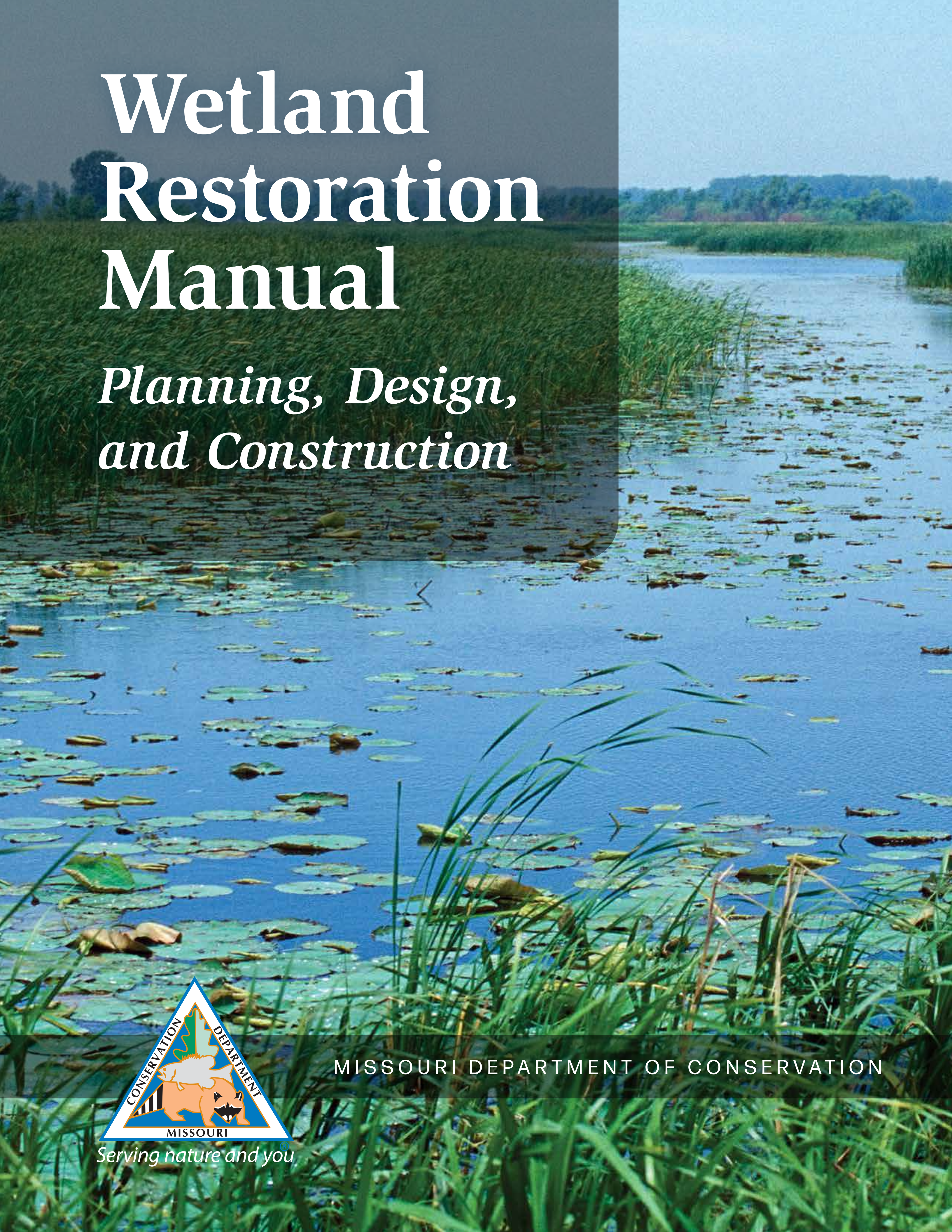
Wetland Restoration Manual

Planning, Design, and Construction



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Cover: Grand Pass Conservation Area marsh. Photo by Jim Rathert

Wetland Restoration Manual

Planning, Design, and Construction

By Mike McClure

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Preface

By Rod Doolen, MDC Wetland Services biologist, retired

Wetlands are integral to the ecosystem of this planet. In their natural state, wetlands support a diversity of plants and wildlife and also play a critical role in modulating floodwaters, filtering runoff, and providing other abiotic functions. Due to their fertile soils and our ability to transform them, wetlands have been converted to what we have seen as needed and useful: crop fields, pastures, housing complexes, shopping centers, etc. These conversions, however, severely limit the capacity of wetlands to support a diversity of species and reduce natural flooding, and, as a whole, they reduce the ability of the planet to absorb ecological adversity. Restoring wetlands puts back part of the planet's ability to provide us with a good place to live.

Presettlement wetlands were exceptionally diverse, both from a species standpoint and an abiotic functional standpoint. The intertwining of the biotic and abiotic components of wetlands cannot be overstated. The mass of the biotic component of wetlands was and is extremely important for the health of the planet. Original wetlands were highly efficient examples of species diversity and function. The point being: when we restore wetlands using original form and function as a basis for modern-day restorations, we get the best output for our input. While we know we cannot restore any wetland back to its original form and function, the closer we get, the better the ecological result. With the changes the planet is now enduring, well-designed wetlands that are more resilient and better able to adapt to continuing climate fluctuations are extremely important. If the original wetland is used as a template, the diversity of species will be better served as will the wetland's ability to filter water contaminants and sediment.

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Introduction

Since European settlement, Missouri has lost more than 90 percent of its historical wetlands. These wetlands included marshes, swamps and timbered wetlands, wet prairies, oxbow lakes, and even fens. Although the ecological importance of wetlands has always been recognized, Missouri's first wetland restorations were largely focused on providing waterfowl habitat and hunting opportunity, giving little notice to wetland function and the ecological benefits provided. These restorations occurred primarily on public land beginning with Swan Lake National Wildlife Refuge in the 1930s and the Missouri Department of Conservation's Fountain Grove Conservation Area in 1947. It wasn't until 1989, when the Missouri Department of Conservation drafted its first wetland plan, that the attention turned to private land, with an ambitious goal of 12,500 acres to be restored over the next 25 years. Still, restorations were heavily focused on waterfowl and waterfowl hunting — no surprise since the planners consisted mostly of waterfowl managers.

The opportunity for wetland restorations on private lands leapt forward after the authorization of the Wetland Reserve Program (WRP) in the 1990 Farm Bill. Missouri, along with seven other states, was chosen as a pilot for the program. The WRP coincided with the Great Flood of 1993 in the Midwest, which resulted in significant negative impacts to farm operations in the region. These impacts were both physical (damaged land and infrastructure) and financial. Suddenly, opportunity and interest in wetland restoration was everywhere.

Early WRP restorations still followed the old models, which constructed berms with steep slopes, narrow top widths, and excessive freeboard (distance between berm top and maximum pool elevation), resulting in frequent damage. In addition, pool levels were planned at elevations that covered the entire restoration area, causing large portions to have excessive depth. Although this method provided fine habitat for migrating waterfowl, it failed to address the needs of nongame, wetland-dependent species and of wetland function. But over the next 30 years, WRP became a proving ground for a wetland restoration philosophy that focuses on all facets of the wetland ecosystem. Included in this philosophy are six general restoration goals which can be applied to all restoration projects, big and small. They are:

- Identify and include priority habitats, watershed objectives, and floral and faunal species
- Restore the site to historic conditions to the extent possible
- Reintroduce landscape features, including macro/microtopography, to the site
- Avoid overpowering the existing topography and the creation of "flood stage" wetlands
- Provide floodplain connectivity when possible
- Recognize the capabilities of the site and restore accordingly

The purpose of this manual is to provide future wetland biologists with an understanding of a wetland restoration philosophy that is a result of a 30-year evolution and one that can be applied anywhere wetland restorations occur. It also aims to provide the basic tools for carrying out a restoration.

The restoration process is divided into four primary steps: Site Analysis, Topographic Survey, Conceptual Design, and Final Design/Construction.

Section 1: *Site Analysis*

The first step in developing your restoration plan is to identify your objectives. Objectives can revolve around habitat types, target species, watershed needs, landowner and/or program objectives or any combination of these or other priorities. Setting objectives that are clear and *achievable* will help ensure a successful restoration.

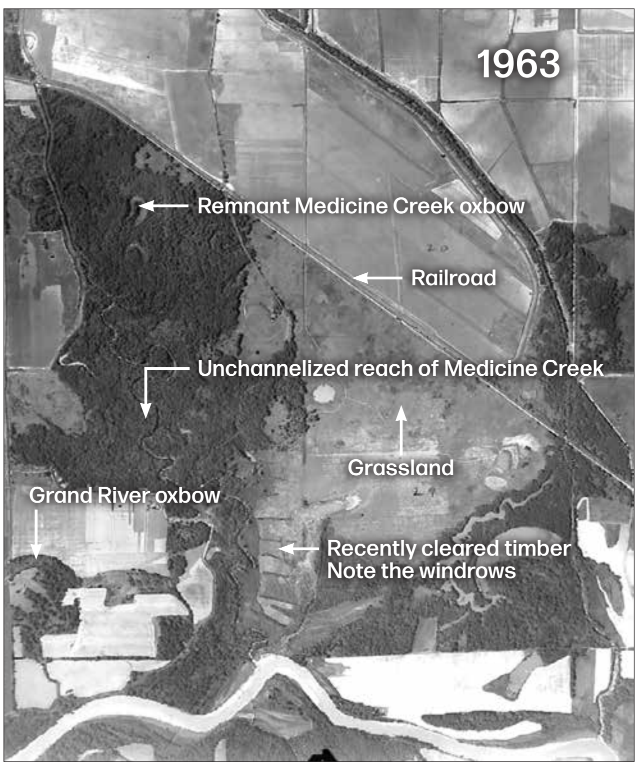
Once you've defined the objectives of your restoration, it is imperative that you become familiar with the site and how it interacts with adjacent land and the watershed. Historical conditions, soil types, water sources (overland flow, groundwater, precipitation) and adjacent land uses will all factor into the final plan and will help you identify the strengths and, perhaps more importantly, the limitations of the restoration site.

Site analysis can be broken into two equally important parts: off-site and on-site evaluation.

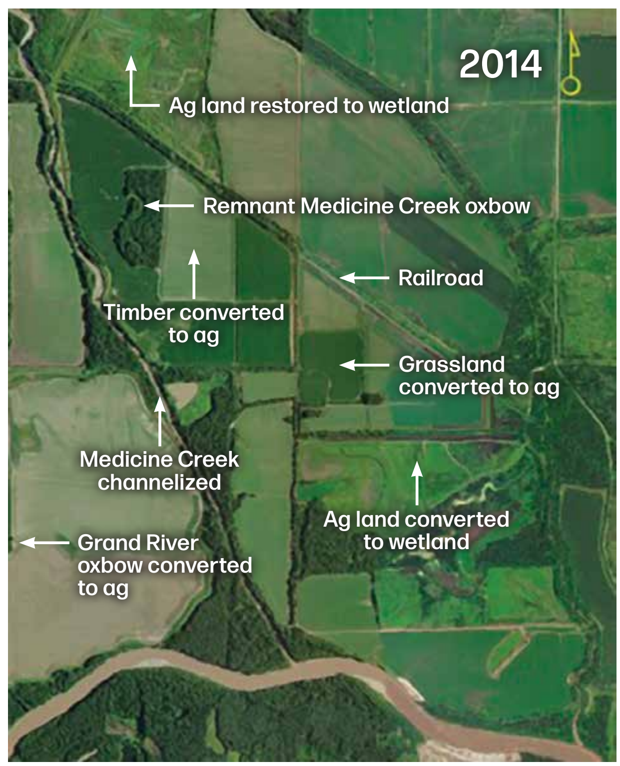
Off-site Analysis

The purpose of an off-site review is to become familiar with the land prior to visiting the site. A thorough review at the desk will help you target key areas once on-site. Think of it as studying before an exam. The more you prepare, the more successful you'll be. The information you gain from reviewing historical information, aerial imagery, soil surveys, and landowner interviews will not only aid you in determining the potential of the restoration site but will also be the foundation of the plan itself.

Figure 1: Comparison of historical and recent aerial imagery of Medicine Creek in Livingston County, Missouri.



1a: A 1963 photograph showing an unchannelized reach of lower Medicine Creek, an oxbow lake on Grand River, and an area of bottomland hardwoods and uncropped grassland.



1b: A 2014 photograph of the same area. Note the conversion of bottomland hardwoods and grassland to agricultural use (including the filling of the Grand River oxbow) and the channelization of lower Medicine Creek. Also notable is the return of agricultural (ag) lands to wetlands restored through the Wetland Reserve Program.

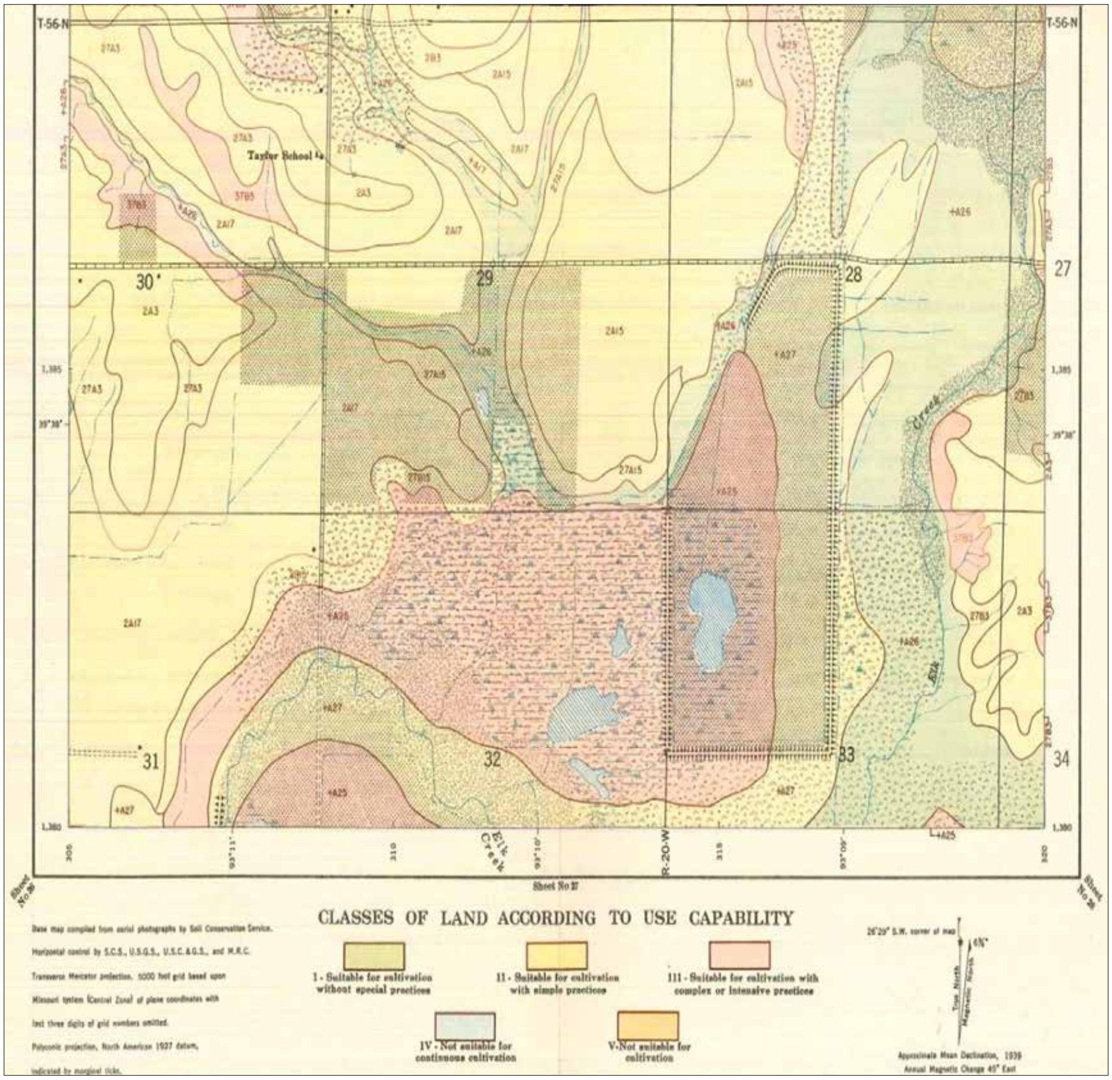


Figure 2: An excerpt from the 1942 Chariton County, Missouri Soil Survey, showing the NE portion of Swan Lake National Wildlife Refuge.

Historical Land Information

Aerial imagery (past and present) is a good starting place for an off-site review. The USDA Farm Service Agency (FSA) often has aerial imagery from the 1930s, '40s, and '50s that provide a wealth of information. Archived soil surveys, Bureau of Land Management–General Land Office (GLO) notes, and U.S. Army Corps of Engineers maps are additional sources of historical information. This information can typically be found on the websites of the USDA Natural Resource Conservation Service, Bureau of Land Management, and U.S. Army Corps of Engineers. Finally, don't forget personal knowledge of the landowner and/or their predecessors. All these information sources can assist in identifying historical landcover, land uses, and alterations to the landscape that can provide clues to help guide the restoration plan. This may include signatures, or evidence of past wetland communities that are no longer present, remnant stream channels, or indicators of wetland depressions. You may discover shifts and potential limitations due to wetland drainage, stream alterations, or alterations to ground or surface water flow from the development of roads or railways.

Current Land Information

Once you've got a historical perspective, it's time to jump to the present. Aerial imagery, 7.5-minute quadrangle maps, current soil surveys, topographic information (Light Detection and Ranging [lidar]), and landowner interviews are all valuable sources of information. Utilize these sources to determine land use (on-site and adjacent) and to identify drainage patterns and water sources. While reviewing current aerial imagery, identify any wetland signatures (remnant wetland features or areas of wetness)

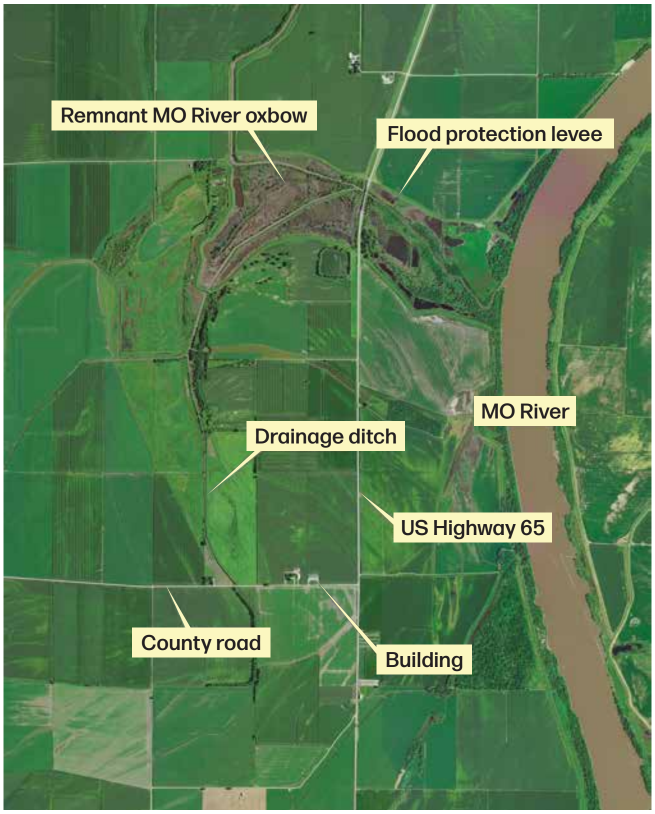
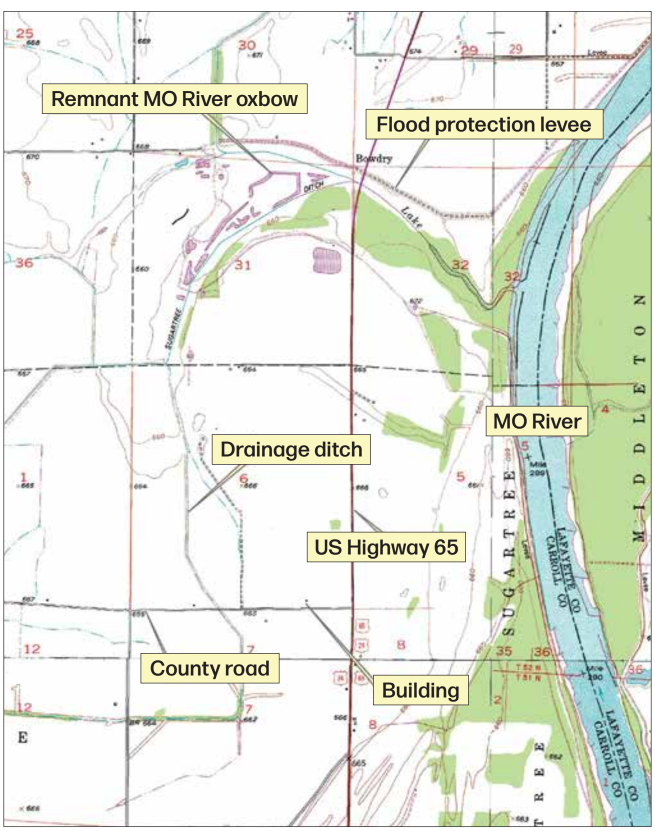


Figure 3: Recent aerial imagery showing landscape features and infrastructure examples.



that may exist on or near the property. Also compare current imagery to the historical information referred to above. Wetland inventory maps and databases related to threatened and endangered species are also beneficial sources to include in your off-site analysis.

Aerial photos, quad maps, and GIS resources, such as lidar, are important tools for understanding the landscape.

Aerial Imagery

Reviewing both current and past imagery will provide insight to current and historical land uses, water sources, land alterations, drainage patterns, wetland signatures (wet areas and remnant wetland features), surrounding infrastructure and land uses. Options for images include those taken during different seasons (leaf on, leaf off) and with infrared. Use this information to begin the foundation of your plan.

7.5-Minute Quadrangle Maps

United States Geological Survey 7.5-minute quadrangle maps, or quad maps for short, are a source of general topographic information with contours at 10-foot intervals. Even though they are general, quad maps are useful in determining significant topographic features and elevation changes. Levees, streams, ditches, and historic wetland signatures (oxbow lakes and depressional areas), many of which have now been eliminated, can all be identified on the quad map. Infrastructure such as roads, railroads, etc. are routinely depicted on these maps as is historical land cover, in terms of open land and timber. Quad maps are also useful in determining the drainage area of a site, which factors heavily into assessing hydrology. It is important to remember, however, that the quad maps were created in the 1960s and '70s and are therefore somewhat dated. Changes, like new levees, new roads, etc., that occurred after the maps' publication will not be included. In short, 7.5-minute quad maps are a useful information source in determining potential restoration opportunities and challenges.

Lidar

Lidar is a GIS-based survey where topographical information is gathered by flying a plane over the area. It is, without doubt, a game changer in wetland planning. Becoming familiar with this resource will allow you to glimpse the entire topography of a site and its surrounding area. In its most basic use, lidar displays topography in the form of raster files, digital elevation models, and hillshades where elevation is depicted in color variations or through the generation of contour lines where elevation is shown by lines representing individual elevations at an interval of the user's choice (e.g., 0.5 feet, 1.0 feet).

Figure 4: 7.5-minute quadrangle map of the same area in Figure 3, showing landscape features and infrastructure.

Most information sources have limitations, and lidar is no exception. If the survey flight occurred some time ago, the data may be dated and, like the quad maps, they may not show recent topographic changes resulting from human activities, sedimentation, and/or scour. Landcover such as vegetation type or height and surface water can also affect the accuracy of lidar. Nevertheless, because it provides so much topographic information, lidar is a fabulous planning tool for site evaluation both on-site and off-site, and, subsequently, for determining water lines or pool elevations.

Landowner Interview

Stories are best told by the people who lived them, and it's the same with the land. The local knowledge of the individuals who work the land, as well as that of their predecessors, can be an asset in wetland planning. Information pertaining to flooding/hydrology, past land use, vegetative communities, and more can all be learned from listening to these individuals. Do not overlook this opportunity, as their perspective is key.

In addition to obtaining historical data, be sure to inquire about the landowner's objectives and interests as well as the management resources that are/will be at their disposal (time and equipment). These factors may impact the direction of the restoration plan.

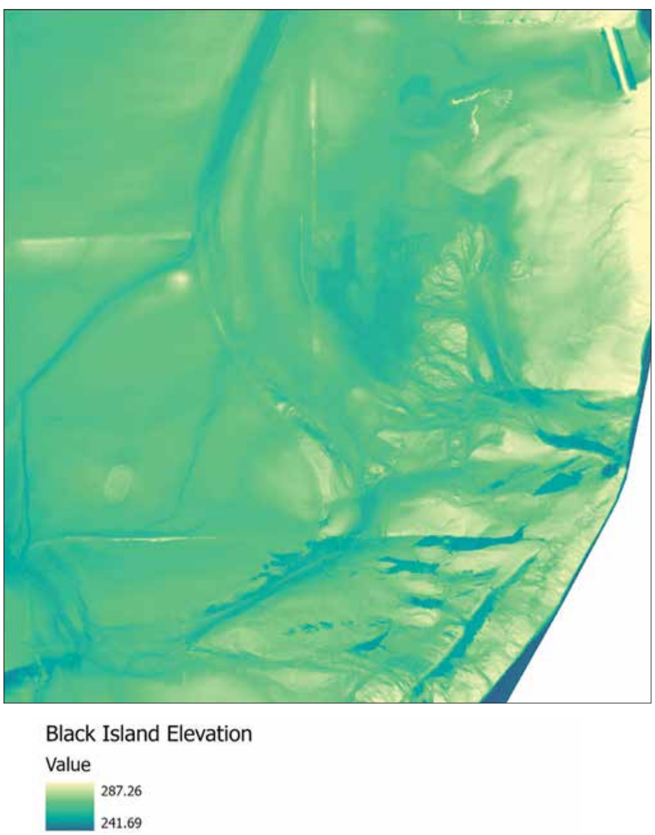


Figure 5: Lidar images are GIS-based topographic surveys and use color variation to show elevational differences.

Satellite Data

Aerial image products rarely show flooding because the primary intent often is to capture the land use and not ephemeral weather events. However, there is a growing array of remote sensing platforms that orbit the earth and repeatedly capture data over time. In the past, resolution of these datasets has been quite coarse (30 m pixels), but the pixel size has begun to fall, and as it does, the level of detail will continue to improve. Despite coarse resolution, this remote sensing data can be used to highlight the extent, duration, and frequency of large flood events. Some satellite imaging can only provide this information for open or herbaceous habitats because it cannot show flooded conditions under the forest canopy. However, satellite imagery collected with synthetic aperture radar (SAR) is based on radar reflectance; it is not bound by cloud or light and can penetrate vegetation. This data has been used increasingly to show flood duration and extent across wetland habitat types. There are a growing number of links and web platforms that can be used to access and download these datasets.

worldview.earthdata.nasa.gov

glovis.usgs.gov/app

floodobservatory.colorado.edu

global-flood-database.cloudstreet.ai

global-surface-water.appspot.com

Soils

Soils are the most critical component of a wetland restoration. Water availability and topography are crucial elements, but soil types are the foundation on which a plan is built. Success or failure of your restoration can hinge on your understanding of soils. Many obstacles in a wetland restoration can be overcome — topography can be altered or created, and hydrology can be guaranteed by wells or pumps — but without suitable soils, all the funds and engineering in the world will not prevent failure.

Web Soil Survey Tool

The USDA's Natural Resources Conservation Service (NRCS) Web Soil Survey is a valuable resource to gather information about the soils on any site. It can be accessed online at **websoilsurvey.sc.egov.usda.gov/App**

This database contains valuable information for wetland restoration, including soil maps, profile descriptions, textures, topography, landforms, and the ecological history of the site. Remember, Web Soil Survey is a tool that was developed at a large scale and is useful for general planning purposes, but to determine specific soil properties at your site, nothing will replace an on-site investigation. When doing an on-site investigation, be sure to look at the soils across the whole site and several feet below the surface to confirm the mapped soil types and any soil variability which might compromise the planned restoration.

Soil Textural Triangle

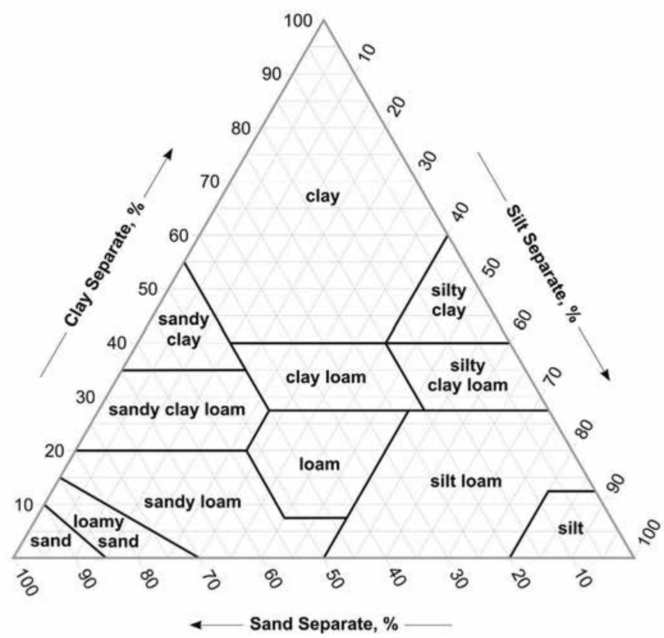


Figure 6: Soil textures are named using the textural triangle chart, which shows soil categories based on percentages of silt, sand, and clay.

This tool will allow you to zoom in to your specific area of interest and learn much about its restoration potential. Critical information like soil texture, slope, typical profile, landform, hydric rating, soil properties, and ecological site description/vegetative classification are all detailed here. Let's look at each category in more detail.

SOIL TEXTURE

Soil texture refers to particle size classes of sand, silt, and clay, and the percentage of each of these sizes within a soil type. Clay has the smallest particles which can be seen with a microscope, followed by silt particles, which can be seen with a magnifying glass, and finally sand particles, which can be seen with the naked eye. The finer the soil texture, or, in other words, the higher the clay content, the more wetland potential there will be. Clay content for any map unit can be found in the "Soil Data Explorer" section of the Web Soil Survey under "Soil Physical Properties and Qualities," but remember an on-site investigation is needed to verify the soils as mapped.

A few common texture descriptions you will encounter include clay, silty clay, silty clay loam, silt loam, and sand. Of course, these are just a few and there are many more combinations. As a rule, a minimum of 25–30 percent clay is needed to impound water. Obviously, the higher the clay content, the better the chance for success in holding water. Some soil types transcend county boundaries; however, their textural makeup can differ, so be sure to conduct an on-site investigation to verify.

MAP UNIT DESCRIPTION

In Web Soil Survey under the "Soil Map" tab you will find a list of soils within your area of interest. Each of the soils listed in the table are hot links to the "map unit description." Clicking on a soil will bring up a report that provides information about that soil type and related information.

Landform Setting

Floodplain landforms are floodplain steps, floodplains, and drainage ways. These setting descriptions will also include information on the shape of the landform. Shapes like convex, concave, and linear are used to give the user a general idea of the soil microtopography. The soil setting data will assist you to understand the historical ecological habitat under which the site developed. Restoration of wetlands to their historical wetland ecological habitats are the easiest restorations to accomplish.

Floodplains develop when streams overflow from rainfall events. Natural stream levees can form on floodplains close to a stream where the coarser particles, like sand, fall out of the water first and build up over time. These landforms usually contain higher percentages of the coarser textures like sand and silt, making them less desirable for ponded wetlands. Floodplains that occur farther from the stream, where the overland floodwater is slow, typically contain more clay and are more poorly drained, resulting in sites that are more desirable for ponded wetland restoration.

Typical Profile

The map unit description also describes a "typical profile" for each soil. Information in the typical profile includes textures for each soil horizon. Below is an example of a typical profile for "Booker Silty Clay." The soil horizon designations of A, Bg1, Bg2, etc. refer to soil layers, beginning with the surface, each having different soil properties, such as texture, color, etc.

- A - 0 to 9 inches: silty clay
- Bg1 - 9 to 23 inches: clay
- Bg2 - 23 to 49 inches: clay
- BCg - 49 to 79 inches: silty clay

Soil Properties and Qualities

The map unit description also contains other valuable information pertinent to a site's suitability for specific types of wetland restoration. Slope, soil depth, restrictive layers, permeability, drainage class, flooding frequency, and ponding are all soil properties that can affect wetland restoration.

- **Slope** refers to the inclination or slant of the landform. Slope is measured by determining the fall of the land over a given distance. The flatter the slope, the slower the water runoff and the higher the probability for ponding the water.

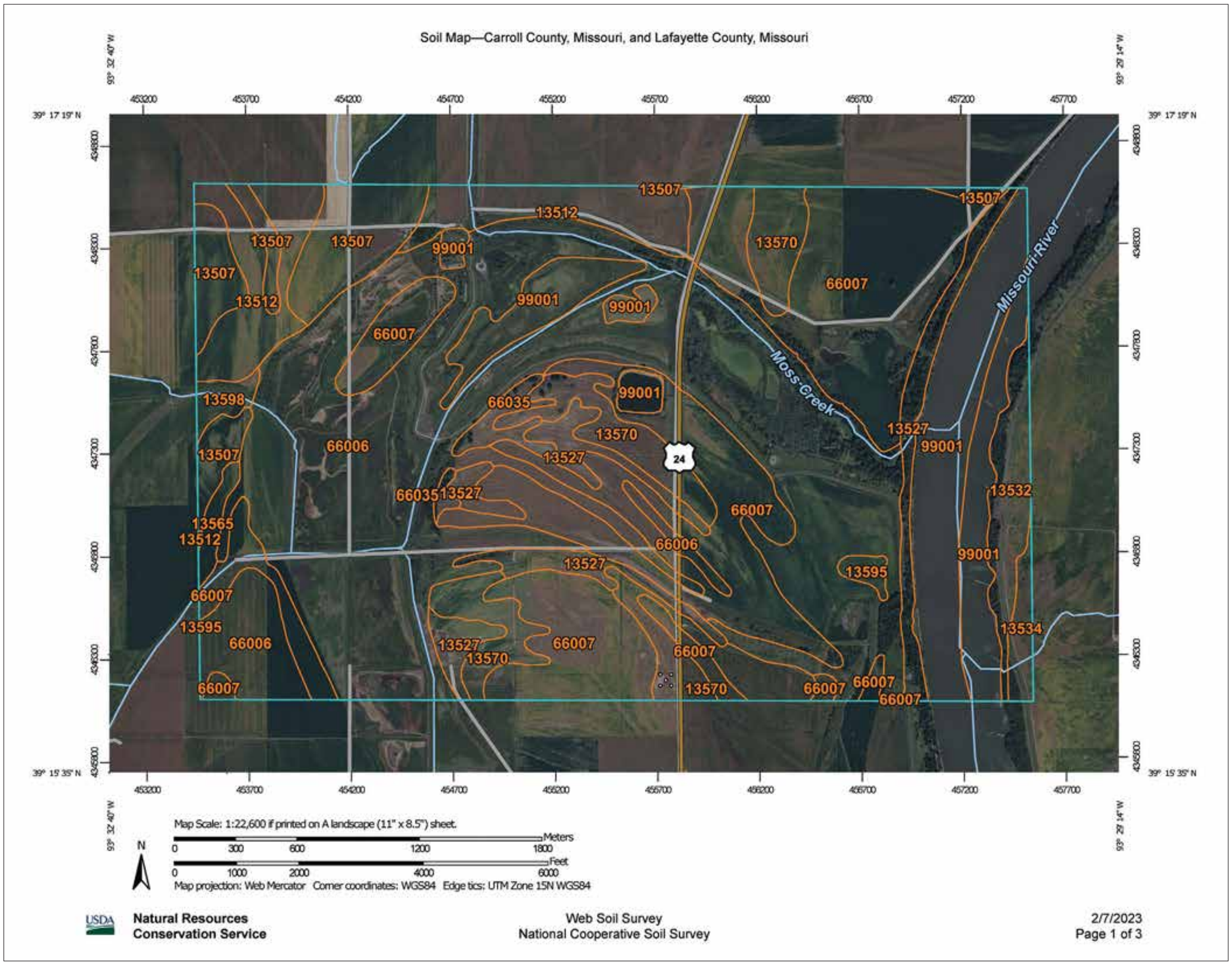


Figure 7: The Web Soil Survey generates maps like this one that show soil types, indicated by numbers that correlate with a map unit legend. See Appendix A for an example of a complete soil survey with legend and information table.

- **Depth to restrictive feature** refers to a soil horizon that contains soil properties that significantly impede the movement of water, roots, or air through the soil. Examples of restrictive features include water in the soil, strongly contrasting textures, clayey layers, and bedrock.
- **Drainage class** refers to the degree, frequency, and duration of soil wetness. A few examples of soil drainage classes are very poorly drained, poorly drained, somewhat poorly drained, moderately well drained, and well drained. Drainage classes vary from state to state as they are soil interpretations. Somewhat poorly drained soils are generally the best for row crop production, and poorly and very poorly drained soils are better for ponding water.
- **Permeability** is the capacity of the soil to transmit water vertically through the soil profile. Permeability is measured in increments of inches per hour or in micrometers per second. The lower the permeability, the slower water moves through the soil profile. For example, a very wet soil would have a rating of "very low to moderately low, 0.00 inches to 0.06 inches per hour."
- **Frequency of flooding and ponding** refers to properties related to the site hydrology. Flooding and ponding are described by frequency and duration. Terms like "frequent," "occasional," "rare," and "none" describe the frequency, and terms like "brief," "long," and "very long" are examples of duration. Flooding and ponding descriptions give information on site hydrology to assist with planning and successful wetland restoration.

As mentioned before, the Web Soil Survey is certainly one of the most valuable tools at a planner's disposal. That said, it cannot be stressed enough that soil surveys are somewhat general, and the information provided should always be verified in the field.

Figure 8: A soil ribbon made from a sample taken in the field. The 2" plus length indicates greater than 25% clay.

Hydrologic Review

It goes without saying that water is quite important when it comes to wetlands.

Identifying water sources and alterations to these sources is a necessary exercise and one that begins from the desk. Natural sources of wetland hydrology include out-of-bank flows from rivers and streams, runoff from upland areas, precipitation that falls on the site itself, subsurface water tables, or groundwater discharge, which can form seeps, fens, and springs. The first two, out-of-bank flows and runoff, can be determined by a review of aerial imagery, lidar, and/or 7.5-minute quad maps. Look for features that may impede or provide out-of-bank flows or hill runoff. Keep in mind that larger floodplains have more space to store floodwaters and are more likely to remain inundated for longer periods. Headwater streams have less space and are more likely to have small pockets kept wet by groundwater discharge. Elevated water tables are hard to predict and can be influenced by soils, geology, infiltration, and adjacent river levels.

The presence of a water source is not necessarily a guarantee of hydrology. In most agricultural settings, hydrology has almost certainly been altered in one way or another. Practices such as drainage ditches, levees, diversions, and drain tiles are frequently used to keep water off the land to make it more agriculturally productive. It is important to identify and understand these alterations and how they affect the restoration site and the surrounding land. Failure to do so can have serious consequences, especially when it comes to off-site impacts. Review aerial imagery and additional resources like lidar to identify not only water sources but also hydrologic alterations that will affect the restoration. This review can reveal opportunities (hill runoff, ditches that overflow) and shortfalls (levees or other impediments to water flow) that will need to be addressed.

Reviewing the information covered above and piecing it together like blocks in a building will tell a story of the prospective restoration site. Once you've identified the site's strengths and weaknesses, it's time to go to the site.

On-site Analysis

The purpose of the on-site planning visit is twofold. First, it's a chance to confirm much of the information that you learned during the off-site review by evaluating soil types, alterations to hydrology, existing land cover and use, and existing hydrology. Second, the site visit is an opportunity to gather additional information regarding restoration potential or challenges that may not be obvious in a remote setting, in real time. Always take good notes and identify your findings on an aerial photograph during the on-site visit. Taking photos of different parts of the site to link to your written observations can also be helpful.

Soil Verification

As mentioned earlier, because the soil survey is general, it's critical that you verify soils information on-site. To help eliminate any doubt regarding this facet of restoration potential, use a soil probe to pull samples from the site.

When taking soil samples:

- Pay close attention to location.
- Take samples at a minimum depth of 36 inches.
- Target the samples at
  - elevation changes
  - obvious changes to landforms, such as ridges or swales
  - obvious changes in vegetation
- Determine number of samples by the degree of variations described above. This will vary from site to site.

For each sample:

- Look for obvious changes in color and texture.
- Remove sections of the soil within the soil probe at intervals based on visible changes (e.g., color or texture) in the sample, or every 4–6 inches, and roll this into a ball.
- Create a ribbon by working the soil between the thumb and index finger. The longer the ribbon, the more clay content. A ribbon that is 2 inches or longer is generally sufficient for wetland restoration.

In addition to clay content, look for changes in soil texture within the soil profile. For wetland construction, sand lens or silt layers near the surface (less than or equal to 36") should be avoided, especially when considering any form of excavation or creative borrow (sources of earthfill that

Figure 9: This small ditch, which has been created by receding floodwaters, is an example of a drainage pattern.

mimic natural features, such as oxbows, depressional areas, etc.). If soil investigations in the borrow areas reveal potential issues due to textural changes, the borrow should be relocated to a more suitable area. In the event sand or silt lens are discovered later during construction, which is possible in some floodplains, construction activity should be halted until further review.

If you are not confident in your findings, request assistance from an NRCS soil scientist or other professional with soil identification experience. Mistakes involving soils and wetland restorations are often permanent and irreversible. It pays to be sure!

Land Use

Use the site visit to verify existing land uses of both the site and adjoining/nearby land. First, identify property lines and any evidence of ownership changes. Look for evidence of cropping, drainage, and infrastructure both publicly and privately owned. As you identify the above uses, think of how they may impact any restoration concepts you may have.

Evidence of Hydrology

While on-site, look for evidence of hydrology from the perspective of a water source and from that of drainage. Drainage patterns/scouring, water marks, deposition, and drift lines (windrows of sedimentation, logs/sticks, leaves, crop residue, etc.) are all good indicators of hydrology. This information will help answer important questions, such as, is there evidence of water current and velocity that will need to be addressed in the restoration plan? Any or all of these hydrologic clues can affect all aspects of the restoration plan from infrastructure built to vegetation establishment.

Existing Conditions and Infrastructure

Use the site visit to make note of existing land uses (e.g., row crop, pasture, old field) on-site and nearby. The adjoining land use (especially cropping and public infrastructure, drainage ditches, flood protection levees, roads, pipelines, powerlines, railroads, etc.) could dictate placement of berms, water control structures, and even planned vegetative cover. It is important to remember any restoration activity that alters the flow of water across the landscape could have negative impacts on neighboring land. Some

Figure 10: Water marks on trees are indicators of hydrology. Note the contrasting colors at the base of this green ash; the darker area indicates the depth of prolonged, frequent inundation.

Figure 11: Drift lines, such as this pile of sticks and debris, can tell you a lot about hydrology. For example, piles that occur on the upstream side of an obstruction (the silver maples in this photo) indicate the direction of the flow. The height of the debris pile can give clues about depth during flooding.

negative impacts could have legal implications regarding Missouri drainage laws. A few examples:

- A berm perpendicular to flood flows could add friction and impede flow during a flood event, causing water levels to rise. The result could be additional crop loss or reduced yields on the adjoining land.
- Placement of a water control structure that releases impounded water onto neighboring land or drainage ditch could damage crops or prolong wetness on that land.
- Planting trees next to adjoining crop fields or public roads could sap water and nutrients and/or prevent drying, prevent thawing in winter, and hinder maintenance.

Note any existing infrastructure such as levees, ditches, and pipes. Consider whether this infrastructure is something that can be used in the restoration plan or something that needs to be avoided, removed, or altered.

Finally, while on-site look for subtle changes in topography. Drowned out places in fields (areas of dead or no vegetation due to prolonged inundation) or bands of native plant species, such as cattail, smartweed, cocklebur, or giant ragweed indicate differences in elevation. These subtle differences could have an impact on the restoration plan.

Special Challenges

Utilize the site visit to identify any special circumstances that may present a challenge to the restoration plan. Look for evidence of existing easements (signs of maintenance or frequent use) such as levee and drainage districts or rights-of-way associated with public road, railroad, natural gas lines, or powerlines. Uses such as these do not always show on remote resources used for off-site analyses and may only be confirmed by walking the land.

Take note of any high quality, existing plant communities that could enhance the plan or be harmed by restoration activities. These existing plant communities can already be providing critical habitat for sensitive species such as reptiles and amphibians and alteration could be undesirable.

After the site visit is complete, combine the information gathered during the on-site visit with the information obtained through the off-site analysis and begin planning a preliminary restoration design. Determining a general direction for the restoration plan, including placement of berms, pool areas, water control structures, and plantings, will aid in the next step — the topographic survey.

Section 2: *Topographic Survey*

A topographic survey, or topo survey for short, is an engineering process or tool that is used to map the surface of the land, concentrating on elevations and contours. Information gathered during the survey is converted into a surface model and can be displayed in several ways; the two most common methods are to plot the model on paper, or to display it in a Geographic Information System (GIS) mapping model. The topographic survey is a two-dimensional representation of a three-dimensional world.

Biologists and planners rely heavily on topographic surveys when developing conceptual restoration plans, and engineers will use the same data to generate earthfill quantities, water control structure plans, final designs, and construction plans. This section will look at the tools, methods, and interpretation of the topographic survey.

Survey Equipment

Survey data can be collected using high-tech equipment such as survey grade Global Positioning System (GPS) or by simply assessing naturally occurring landscape clues like existing waterlines, differences in plant species, robustness of plant growth, or condition of plant or leaf litter. The most common tools used to perform topographic surveys, in order of simplicity, are natural indicators, hand level, lidar, dumpy level/transit, laser level, total station, and survey grade GPS. We'll explore each of these in more detail below.

Naturally Occurring Indicators

Natural land features can be very good indicators of topography. Understanding them allows you to make an instant assessment of the terrain.

A general topographic assumption in Missouri is that the land falls (decreases in elevation) away from the stream (due to sedimentation patterns) and downstream. Because water lies flat on the landscape, it is a dependable level for looking at differences in elevation, so by flagging various water lines during a flood event, you can obtain information about the lay of the land.

Identifying and understanding wetland vegetation often can serve as the first topographic survey. Wetland

Figure 12: As a general rule, land elevations decrease away from a stream as well as downstream.

Image from *Hydrologic, Soil, and Vegetation Gradients in Remnant and Constructed Riparian Wetlands in West-Central Missouri, 2001–04*: U.S. Geological Survey Scientific Investigations Report 2004-5216. Appears here courtesy of the U.S. Geological Survey.

Figure 13: Waterlines after a hard rain can show depressional areas within a field.

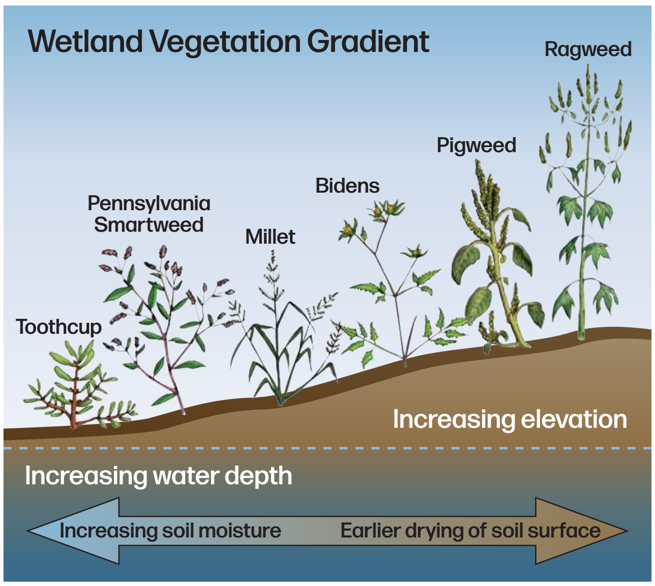


Figure 14: Vegetation gradient, showing how different plant species grow at different elevations.

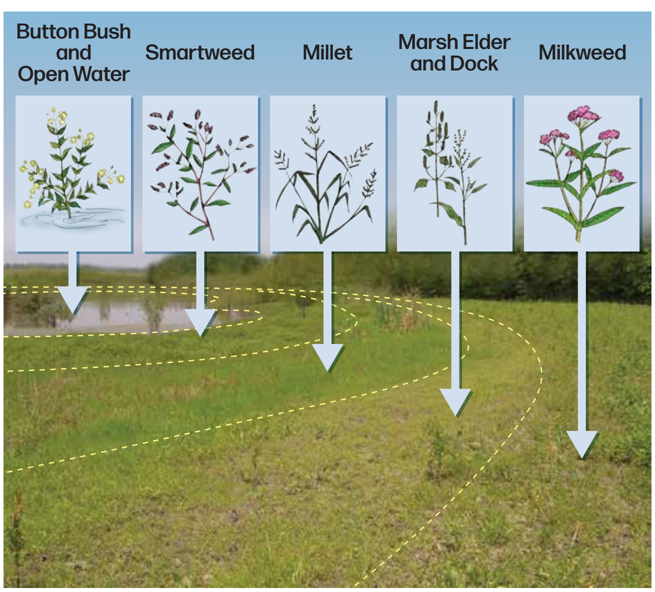


Figure 15: Different bands of vegetation can often be seen following depressional contours.

vegetation often occurs in bands related to receding water levels. Also, germination conditions like soil temperature and texture vary for wetland flora and can indicate subtle elevation change. For example, many broadleaf plants like annual bidens (*Bidens spp.*) are early germinators and will often occur on areas that are dry first, which tend to be higher in elevation. Grasses like wild millet (*Echinochloia sp.*) and sprangle top (*Leptochloa filiformis*) require warmer soil temperatures for germination and typically germinate later, often in lower elevations. This is not a hard-and-fast rule, however. Obligate hydrophytes like cattails (*Typha latifolia* or *Typha angustifolia*) and water primrose (*Ludwigia sp.*) can grow in standing water and therefore usually grow in the lowest elevations. On the flipside, an indicator that a site might dry out quickly is the presence of giant ragweed (*Ambrosia trifida*), pigweed (*Amaranthus retroflexus*), and cocklebur (*Xanthium strumarium*), which can germinate in drier and/or coarser textured soils.

In summation, visually distinct zones or differing "bands" of vegetation can occur across the elevational gradient of a depressional area. By recognizing these vegetative bands, a surveyor can get a good feel of the terrain without the aid of an instrument.

Information gathered with this method is very basic and cannot be used to compute engineering quantities or a final design. It is, however, a guide for performing a more detailed topographic survey by identifying features that need to be captured with an instrument.

Hand Level

A hand level is a tool used for a general topographic survey; the information obtained is an estimation, not a precise measurement. This method can be used to

Figure 16: Hand levels, like the one shown here, are handy for general survey information but are not typically used to obtain data for design purposes.

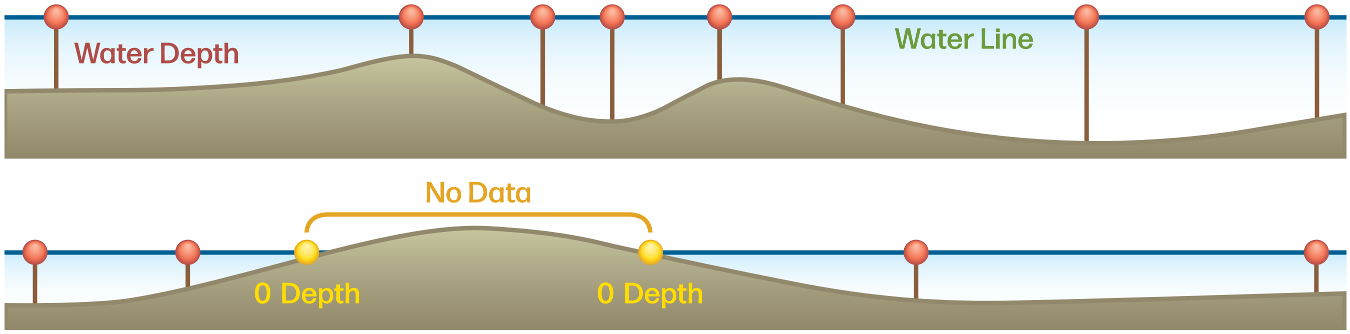


Figure 17: An example of the point spacing of water depth measurements used to determine topography changes under flooded conditions.

compare multiple points to a reference point to get an estimation of elevation or distance. Hand levels are timesaving because there is no instrument to set up and they can be used by a single individual. The trade-off is they are not as accurate as other survey equipment and, like natural features, should only be used for information gathering and not design purposes.

Water Levels and Depth

As already mentioned, waterlines can be helpful natural indicators of topography and indicate the perimeter of low-lying areas. However, you can also obtain topographic insight within the flooded area. If you are confident from your off-site analysis that flooded conditions are less than 4 feet deep, with minimal flow, and therefore not a threat to safety, another option for reconnaissance is available. With a measuring stick in one hand and a GPS in the other, you can walk transects across a flooded area. By taking measurements and logging the water depth into the GPS unit at repeated intervals (i.e., every 20 yards or so depending upon the size) and whenever the water level moves up or down your waders 4 inches, you can capture a site's elevational differences. Using several staff to cover more ground at once is one way to enhance this method. For sites deeper than 4 feet, such as a borrow or scour hole, a boat and longer pole are a rudimentary solution. A GPS-enabled depth finder is a more technical solution for mapping these locations with deeper flooding.

The downside to this methodology is that you can only measure areas that are flooded. If there are dry patches, the elevations of islands that are not inundated will be missed. It is important to be sure that water levels remain stable during the survey period. Once you are back in the office, the GPS points and water depths can provide an adequate point cloud to generate a two-dimensional surface model. The width of the point spacing may make this coarser than a lidar-based elevation model; however, it can still provide a first cut for planning and better resolution than the 10-meter topo line found on USGS maps. This methodology can also be used to fill in holes within lidar datasets that may have been created when portions of an area were flooded.

Laser Level

A laser level is an electronic survey instrument that is mounted on a tripod and utilizes a rotating laser beam projector. If you use a laser level in conjunction with a survey rod and receiver, you can record elevational data. Record point data in an engineering field notebook and convert it to elevations. The primary downfall of a laser level is it does not provide accurate point coordinates unless the points are recorded with a handheld GPS device. If used in this fashion, the information obtained with a laser level can be used to complete an engineering design.

Laser levels can be operated by a single individual and require a clear line of sight. Larger areas and those with blocks of timber or brushy fence lines can obstruct the view and may require you to change laser level positions to cover a site. This will require some extra work to anchor and link your elevational measurements to ensure they match up. In terms of cost, laser levels are quite reasonable and work well in open fields that are dry.

Figure 18: A laser level and rod with receiver.

Figure 19: A dumpy level and survey rod.

Transit or Dumpy Level

Dumpy levels or transits have been around for a long time and are quite accurate. In fact, this survey method was used by Lewis and Clark as they charted the Louisiana Purchase in the early 19th century and remained the "go-to" method for decades until the development of electronic instruments.

Dumpy levels are survey instruments that are mounted on a tripod and are used in coordination with a level rod or staff. Vertical and horizontal data obtained using a dumpy level include elevation, distance to a point, and the azimuth (compass bearing) of a point, which all can be plotted to give a representation of the topography. The survey generated can be used to complete engineering designs. Record your survey shots (rod readings) in an engineering field notebook and "reduce" them to ground level elevations back at the desk. These elevations can then be plotted on paper. To reduce your survey shots, subtract each rod reading from the height of the instrument (HI). The HI is determined by taking a survey shot on the benchmark (TBM), or another known elevation, and adding that rod reading to the TBM. For example: If the TBM elevation is 650 and the rod reading at the TBM is 6.2, then the HI would be 656.2 (650 + 6.2). Then if you took a survey shot at another location on that site and had a rod reading of 8.0, you would subtract 8 from the HI (656.2) to get the elevation of 648.2 for that survey shot location.

Some shortcomings of a dumpy level are that it requires two people and a clear line of sight. It is also time consuming and requires a considerable amount of math when converting the field notes.

Lidar

Lidar (Light Detection and Ranging) is a topographic survey taken from the air, using a laser to measure variable distances to the earth. From this data, three-dimensional models and/or contour lines can be generated to show topography. Lidar data is accessed on the computer using GIS programs and can be accessed through the University of Missouri's GIS server. Most state and federal agencies have access to lidar. Lidar data can be used to complete engineering designs, but care should be taken because ground conditions, such as vegetation type and standing water, can affect accuracy. When using lidar, it is a good practice to combine its use with other survey methods, such as survey grade GPS or a total station, to verify its accuracy. This can be accomplished by setting control points or representative transects that can then be compared to lidar. Lidar is often used in combination with other survey methods, especially where conditions make ground surveys difficult or where access is limited (off-site areas). It is an excellent planning tool but should not be used as a stand-alone source of topographic information when completing a final design.

One striking advantage of lidar is that most available data products are for a whole county of Missouri. While ground surveys will be limited to the elevations of a particular parcel or landowner, lidar won't be constrained to this

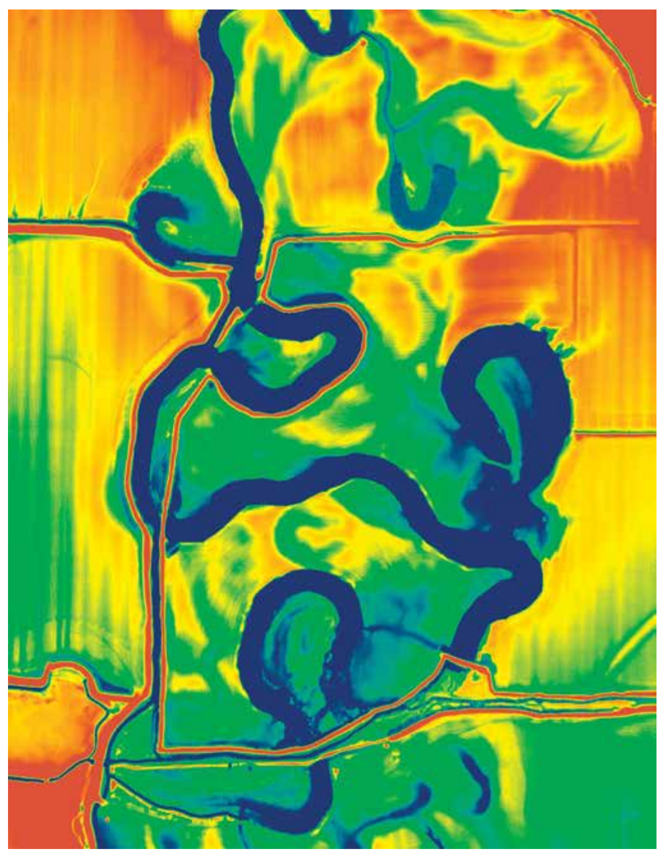


Figure 20: A lidar image using a color scale to depict topography.

scale. It can help identify larger or nearby features, such as ridges or swales, that may be directing water to, or away from, a location. A site's design can be doomed if interactions with the surrounding landscape are overlooked.

Total Station

A total station is a survey tool that combines an electromagnetic distance measuring instrument with an electronic theodolite (transit). It also has an integrated microprocessor, data collector, and storage system that allows it to measure horizontal and vertical angles as well as sloping distance from a survey rod and prism to the instrument. Data processed by the total station includes horizontal distance to a point, distance between points, point elevation, and the latitudinal and longitudinal coordinates of each point. After survey completion, this data is downloaded into a computer where it is used in design software such as AutoCAD.

Figure 21a: A surveyor using a total station.

Figure 21b: A prism, or target, is attached to a rod and used to accept signals sent by the total station.

Total stations are expensive and typically require at least two people to complete a survey, although newer versions are available that can be operated by one individual. Larger crews can expedite survey time. Total stations are often used in combination with survey grade GPS. A clear line of site is also required. All in all, it is a very accurate and dependable survey tool.

Survey Grade GPS

Survey grade GPS utilizes receivers that receive information from satellites and has a higher degree of accuracy than standard GPS units. The equipment can be mounted to a vehicle, such as an ATV or UTV, or on a rod for individual shots. Typically, for topographic surveys, a combination of both is used: vehicle mount for continuous topographic measurements and rod mount for surveying pipes, levee cross sections, benchmarks, or other individual points or features. When using continuous topo mode, you can take individual survey points (shots) at an interval of your choice depending on the desired amount of accuracy and detail (i.e., every 50 feet, 100 feet, etc.). Time spent acquiring a shot also affects accuracy. For example, more time should be dedicated to establishing an elevation for a benchmark than for points collected during continuous topo mode. You can assign an identifying survey code to individual shots for easy identification of the distinguishing features during survey interpretation. These shots can be turned on or off depending on the desired view.

Data recorded during a GPS survey is downloaded to a computer and analyzed with design software like AutoCAD. Survey information is typically displayed as contours or individual points. Surveys can either be printed or viewed in a GIS program like ArcMap. Survey grade GPS does require unobstructed visibility to the sky in order to receive information from satellites. The ability to survey can be affected by canopy cover from vegetation (generally trees) or from satellites that are low on the horizon. A minimum of five to six satellites are required for surveying. The more satellites available, the greater the reliability and accuracy. The availability and position of satellites can be viewed while surveying. Survey grade RTK GPS is the go-to equipment of the 21st century.

Figure 22a: Surveying with a survey grade GPS unit mounted to a UTV.

Figure 22b: A surveyor taking shots with survey grade GPS unit that is mounted to a rod or pole.

Conducting the Topographic Survey

This section will focus on gathering survey information using survey grade GPS. For detailed information regarding survey procedures and protocols refer to NRCS eDirectives-Part 650-Engineering Field Handbook, Chapter 1-Surveying.

This publication is available online at **directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=47739.wba**

As a rule of thumb, a survey is only as good as the surveyor; therefore, accuracy and detail are essential to develop the best plan and a final design. It is crucial to capture all topographic changes in the landscape (obvious highs and lows) to accurately model the land. In addition, since the survey information is the basis for the final design and associated engineering quantities, it is also ultimately tied to the cost of the restoration or construction design. An inaccurate survey will result in quantity errors that can lead to budget shortfalls. Do not skimp on time spent surveying. Whenever possible, as the planner, you should participate in completing the topographic survey. Doing so allows you to set eyes on the natural features of a site both in the office and field. Sometimes seeing something in the field can transform your understanding of a site's function, which was previously unrealized because of its unassuming small scale on a map in the office.

Individual topics covered in this portion include survey ground conditions, topographic survey accuracy and detail, existing features, and special challenges.

Ground Conditions

Prior to conducting a topographic survey, it is a good practice to assess existing ground conditions on the site. Vegetation, snow, mud, ice, and water can all affect survey accuracy or even the ability to complete the survey.

Vegetation

The existing vegetation on a site can affect a survey in several ways. First, and the most obvious, is canopy cover, which can interfere with surveys done with survey grade GPS equipment. If you are surveying in or close to trees, the equipment's ability to "see" satellites may be reduced, so it is always a good idea to survey these areas, during "leaf-off" or wintertime periods. Even then, the ability to survey and the survey accuracy can be affected if tree stem density is high or if satellites are low on the horizon. Situations like this can be overcome by utilizing a total station to collect survey data for those areas where satellite signal is lacking. This data can then be incorporated into the general survey. It is important to note that a minimum of two benchmarks should be keyed into the total station to ensure that all points are on the same plane.

Thick or robust emergent vegetation like cattails or reed canary grass (*Phalaris arundinacea*) can also impact a survey. Rank vegetation can "pile up" under a survey vehicle, making forward progress difficult. In addition, it can also create a "false surface," where the vehicle rides on top of thick vegetation, and that surface is surveyed, not the actual ground. The result is a survey that is inaccurate. This false surface created by heavy plant cover can also affect aerial-based lidar. Indicators of a false surface on lidar images are textures that appear "pimply" or "bubbled" rather than the typical smooth surface.

Dealing with these situations will be discussed in more detail later in this section.

Snow and Mud

Anything that can alter the ground surface can affect the topographic survey. Snow and mud are two of the most common factors that a surveyor will encounter. Both can affect accuracy. Deep snow will create a "false surface," which, like rank vegetation, results in the actual ground not being surveyed. Deep snow can also hinder the ability to survey by limiting forward progress of the survey vehicle.

Soft or deep mud affects survey accuracy in the opposite direction of snow. If the survey vehicle sinks in the mud, the recorded survey readings will be lower than the true ground elevation.

Critical design features like planned waterlines, berms, and water control structure (WCS) placement, and earthfill quantities can all be affected by these conditions. It is important to remember that survey conditions are seldom perfect, so you will need to assess the situation and the amount of the site that is impacted by these conditions and act accordingly.

Ice and Water

Ice affects survey accuracy for obvious reasons. If ice is strong enough to support the surveyor, then the ice, not the ground, is the surface that is being surveyed. Water can be surveyed through if it is not too deep to prevent access with equipment or on foot; however, an effort should be made to determine the consistency of the substrate (mud) and how that can affect survey accuracy.

General Survey Considerations

It is recommended that the planner conduct or participate in the topographic survey. As mentioned before, accuracy and detail are critical. To ensure good coverage, conduct the survey on a grid at speeds less than 6 mph. Typically, a grid survey is done with a vehicle such as a UTV or ATV. Space survey transects 50 to 100 feet apart, and do the same for individual survey points.

After the survey receiver is mounted to the vehicle and started, measure the antenna height from the ground and enter it into the data collector. All points surveyed after this will be relative to the antenna height. As mentioned earlier, topographic features (ridges and/or swales) often occur between the survey transects. Be sure to capture these areas so the survey is accurate. Also, select the distance between points and enter that into the data collector at this time.

Before you begin the survey, establish a Temporary Benchmark (TBM) or Bench Mark (BM) that is a known reference point to which the entire survey will be oriented. This point(s) will be assigned a separate code distinguishing it from the rest of the survey. TBMs commonly consist of a steel rod driven into the ground and topped with an orange survey cap, but they can be other permanent features like pipes, concrete structures, etc. Once established, the TBM should be well marked with a painted and flagged wooden stake. Pertinent information such as TBM elevation, TBM number (if more than one), and TBM point coordinates should be written on the stake.

Once the benchmark is established, the field survey can begin. While surveying, pay close attention to changes in vegetation or obvious elevation changes that may fall between transects and subsequently be unrecorded. If these situations arise, be sure to survey these areas as they may indicate very subtle elevation changes or landforms. In addition to surveying the area to be restored, it may be necessary to get limited survey information from adjacent land to ensure the restoration will have no negative effects on neighboring areas. This information is especially needed if there are no distinguishing features between the two properties such as a levee or drainage ditch. Be sure to get permission for access if the adjacent land is under different ownership.

Existing infrastructure (levees, ditches, pipes, roads, etc.) should be surveyed in detail and each structure given its own identifying survey code. The following information should be recorded:

- **Levees:** Elevation of levee tops (both sides) and elevation at levee toes (both sides). Top width and levee side slope can be determined from this information.
- **Ditches:** Elevation of ditch banks (both sides) along with flowline elevations (flowline elevation is taken at the bottom of the ditch). Bottom width and bank side slope can be determined from this information.
- **Pipes:** Flowline elevation (i.e., inside bottom elevation) of both inlet and outlet pipes as well as elevation of the top of the pipes. These measurements can also be used to determine the diameter of the pipe. To determine the length of the pipe, calculate the slope length at the water control structure and add that to the top width of the berm.

Special Considerations

Circumstances may exist on a survey area that warrant special action.

Surveying In or Around Timber

If survey data is required in areas that are in or near standing timber, adequate reception may not be available to use the GPS survey equipment. In this case, topographic information can be derived later from lidar. To ensure accuracy, record representative points in the affected area with a laser level or other suitable survey instrument. Lidar data can then be correlated to the initial benchmark elevations.

Robust Emergent Vegetation

In the event large-scale robust emergent vegetation presents survey challenges, some form of site preparation may be required prior to surveying. The simplest, most cost-effective method is to mow transects through the affected area. In extreme cases, prescribed fire may be useful.

Embedded Plant Communities

Plant communities may be embedded within an area to be surveyed and can be recorded by surveying the perimeter of these areas using a separate identifying survey code. Doing this will allow design staff to place a boundary line around the area(s) in question. Although this is not necessary, it can be beneficial in planning, especially if the area is a rare or critical habitat type that should be left standing.

The Finished Product

Once the field work is complete, the collected survey data needs to be put into a form that is usable. Printed surveys and GIS formats are the best options. There are good points to both, but, ultimately, the decision rests with the planner's preference.

Printed Surveys

After downloading the survey data into design software such as AutoCAD, design staff can print paper copies of the survey for use by the planner. Printed versions should include:

- Individual survey points (with and without contour lines)
- Contour lines (0.5' intervals at a minimum; with and without survey points)
- Copies with and without aerial photography
- Accurate scale (i.e., 1 inch = 200 feet)
- Printed on 11-inch x 17-inch paper

Positive aspects of using printed surveys include that you can make notes on the survey and can view the whole tract or field. Printed surveys also aid in visualizing waterlines and other features as they make it easy to review individual shots to the tenth of a foot.

But printed surveys also have some limitations. Depending on the size of the area surveyed and/or the paper used, printed surveys can be cluttered and difficult to read, especially when individual points are shown. On the same note, large-area surveys may not fit on one piece of paper, and therefore may need to be pieced together. This can be time consuming. In addition, gaining a "bird's-eye view" from large-area surveys can be difficult, which can complicate multiple pool planning by reducing your ability to visualize how those pools interact on the landscape. (See Appendix B on pages 44–45 for examples of printed surveys.)

GIS Formats

Placing survey data into a geographic information system (GIS) and viewing it in programs like ArcMap is becoming increasingly popular. With this format, survey data is added as layers (points, contour lines, aerial imagery, etc.) that can be viewed individually or in various combinations. Furthermore, additional information such as soil surveys can be added, allowing you to correlate elevations to soil types and landforms. Another benefit of the GIS format is that shapefiles of the conceptual design can be imported into design programs and used to produce the final design. Placement of planned earthwork features, WCSs, and vegetative plantings can then be designed exactly as planned with no misinterpretation of placement. Like the printed version, GIS formats can also be challenging to interpret as a whole if the surveyed area is large.

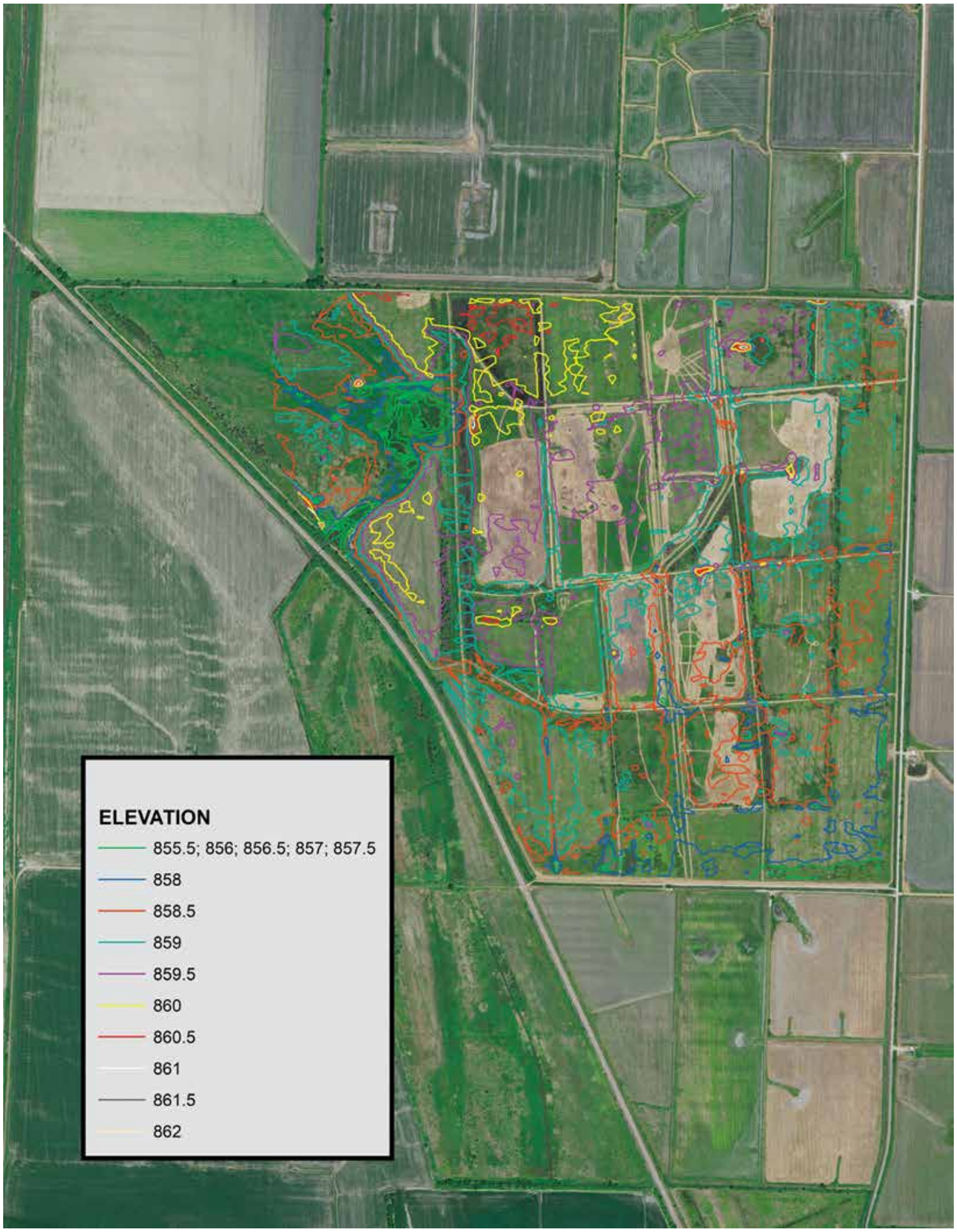


Figure 23: GIS-formatted survey completed using survey grade GPS. In this example, each contour line (elevation) has been assigned a color to help the user visualize "depth" or changes in topography.

Section 3: *Conceptual Design*

The conceptual design is best defined as the planner's vision for the best restoration plan for a particular site and serves as a road map for the designer to complete a final design. Included in this vision are all facets of a restoration plan: waterlines, pool areas, earthwork (type and scope), water control structures, and planned vegetative communities.

The direction of this vision has undergone a significant evolution over the last 25 years. Early restorations sought to put water over the entire tract using berms with steep slopes, narrow tops, and generous freeboard (distance between berm top and maximum pool elevation). Waterfowl were the target species and moist soil (managing for annual seed-producing plants for waterfowl) was the planned vegetative community. Water depths averaged 18–24 inches and little thought was given to plant diversity and wetland function. Infrastructure damage from flooding was common and sometimes extensive.

This damage became the driving force behind the future evolution of designs. Restorations began to incorporate flatter slopes, less freeboard, more "creative borrows" (borrow areas that mimic natural floodplain features), and shallower water depths. In addition, berms were aligned on the contour (generally following a similar elevation) to reduce height and construction costs. The goal to cover 100 percent of a tract with water remained and waterfowl were still the target species, but the use of shallower water made the areas inviting to more wildlife species.

Today's restorations seek to recreate landscape features (stream banks, ridges, etc.) both high and low. In many cases, these features have replaced traditional impoundment structures. Building berms with flatter slopes (8:1 or 10:1 [i.e., 8 feet or 10 feet of slope for every foot of drop]) and extra wide tops (anywhere from 15 to 120 feet wide), reducing freeboard, and aligning berms to be more parallel to flows (so they blend into the floodplain) has all but eliminated damage from flooding. Shallower water depths, averaging 1 foot or less, are the norm, and the importance of saturated and adjacent terrestrial areas has been recognized. Finally, special attention is paid to placing habitats where they historically resided.

This section will look at the aspects of completing a conceptual design, including topographic survey interpretation, waterline determination, planned infrastructure, seedings/plantings, and completion of the final design. In addition, we'll look at planning for the enhancement of existing wetland restorations.

Interpreting the Topographic Survey

Development of a conceptual design begins with a thorough review of the topographic survey. Survey data representing general topography, existing infrastructure, and off-site features should all be reviewed in detail.

General Topography

The correct interpretation of a site's topography is the foundation of any wetland restoration plan. Common ways to assess a survey are to generate maps with contour lines and maps that show the elevations' individual points. Overlaying these features on an aerial photograph is also recommended so you can compare topography and existing features.

Contour lines will project a general image of the rise and fall of the land along with existing drainage patterns. At a minimum, contour lines should be generated at intervals of 0.5 feet. Depending on the actual site characteristics, some contour maps can be busy and confusing, making them difficult to interpret. In instances such as this, it may be helpful to assign colors to individual contour lines or the areas between contour lines. Doing this can make it easier to distinguish between elevations and to visualize depth on a two-dimensional scale. You will need to "trick" your mind into seeing this two-dimensional model in 3D.

Another way to visually represent the topography is to overlay multiple layers in ArcGIS. Surface models often are represented as rasters or Triangulated Irregular Networks (TINs) and elevations can be classified with a customized color range (i.e., lower, wetter elevations as blue and higher, drier elevations as yellow or brown, with intermediate elevations as shades of green). To better visualize depth

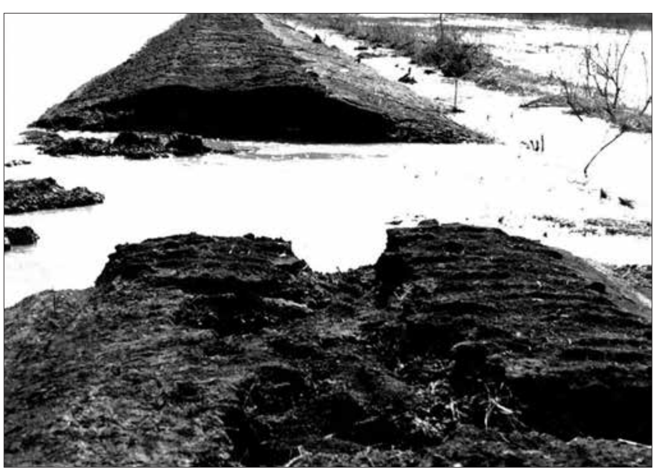


Figure 24: Wetland berm damaged by flooding soon after it was built.

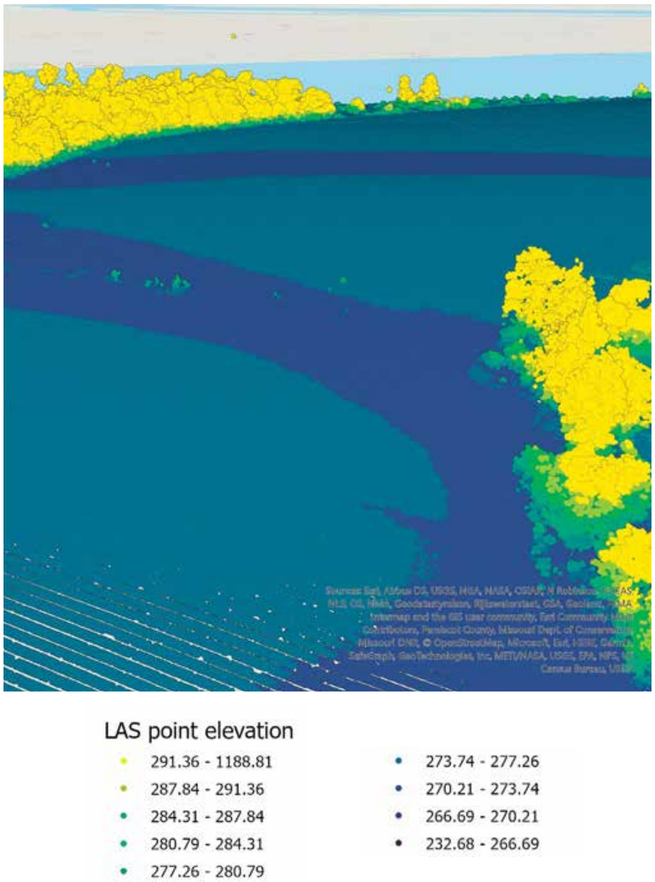


Figure 25: Lidar point cloud image, showing elevational differences, vegetation, and stream channels.

on your map, you can use hillshading to create more contrast in locations with sharp elevational change. If you overlay a transparent hillshade with labeled contour lines and place a color gradient beneath it, it can provide you with adequate detail at multiple scales to help you better interpret the topography. To get a true representation of the terrain, you may need to view the individual points between contour lines.

As a part of this review, correlate the survey to soils information. Doing this will help you identify landforms and the plant communities that historically occupied them, which will ultimately help you decide which habitats are possible and where. Viewing the topographic survey in a GIS format makes comparison to soil types much easier.

The importance of an accurate assessment of the topographic survey cannot be overstated. Take time to understand your site's topography so you can develop a plan that fits seamlessly into the floodplain or landscape.

Existing Infrastructure

Review survey data that represents existing infrastructure carefully. Generally, when infrastructure features (e.g., levee top or flowline of ditch) are surveyed, they are assigned their own representative code so they can be easily distinguished from general topographic information. Assess these features in the context of whether they are a limiting factor (e.g., private ownership, levee district levee, public drainage, or other existing easement). If these situations exist, you may need to design around them. Also, assess existing infrastructure to see if it can be utilized in the restoration or removed all together.

Off-site Features/Adjacent Land

Adjacent land and off-site features or infrastructure can impact a wetland restoration plan. When reviewing survey data of these features, watch for any potential or perceived adverse effects the restoration may cause, such as increased wetness or ponding. Critical features include, but are not limited to, property lines, adjacent cropland, drainage ditches, roads, pipelines, powerlines, and other infrastructure. Historical drainages may sweep across these smaller, often linear, human-made features but only become evident during flood events. Accounting for the scale and connectivity of these low-lying areas is important prior to a flood, rather than after it. Analyze both natural and built features carefully so you can plan accordingly and avoid problems.

Figure 26: Multiple layers (semi-transparent hillshade, contour lines, and color gradient) used to visualize a surface model in ArcGIS.

Determining the Waterline

Determining the waterline, or maximum pool elevation, is likely the most important decision in the development of the restoration plan. Everything else, such as berm type and placement, WCS type and size, and vegetative plantings, are all relative to this elevation. First and foremost, topography is the primary factor affecting waterline determination, followed by soil types and target wildlife or floral species and habitats.

Waterline placement is a balance between surface acres of water and water depth. Very simply stated, surface acres of water refer to the number of acres that are inundated at full pool (i.e., maximum pool elevation). A desirable waterline will maximize the amount of inundated area while avoiding excessive depth over large areas. Remember, most wetland-dependent species, including waterfowl, prefer water depths of 1 foot or less. So you should strive to provide an average pool depth of approximately 1 foot.

Average depth at full pool can be determined by dividing the amount of acre/feet of water (one acre one foot deep) by the total surface acres of water. If the average depth exceeds 1 foot, you risk the waterline "overpowering" the existing topography, which can result in plant communities that are less diverse and often dominated by perennials. As mentioned before, review the point data to confirm actual depths between contour lines, especially in the last 0.5 feet to full pool. From the contour map, you may easily envision a depth of 6 inches in the last 0.5-foot contour area, but in reality it may be much shallower. In situations like this, you may wish to pick a waterline that does not fall on half-foot contours to add a little additional depth. Doing so will not only add depth in the upper reaches of the pool but can also increase surface acres. If ground conditions prevent you from increasing the waterline elevation, there are other ways to provide depth. These will be covered later.

The primary focus of most wetland restorations is to create a range of shallowly flooded habitats, but be careful not to discount the importance of adjacent or nearby saturated, temporarily flooded, and terrestrial areas as well. The most ecologically successful restorations will incorporate this greater spectrum of habitat zones when possible, resulting in more diverse plant communities both in community type and species richness. Subsequently, an increase in wildlife species' use of the area and species diversity will follow the increase in plant diversity, soil moisture conditions, and diversity of water depths. One final element to consider when selecting a waterline is edge. Sometimes, minor adjustments to the waterline, up or down, can result in an increase of "shoreline" or water/land interface that can be a critical factor in the life cycle of some wetland-dependent wildlife.

In some instances, especially when restoring large tracts, it may be desirable, or necessary, to create multiple pools or to split a pool with a contour levee. Multiple pools may be warranted in order to:

- Take advantage of gradual topographic increases to provide additional surface acres
- Avoid excessive water depth in one portion of the pool
- Increase the manageability of a tract by allowing varying water management strategies between pools and years
- Provide a dedicated habitat type (e.g., semipermanent marsh that provides reliable nesting habitat for least bitterns)

When considering multiple pools, remember the cardinal rule, "don't try to force a piece of land to do what it can't." Keeping this in mind, refer to the historical land covers and their landscape position and plan accordingly. Doing so will help ensure the desired results and overall success of the restoration.

Planned Infrastructure

Following the establishment of the waterline, you will need to decide which processes are required to provide the hydrology to achieve the desired habitats. In nearly all restoration scenarios, creating the appropriate hydrology will include some level of earthwork, installation of pipes and water control structures and, in some instances, specialized plantings.

Earthwork

Earthwork is a construction term that refers to building impoundment structures (e.g., berms, habitat mounds, etc.) or other earthen features. Most areas where wetland restoration or reconstruction is planned have been altered to an extent that water drains off the landscape. Construction of earthen impoundment berms is the easiest, most cost-effective method of restoring hydrology to a site, and it comes in many forms. Traditional berms or levees, ditch plugs, and landscape feature or spoils are the most common types of impoundment berms.

Traditional Berms or Levees

Traditional-style berms are the old standby when it comes to hydrology restoration. They are similar to flood protection levees, except that these berms are designed to hold shallow water in, rather than to hold flood water out. Their function is basically limited to this purpose, and as such, they offer little in terms of wildlife habitat. In addition, they can be prone to flood damage. They are generally constructed with a uniform top width (minimum 15 feet) and side slopes (8:1 minimum). In flood prone areas, design characteristics are tailored to the landscape setting in which they reside. For instance, in areas of frequent flooding or excessive current, wider tops and flatter slopes (greater than 8:1) are needed to reduce damage. Flatter

Figure 27: Aerial view of a spoil. The area outlined in yellow shows the spoil. Note how the spoil blends into natural ground features.

slopes also help to discourage burrowing animals. In flood prone areas, berm alignment should be parallel to the water flow as much as possible.

Traditional berms are typically constructed with 0.5 feet of freeboard and a designated floodway or overflow area. Traditional berms are seeded using rates and species designed to protect against erosion, such as the NRCS 342–Critical Area Planting Standard and Specification. Seeding will be discussed in greater detail later.

Ditch Plugs

Ditch plugs are simply what they are named, a plug in a ditch. Designed and constructed like traditional berms, the primary difference is the length, which is usually confined to the width of the ditch being plugged. Top elevations of ditch plugs are typically designed at an elevation greater than that of the adjacent ditch banks, which allows overflow to go around the constructed berm on natural ground. Ditch plugs are seeded using the same standards as traditional levees.

Landscape Features or Spoils

As restoration philosophy has evolved, constructed landscape features (spoils) are becoming more commonly used as impoundment structures (either stand-alone or in combination with traditional berms) when site conditions are appropriate. These features, which can be thought of as creative deposition, along with creative borrow areas, are collectively referred to as macrotopography. Spoils are designed to emulate large-scale landscape features like natural stream levees or other high ground features. Top widths and side slopes of spoils vary depending on the landform, with top widths routinely ranging from 50 to 200 feet and side slopes ranging from 4:1 to 20:1. In addition, the top widths do not need to be uniform on any given structure. Due to their broad tops and long slopes, spoils are extremely flood-friendly and virtually damage free. Planted to native vegetation, they can also provide important terrestrial habitat that is associated with the wetland component. Like traditional berms, top elevations of spoils are designed with 0.5 feet of freeboard and they should be aligned parallel to flood flows as much as possible.

In addition to serving as an impoundment structure, spoils can be stand-alone habitat features with many other functions. Depending on placement, they can be used to provide protection to critical infrastructure such as WCSs by acting as wave barriers, can serve as interior plugs to take advantage of microtopography within a larger pool, and/or be constructed and positioned to attract burrowing animals like muskrats and beavers. Because these animals favor elevated areas with steep slopes for denning, use of spoils for habitat purposes may aid in keeping them from burrowing into more critical infrastructure. When spoils are used as stand-alone habitat features, top elevations can be varied from spoil to spoil. For example, one spoil could be 0.3 feet below the waterline, one spoil could be equal to the water line, and another 0.3 feet above the waterline. Doing so will increase plant diversity based on elevation.

Floodways and Spillways

All impoundment structures should be designed with a

Figure 28a: A constructed floodway created by downgrading an existing flood protection levee.

Figure 28b: Poorly designed floodway. Note the trapped water between the two training berms. These large pin oaks eventually died as a result.

designated overflow or water entry and exit point. These areas are referred to as a floodway and are designed to handle frequent water flow. They have flatter slopes, wider top widths, and a slightly lower top elevation.

Two critical elements of planning floodways are size and location. When sizing a floodway, consider the duration and frequency of flood events. Floodways are routinely damaged when floodwaters exit the pool, so the goal should be a floodway that is wide enough to allow the excess pool water to exit simultaneously with the receding floodwater. As a rule, floodways can be too small but are rarely too big, so lengths of 300–500 feet are advisable.

If you're placing floodways or emergency spillways at both the upper and lower ends of the restoration, you should build them at least equal in length. Or, even better, make the lower spillway wider than the upper. The upper floodway can also be designed at a slightly higher elevation than the lower to allow for backwater flooding prior to accepting headwater flows. This will aid in reducing current, sediment deposition, and damage.

EARTHFILL QUANTITY WORKSHEET

Project:	Joe Landowner	Comp. By:	mkm
Practice:	Dike #1	Check. By:	
Reach:	1	Print Date:	9/7/2022 7:48
Left Slope = 6	Top Width = 15	Right Slope = 6	
Beginning Station =		Beginning Elevation =	641.5
Ending Station =	345	Ending Elevation =	641.5
Grade (ft/ft):			Page 1

Grade El.	Station	Elevation	Height (FT)	End Area	Distance (FT)	Incr. Vol. (CY)	Cum. Vol. (CY)
641.5		641.5					
					100.0	183.3	
641.5	100	638.5	3.0	99.00			183.3
					100.0	348.2	
641.5	200	638.7	2.8	89.04			531.6
					74.0	218.7	
641.5	274	639.1	2.4	70.56			750.3
					71.0	92.8	
641.5	345	641.5					843.0

Page 2

CONSTRUCTION CHECKOUT SHEET

Project:	Joe Landowner	Comp. By:	
Practice:	Dike #1	Check. By:	
Reach:	1	Date:	
Left Slope = 6	Top Width = 15	Right Slope = 6	

TBM#	TBM Elev.	+ BS	= HI	TBM Description:

% Overfill = 10% — Page 1a

Station (ft)	Rod Rdg. (FS)	Const. El. (HI – FS)	Plan El.	Deviation (+/–)	Notes
			641.5		
100			641.5		
200			641.8		
274			641.8		
345			641.7		
			641.5		

Page 2a

Figure 29: Example of earth-fill computation completed using an Excel formula sheet.

Locate floodways on or as close to natural ground as possible. Doing so will reduce the amount of overfall, which is the distance water drops when coming over a surface. The more overfall there is, the more velocity water has when flowing, which will lead to erosion, damage, and ultimately failure. Current, debris, and sedimentation are other factors that should be considered with floodway location. Swift water carries high sediment loads and debris, so, when possible, locate the floodway in areas that are off-channel and that are in backwater or low current situations. Properly located floodways can add years of longevity to a wetland by preventing excess sedimentation, in addition to reduction of debris buildup and unwanted flood-borne seeds. Floodways should be seeded using species and rates designed to minimize erosion.

Computing Earthwork Quantities

Accurate earthwork quantities are essential for project budgets, contractor use, and for final payment. In some cases, however, you may not have access to engineering resources like AutoCAD. If you find yourself in this situation, a spreadsheet with formulas is available on the MDC website at **mdc.mo.gov/wetland-management**.

You can use the worksheet to compute your yardage quantities. Survey the levee alignment at 100-foot intervals using a laser level and record the point locations with a GPS device (for stakeout purposes). Enter the survey data (measured rod readings) into the formula worksheet along with the top width, slope, and planned top elevation, and then compute the quantities.

Creative Borrows

Twenty to twenty-five years ago, nearly all wetland restorations were constructed using a bulldozer. This method limited borrow areas (sources of fill material) for berm construction to what is called side borrow. These borrow areas were adjacent and parallel to the berm. Often they were deep, which contributed to damage from burrowing animals that were attracted by the placement of deep water adjacent to the levee toe.

Today, the sources of fill material, or borrow areas, are scattered across the wetland pool in a fashion known as creative borrow. In addition to being a borrow source, creative borrows have increased functionality by emulating natural floodplain features like oxbow lakes and other depressional areas. The shapes of planned borrows should mimic those common to the watershed, such as wetland signatures and oxbows (size to scale of watershed). In a time when the average pool depths are getting shallower, creative borrows provide depth, edge, and increased habitat diversity. You can add even more edge and diversity by incorporating islands, basking logs, and varying bottom elevations. In some respects, utilizing creative borrow techniques contributes to berm stability by locating deep water away from the levee toes.

In most cases, borrow areas, or cuts, are designed features but not always considered “pay items.” This is because borrow quantities are typically balanced with the amount of excavated soil, or fill material, needed for berms, levees, or other habitat features. Depending on the site, balancing cuts and fills will still provide ample depth across the wetland pool. If you feel more depth is needed, you can create additional borrow areas or increase the depth of existing depressions. The challenge of adding more borrows is where to put the fill. If this is the case, use the fill to increase the top width and/or slope of planned berms or spoils, or spread it across areas above the waterline.

Because creative borrows are located across the restoration site, the material will usually be hauled using tractors and scrapers. To maintain construction efficiency and cost effectiveness, keep borrows relatively close to their destination. Six-hundred-fifty feet or less is a good rule of

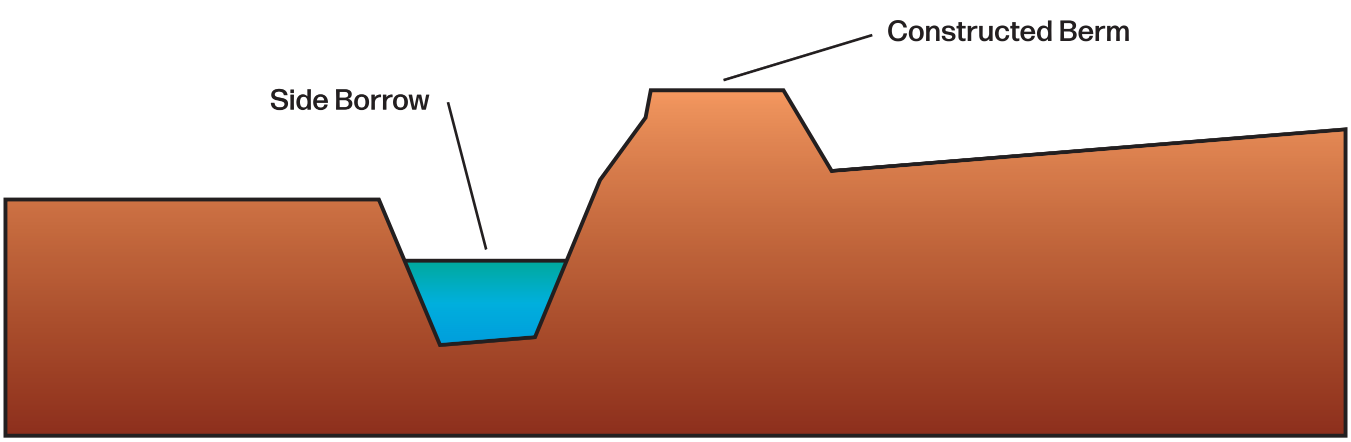


Figure 30: This image illustrates side borrow. Borrowing fill material in this manner creates a situation where deep water is adjacent to the berm or levee, creating ideal places for beaver and muskrat to burrow into and, in turn, reduce the integrity of the levee. Once a common construction method, side borrow is frowned upon today.

Figure 31a: Creative borrow is a construction method where fill material is taken from areas that resemble naturally occurring features that occur on the landscape, such as the oxbow lakes shown here.

thumb, although circumstances may require longer hauls. Creative borrows are typically allowed to naturally regenerate to native vegetation and are rarely seeded.

Additional thoughts on creative borrows:

- Be sure to verify soil types and the corresponding soil profiles to avoid compromising the water-holding capabilities of the site by hitting a sand vein or other permeable layer.
- Locate borrows across the gradient to provide semi-permanent water at multiple elevations once a pool is drained.
- Utilize borrows as a water delivery system by connecting them to a water source (well or pump) and to each other.
- Locate borrow areas outside the designed pool areas to provide additional small, temporal, or semipermanent wetland features. This can be especially useful when soil types pose a risk of hitting a sand lens or vein.

Finally, consider the planned longevity of the restoration. Since many wetland restorations are associated with state or federal financial assistance programs, such as the USDA Wetland Reserve Easement (WRE) program, some thought should be given to the possibility of contracts or agreements expiring in the future. If land use is expected to return to agricultural activities after the restoration contract expires, it may be wise to make the borrow design and location more conservative. Be sure to discuss this with the landowner.

Water Control Structures (WCS) and Pipe

A water control structure (WCS) is anything that regulates the water level in any given water body (e.g., a wetland pool). WCSs can be as simple as a piece of plywood covering a pipe inlet or as complex as a concrete structure with multiple gates, valves, and stop logs. This manual will address commonly used and affordable WCS types, pipe options, pros and cons of different WCS types, and sizing of these structures.

WCS Types – Stop Logs

Stop-log water control structures serve two primary functions. First, they serve as the primary overflow for the wetland pool, and second, they allow for wetland managers to manipulate water levels in order to affect plant communities within the pool. There are several WCS types at the planner's disposal, each of them is well suited for specific circumstances. For wetland restorations, it is

Figure 31b: Recently constructed creative borrow. Note how the layout weaves through existing woody cover to provide deep water next to willows.

advantageous but not necessary to use structures that are "self-managing." Commonly referred to as stop log structures, there are three basic variations: inline stop logs, inlet type stop logs (also called end type), and manhole stop logs.

Stop logs are simple box structures that are affixed to a pipe and used to regulate pool levels, using boards. A track inside the structure holds the boards in place; boards can be added or subtracted as needed. This allows for graduated water-level management (filling, maintaining, or draining) depending on the number of boards installed. Individual boards can vary in size and are commonly placed at heights of 3, 6, and 8 inches. Excess water can flow over the weir (top board) and out, thus maintaining a constant level. Water levels can be raised or lowered by simply adding or removing boards. Boards are made from PVC, wood, metal, and other materials. A variety of pipe materials (PVC, steel, etc.) can be used, although pipe type must be specified at the time of ordering.

INLINE STOP LOG

Inline stop logs can be constructed from materials such as PVC, steel, or fiberglass and all function the same. Buried within the levee or berm, they have an inlet and outlet pipe on either side for draining and filling. PVC and fiberglass versions are commercially available and can accommodate pipe sizes up to 24 inches, while steel versions are often custom built and can accommodate any desired pipe size.

Benefits of inline stop logs include: they are self-regulating, protected from ice and damage from sun (ultraviolet radiation), and they are affordable.

Shortcomings of PVC and fiberglass types are potential fire and machinery damage to exposed portions. This can be offset by surrounding the structure with a rock blanket; however, this adds cost and can be logistically difficult in some restoration settings. Steel versions are not at risk from fire but are susceptible to damage from machinery and are subject to corrosion over time. Also, PVC types should be avoided in favor of steel or fiberglass if being installed in locations with fill heights that are 5 feet or greater. In these situations, shrinking and swelling of soil material can cause shape distortion, making manipulation of boards difficult. PVC types should also be backfilled by hand to avoid damage and/or shape distortion during installation.

Figure 32a: Inline PVC type WCSs are popular choices for water level management. This one is fitted with an internal flap gate which occupies the top board position.

Figure 32b: An inline PVC type WCS prior to installation.

As a rule, avoid the use of stop logs greater than 6 feet in height. Manipulation of structures exceeding this height can be problematic due to pressure on the sides from earthfill as well as maintenance issues arising from simply being deep. If survey information calls for WCSs greater than 6 feet, simply install the box at a higher flowline elevation to reduce the overall height of the stop log.

All inline WCSs are vulnerable to animal damage or activity, primarily from clogging by beavers and muskrats. Overall, however, these are excellent structures for use in shallow wetland restorations.

INLET TYPE (END TYPE) STOP LOG

End type stop logs are functionally equivalent to inline types and are mounted to the end of a pipe, usually on the pool side. They can be susceptible to damage from ice or flood-borne debris because they are free-standing and unprotected by earthwork. In addition, if installed on the pool side, they can float due to excess buoyancy. This can easily be overcome by "strapping" the WCS, using stakes,

Figure 33: Inlet type WCSs, also known as flashboard risers, are attached to a pipe on the pool side of the berm.

Figure 34: Round concrete manhole WCS prior to installation.

posts, or other anchors and wire, cable, etc., to prevent floating. Animal activity around these stop logs is common and will require you to perform maintenance. Finally, because end types are typically installed pool side, access can be difficult. A walkway or dock may be helpful. Regardless, like inline stop logs, end types are good WCSs for shallow wetland developments.

MANHOLE TYPE STOP LOG

Manhole stop log structures are fabricated using a concrete manhole (square or round) and are essentially identical to other inline types except they are larger and more durable. Their large size allows for easy access into the structure and considerable weir length, making them ideal for use in areas where inundation from floods is common, in large pools, or in pools that experience significant upland runoff. They are compatible with any pipe type and, as mentioned above, extremely durable, withstanding damage from fire and machinery. Limiting factors include cost, labor for track/slide fabrication, and weight — they are heavy, requiring larger equipment for installation. Like all inline stop logs, maintenance is required to offset animal activity.

WCS Types – Other

Other WCS types that are not self-managing include flap gates, screw gates, and slide gates. These WCSs are useful in many settings but are typically manipulated manually.

FLAP GATES

A flap gate is a WCS that is designed to allow water flow either in or out while preventing flow from the opposite direction. Fitted on the end of a pipe, flap gates are typically used in wetland restorations as intake pipes. They are not well suited as drain structures in a restoration or water management setting. When used as an intake structure, water enters and flows through the pipe as flood waters rise, then, as waters recede, gravity and head pressure close the gate, preventing water loss. When used in wetland restorations, flap gates should be a watertight variety to prevent leaking. Since flap gates are often installed at low elevations, there is a risk that debris can prevent the gate from sealing, which could result in draining of the pool.

Figure 35: Flap gates, like the one pictured here, are often used to allow flood waters to enter a wetland pool prior to the overtopping of berms.

Figure 36: Slide gate with a built-in flap gate.

SLIDE GATE

Slide gates are simple WCSs that are fitted on the pool side end of a pipe. They are ideal for use in wetland pools that are very shallow (less than 1 foot in depth). They must be manually operated and, like end type stop logs, are subject to damage from ice, fire, and machinery. Equipped with one board that slides up or down in a track, slide gates may be opened or closed to allow water in or out.

SCREW GATE

Typically constructed of cast iron, screw gates operate in much the same manner as a slide gate, except the "gate" is mounted to a threaded rod and raised or lowered using a wheel. Screw gates are watertight. Different ratings exist depending on the type of water pressure the structure is subject to (e.g., pool side = external pressure, or water through the pipe = internal pressure). Like any structure mounted at the end of a pipe, access can be difficult without a constructed walkway. Another version of this structure is the screw/flap gate, which combines the two structures, allowing for both automatic water intake and manual drain capabilities.

Pipe

The most common types of pipes used in wetland restorations are SDR 35 (PVC), corrugated metal (CMP), and smooth steel pipe (SSP). In some instances, corrugated plastic pipe can also be used. Typical diameters used are 12", 15", 18", and 24".

For planning purposes, a general guide for sizing pipe diameter follows. Keep in mind that this guide is for drain times only and does not take into account runoff from upland sources.

0–40-acre pool: 12"

40–60-acre pool: 15"

60–80-acre pool: 18"

>80-acre pool: 24"

Use site-specific and design criteria to determine the actual pipe diameter. Drainage area, draw-down time, and height of water out both the primary and auxiliary spillways, all guide this determination. Regardless of design criteria, a 12-inch diameter is the minimum, based upon maintenance of the structure and pipe.

SDR 35

SDR 35 pipe is often the pipe of choice for wetland restorations. Available in a variety of pipe diameters, it is relatively easy to install and cost effective, although prices can fluctuate wildly with oil prices. Care should be taken when backfilling to avoid pipe damage, and exposed sections of pipe are subject to damage from fire and UV radiation. Life expectancy of SDR 35 is more than 30 years.

Figure 37: A screw gate mounted to a concrete headwall.

Figure 38: SDR 35 pipe is relatively lightweight and easy to install.

SMOOTH STEEL PIPE

Smooth steel pipe (new or used) can be used in wetland restorations and is extremely durable. New pipe has a life expectancy of 30 years or longer but is susceptible to pitting and corrosion, depending on soil moisture and type. Installation is more difficult than SDR 35 due to its weight, and welding may be needed if long lengths are required.

CORRUGATED METAL PIPE (CMP)

Corrugated metal pipe (CMP) has long been used in wetland restorations because of its availability and relatively low cost. It comes in a wide range of diameters and is relatively easy to install. Individual pipe sections are joined together using bands, which can be problematic in some conditions. In addition, joints may require sealing with tar or another similar substance from the inside (only on large diameter). It should be noted that due to its life expectancy (15 years), some financial assistance programs do not allow for CMP use.

Figure 40: Corrugated metal pipe (CMP) being fitted with a screw gate.

CORRUGATED PLASTIC PIPE (N12)

Corrugated plastic pipe can be useful in restorations where funds are limited. This being said, it should be used as a last resort. Durability and *buoyancy* are key issues with corrugated plastic pipe.

Figure 41: Corrugated plastic pipe (N12) installed in a berm. Buoyancy is an issue with this pipe due to the hollow corrugations. This pipe has been strapped between two posts to prevent floating.

Figure 39: Smooth steel pipe installed in an existing berm.

Special Considerations

In some instances, it may be desirable to add special protection to WCSs and pipes in the form of rock blankets and trash racks or animal guards. Rock blankets protect WCSs from fire and prevent damage from burrowing animals. Six-inch rock, at a minimum, is generally used for this application.

Trash racks and animal guards are structures that prevent clogging from debris or animal activity. A trash rack is typically constructed over the inlet portion of a pipe using wire panels and posts. Animal guards are commercially available as fabricated wire structures that are inserted into the pipe outlet to prevent animal entry and clogging. Both trash racks and animal guards can prove to be beneficial but require maintenance. A downside to trash racks is they can serve as a platform for beavers and muskrats to build upon, resulting in reduced flow; however, they are still very effective at preventing debris from entering a pipe or WCS.

Figure 42: This constructed trash guard is designed to prevent debris and animal activity from obstructing the WCS and pipe.

Vegetation Establishment: Natural Regeneration, Plantings

The goal of wetland restorations is a functioning wetland with a diverse, native plant community. In many instances, simply restoring the hydrology will be enough to stimulate an already existing seed bank or source, resulting in the desired wetland vegetation. This is referred to as natural regeneration. There are times, however, especially when working with prairie habitats or hardwood timber stands, when plantings or seedings will be necessary to achieve the desired outcome. Other instances where seeding or planting is required is when vegetation is established on constructed infrastructure, such as berms. This is referred to as Critical Area Seeding by the NRCS and will be discussed in more detail later.

Plant composition in wetlands is dictated by the wetland's hydroperiod, which in short, is the degree of seasonal flooding and/or soil saturation. For the purposes of this manual, wetland types will be simplified into two categories: emergent and wooded. Emergent wetlands are dominated by herbaceous vegetation, which, depending on the hydroperiod, will range from annual plant species (moist soil wetlands) to persistent, perennial plant species (emergent marsh species such as cattails). Wooded wetlands can include bottomland hardwood stands (dominated by oak/hickory species); early successional timber stands, also known as "riverfront forest" (dominated by early successional species like cottonwood and silver maple); or shrub-scrub swamp (dominated by buttonbush, willow, etc.). Like emergent wetlands, the hydroperiod of a wooded site will help determine which woody vegetation will ultimately survive. Soil types also play a role in woody vegetation response.

Natural Regeneration

Natural regeneration is a technique that relies on existing seed banks or seed sources to establish native plant communities. In wetland settings, hydrology restoration and cessation of farming are the key triggers for the vegetative response. Typically, no site preparation is required, although timber responses can be accelerated by disking to provide a "mudflat" situation. Generally, naturally regenerating plant communities will begin as early successional species and transition to perennial or climax communities over time. This is by far the most common method of vegetation establishment.

Seeding of Native Herbaceous Habitat

When a specific habitat is desired but the area lacks a naturally occurring seed source, planting is required. This is especially true for native grassland plant communities and rare, regionally significant communities such as river cane. Plantings within wetland pools and/or on adjacent upland and buffer areas will target grassland birds and/or pollinators. Site preparation, either mechanical or chemical, is generally required. Planting is achieved by drilling or broadcasting. Native seed mixes are readily available commercially in Missouri. Select a suitable mixture of grasses and forbs with local ecotype species if possible.

The seeds of some species, such as prairie cordgrass (*Spartina pectinata*), are often unavailable or extremely expensive, making it more efficient to establish them vegetatively. This method involves the planting of rhizomes or plugs to establish the desired species. You can add diversity either through a companion seeding or through natural regeneration. Depending on the existing ground

Figure 43a: Natural regeneration of perennial, herbaceous vegetation. The dominant vegetation in the photo is bur-reed, which provides excellent nest cover for several secretive marsh birds, including American bittern, a species of conservation concern in Missouri.

Figure 43b: Natural regeneration of nodding smartweed and wild millet, annual plants that are highly desirable for migrating waterfowl.

Figure 44: Planting native warm-season grasses in an upland landscape.

cover, mechanical or chemical site preparation may be required prior to planting.

In rare instances, native herbaceous communities can be established through mulching. Mulching requires haying an existing and nearby quality native herbaceous community site and spreading that hayed material (mulching) onto a tilled seed bed, followed by cultipacking, or rolling, the mulched area to crush clods, remove air pockets, and provide a firm seed bed with good seed-to-soil contact. Logistics are critical when using this method. Timing of cutting and baling must occur when the desired species are going to seed. Since the cut vegetation is still relatively green, bales must be transported and spread within 24–36 hours to avoid damaging the seed by heating. Therefore, choose seed source sites that are relatively close to the area to be planted. Use multiple cuttings to capture various species as they go to seed, and take care to exclude areas that contain undesirable or invasive species.

Due to the cost of plantings, pay close attention to the location to be seeded and the potential hydrology of that site. Too much or too little water, depending on species selection, could result in a failed seeding.

Establishing Bottomland Hardwoods

When a natural seed source is unavailable, a good option for establishing hardwood trees is to plant seedlings. Typically for restoration practices, two seedling types are used: container seedlings and bare root seedlings, both of which are commercially available.

Container seedlings are a relatively new concept in which the fruit of a selected species is germinated and grown in containers with screen bottoms. As root growth emerges from the screen, roots air prune and branch out from the pruned location. Roots continue to grow and branch until a mass of roots is established and the seedling is ready for planting.

Because the air-pruned root system can better absorb water and nutrients from the soil, container trees are considered an accelerated growth seedling and are a good choice for establishment, especially in areas where

Figure 45: An example of prairie cordgrass that was established using plugs. Note the diversity of other species that were allowed to naturally regenerate between the established clumps.

Figure 46: This patch of prairie cordgrass was established through mulching.

frequent and deep flooding is common. Site preparation is often required prior to planting, and maintenance of the planted area can at times be desirable but not required. Allowing natural regeneration of pioneer tree species within the planting can add diversity and improve tree form as seedlings grow. The rate and spacing for planting seedlings are dependent on the desired outcome and up to the planner. A rate of 40 trees per acre is common. Planting is almost always by hand. Container seedlings can be more costly than bare root seedlings.

Bare root seedlings are established from seeds planted in the ground. Seedlings are then dug up and bundled for distribution. Consisting primarily of a tap root and short stem, bare root seedlings are usually planted at a rate of 302 trees per acre and can be planted by machine or by hand. This method has been the standard for decades. Site preparation is typically required and maintenance after planting is optional.

Some hardwood species, namely oaks, can be direct seeded. Although not a commonly employed method, direct seeding of acorns or other hardwood fruit can be an effective method of establishment. A primary challenge is locating an adequate seed source that is commercially available. If possible, local ecotype seed should be used. Site preparation is typically required.

Critical Area Seeding

Critical area seeding refers to vegetation establishment that occurs on infrastructure such as levees, floodways, and berms. Because these seedings are meant for erosion prevention rather than habitat, selected species can be native or nonnative, although native plants are preferred if they provide adequate erosion control. Species that have invasive tendencies, such as reed canary grass (*Phalaris arundinacea*), should *never* be used in a wetland restoration capacity. Common species used in critical area seedings include switchgrass, fescue, brome, and/or red top. Consider flood frequency, depth, velocity, and duration, as well as the existing or expected water current, when selecting species to be planted. Site preparation and fertilization are required.

Refer to NRCS Standards and Specifications, Conservation Practice Standard 342–Critical Area Planting.

Invasive Species

Because wetland restorations are often on land that was previously cropland and are subject to flood-borne seeds, they can be plagued by invasive species, such as Johnson grass, purple loosestrife, and phragmites. Pay close attention to off-site and upstream plant communities as a clue to what may lie in store. If invasive species are present, your restoration plan may need to include control or eradication measures.

Enhancing Existing Wetlands

Some of the most difficult wetland designs to develop are those that involve enhancing existing wetlands. Existing restorations will often be wetter than normal, pre-existing conditions. These wet conditions coupled with developing and/or mature existing wetland vegetation can make surveying difficult. Site preparation may be needed to achieve an accurate survey. Furthermore, additional site preparation may be required to facilitate construction.

The decision to enhance an existing restoration usually revolves around some type of change. You may wish to:

- Incorporate a new restoration philosophy or improve an outdated design.
- Reduce or eliminate chronic damage from flooding or animals.
- Take advantage of, or react to, watershed changes.
- Respond to changes in management or restoration objectives.
- Enhance or add microtopography.
- Provide species-friendly water depths.
- Provide additional diversity through plantings.

After the decision to enhance the wetland has been made, a primary consideration is what to do with the existing infrastructure. You have three basic options: keep it and use it, replace it, or remove it, or a combination of these. Carefully examine the condition of existing infrastructure before deciding whether to use it. If the location is acceptable and structural integrity is sound, then it is a good idea to use it to save costs. It may be necessary to improve existing infrastructure by altering top elevation, top width, and/or slope. Depending on the age of the original design, it may be more advantageous to replace and/or relocate infrastructure to achieve contemporary restoration goals.

Piecing It All Together

Because the conceptual design is what will ultimately end up on the ground, it must include all pertinent information that will be needed by the design staff. This can be achieved on a copy of the survey or in a GIS format. GIS formats can be advantageous as the shapes and positions of features can be imported directly into design software and will *not* have to be recreated by design staff. This eliminates the chance that design staff could inadvertently alter the positioning, which could lead to a loss of desired impact.

Along with physical location of features, be sure to include the following information:

Earthwork – Fills

- Top elevation
- Top Width
- Side slope ratios

Earthwork – Borrows

- Bottom elevation (if there is a specific one)
- Bottom width
- Side slope ratios

WCS/Pipe

- Type of WCS
- Weir length (if needed)
- Height of WCS
- Waterline or pool elevation
- Type of pipe
- Diameter of pipe (This can be determined by the designer depending on drainage ratios, draw-down time, maintenance of infrastructure.)
- Trash rack/animal guards

Seedings

- Locations of seedings or plantings
- Seeding sheets with desired species and grass-to-forb ratios
- Tree planting plans

(Seeding sheets and tree planting plans should be completed by the biologist/planner and attached to the final design.)

Other

- Labels that identify each feature (i.e., levee, spoil, borrow, etc.)
- Notes, questions, and/or topics that may need clarification/discussion

Finally, be sure that the conceptual design represents a product that is feasible, constructable, and affordable.

Consultation/Communication with Design Staff

Something that cannot be overstated is that once the conceptual design is complete and delivered to the design staff, it is crucial that the planner/biologist remain in close contact during the design phase.

Alterations to the conceptual design are quite common for a host of engineering reasons. Keeping an open dialogue with the designers will prevent or minimize any loss of planned function or habitats that could occur from these design alterations. Work together as a team to develop a final design that encompasses the "spirit" of your vision and that retains the wetland functions and habitats necessary for a successful restoration.

Section 4: *Final Design and Construction*

The final design is the formal version of the conceptual design and is the blueprint of the planned wetland restoration. It contains the plans that link the planner, designer, and construction contractors together during the construction phase. From this document, quantities (cubic yards of earthwork, feet of pipe, etc.) will be derived and costs will be estimated. It will also be the document that the construction contractor refers to during wetland construction.

Final Design Components

Included in the final design are a cover page, plan view, cross sections, seeding information, standards and specifications, and any pertinent permits needed for construction.

Cover Page

The final design document begins with a cover page. Included on the cover page are the project name, program name/contract number (if applicable), location (section, township, range, latitude and longitude, map insert, and county), table of contents, quantity summary, and a reminder to contact the Missouri One Call System (other states may be different). The cover page serves as a quick reference of the entire project. (See Appendix D, page 47, for an example of a cover page.)

Plan View

The plan view is an overall summary of the design which shows all design components and their locations. It is helpful to provide two versions of a plan view: one overlaid on an aerial photograph and one plain. All design components should be labeled so they may be referenced in detail in subsequent portions of the design. TBM locations should also be shown on the plan view along with their elevations and point coordinates. (See Appendix D, page 48, for an example of a plan view.)

Quantity Tables and Summary

Some designs will include a quantity table and/or summary in addition to the quantity information provided on the cover page. Quantity tables list each labelled component with the specific quantity amount. This table can be beneficial for contractors as they plan construction logistics and strategies. (See Appendix D, pages 49–50, for an example.)

Cross Sections

A cross section is a general view or drawing of a design component (i.e., levee or WCS) depicting a "slice" of that component. Information included on a cross section includes borrow details, levee slope, top elevation, top width, WCS top elevation, waterline, pipe size and length, flowline of pipe (inlet/outlet), plus construction notes specific to each component. Projects with multiples of the same component (e.g., three or four levees or borrow areas) may have one general cross section accompanied by a table outlining details for each component. (See Appendix D, pages 49–51, for an example.)

Seeding Information

Information pertaining to seeding should always be included in the final design. When developed using an NRCS program, such as WRE, all pertinent seeding information (seed type, seeding dates, site preparation, fertilizer, seed amount, and cover crop) can be assembled on one document and will follow conservation practice standards and specifications.

Construction/Seeding Standards and Specifications

Most wetland restoration projects are designed and completed using various NRCS standards and specifications. Each state may use different specifications. To find seeding standards and specifications for Missouri, go to the Field Office Technical Guide (FOTG) section for Missouri on the NRCS website. The most used practices are 657–Wetland Restoration, 587–Structure for Water Control, 342–Critical Area Planting, 327–Conservation Cover, 612–Tree/Shrub Establishment, and 420–Wildlife Habitat Planting. (See Appendix F, page 56.)

Permits

Wetland restorations often involve activity that is regulated by federal, state, or local governments. Common regulatory agencies are the U.S. Army Corps of Engineers (COE), United States Department of Agriculture (USDA), Missouri Department of Natural Resources (MODNR), Federal Emergency Management Agency (FEMA), and other state and local governments. This manual will not go into detail regarding permits, but instead will touch on the laws and associated permits for regulating activity in wetlands and floodplains.

- **Clean Water Act (CWA) — Regulating Agency: COE**
  In 1972, Congress passed the CWA which provided protection for the nation's waterways. Section 404 of the CWA refers to activity in designated wetlands and regulates the placement of fill within those wetlands, requiring a permit for such activity. This is a common permit associated with wetland restoration due to the construction of berms. In order to provide a streamlined process for common activities, like wetland resto-

ration, the COE has developed "Nationwide Permits (NWP)." NWP 27 Wetland Restoration is a commonly required permit for wetland restorations occurring in non-cropland areas.

Section 401 of the CWA regulates discharge of pollutants (including sediment) into the nation's waterways. Often, NWP 27 will include 401 Water Quality Certification. MODNR is the administrating agency in Missouri.

- **Food Security Act of 1985 (FSA) – Regulating Agency: USDA**
  The Food Security Act of 1985 regulates the conversion of wetlands for agricultural purposes. Wetland types regulated by this law include prior converted wetlands, farmed wetlands, and farmed wetland pastures. Although prior converted wetlands (PC) are not generally affected by wetland restoration activities, some documentation may be required. When working with PC, different COE districts have different views regarding the need for a 404 permit. Be sure to check with the district that has jurisdiction over the area you're working in. Finally, previous violations of the FSA could have implications regarding eligibility for certain wetland restoration programs.
- **No-Rise Floodplain Certificates – Regulating Agency: FEMA**
  No-Rise Certifications may be required when development activities within the 100-year floodplain could increase flood heights. To obtain a No-Rise Permit, you may need an engineering analysis showing that the proposed activities will not cause flood levels to increase. Although commonly associated with urban counties, (e.g., St. Louis, St. Charles, Lincoln, Pike, and Boone counties in Missouri), No-Rise Floodplain Certificates are becoming requirements in many rural counties as well. Be sure to contact county officials regarding this matter for clarification and/or needs.

Construction Equipment

Nearly all wetland restoration projects involve some degree of earthmoving using heavy machinery. Therefore, it is vital that you have a full understanding of the uses, capabilities, and limitations of commonly used construction equipment. Failure to do so could result in a project that is logistically unrealistic, which, in turn, could result in cost overruns and/or project abandonment.

Bulldozers, tractors/scrapers, track hoes, skid-steer loaders, and tractors with seeding/tillage equipment are all equipment types commonly associated with wetland construction.

Bulldozers

Bulldozers are track machines with large blades on the front for pushing soil or other material. Although an effective tool for berm construction, bulldozers have a key limitation – the distance that material can be moved. If borrow locations exceed 200 feet from the placement destination, a bulldozer is no longer cost-effective. However, bulldozers are ideal for many other wetland restoration roles, including placement of hauled fill, compaction, and finishing earthwork.

Tractors with Scrapers

The preferred machine for today's wetland restoration is a large horsepower tractor pulling a scraper or "pan." The pan acts as a scoop to load soil material, which can then be hauled long distances for placement. Scrapers can also be used for finishing and can be used effectively for compacting earthfill. Wet working conditions can limit the performance of this equipment, as loaded material will not be ejected or deposited freely. In addition, wet conditions can create mobility issues, such as getting stuck.

Figure 47: Bulldozer being used to "finish" a constructed berm.

Figure 48: Tractor pulling a scraper. Today, this is the go-to earthmoving method used in wetland restorations because it allows for borrow material to be obtained from across the entire project.

Track Hoes or Excavators

A track hoe is a common earthmoving machine that is equipped with a large, toothed bucket for digging. The bucket, which is mounted on an arm or "stick," can be used to remove and place material in small areas. Commonly used for WCS installation, track hoes can also be used in wet situations to load material into scrapers so it may be hauled greater distances. However, using a track hoe in this manner is typically a last resort because it is inefficient, increasing work time as the same unit of material must be handled twice. Other uses for track hoes are levee removal, and/or removal of woody vegetation for site preparation. Track hoes work well in wet conditions but are not well suited for moving material farther than the reach of the "stick."

Rubber-tired backhoes are the smaller cousin of the track hoe and operate in much the same manner. Limitations include a smaller bucket and poor operation in wet conditions.

Figure 49: Track hoe. Typically used for pipe installation or other targeted excavations, here it is being used to downgrade an existing levee where access by more traditional equipment was prohibited by wetness.

Figure 50: A skid-steer loader can be a very handy piece of equipment for wetland restorations; however, its capabilities are limited by its size.

Skid-Steer Loaders

Skid steers are small, wheeled or tracked pieces of earthmoving equipment that are extremely versatile as they can be fitted with a wide variety of buckets and other attachments. Although very handy, their use in wetland restoration is limited due to their small size. They can be useful in back filling around pipes and setting WCSs. Compaction ability is sometimes inadequate due to their small size and weight.

Tractors with Tillage/Seeding Equipment

Standard tractors and tillage/seeding equipment are commonly used in wetland restorations during seeding operations. Grass drills, spreaders, disks, harrows, and cultipackers are all necessary for establishing vegetative cover on constructed berms and levees.

Figure 51: Drilling seed is the preferred method for establishing grasses and forbs.

Preconstruction Conference and Stakeout

Before construction activities begin, it is necessary to hold a preconstruction conference and to stake or lay out the project. The preconstruction conference is a meeting (typically held on-site) in which the design, construction standards and specifications, and seeding requirements are all reviewed in detail. Mandatory attendees include the designer and construction contractor, but it is desirable for the landowner, planner, and equipment operators to also be present. A preconstruction checklist that outlines all pertinent construction issues is available to provide consistency and ensure all topics are covered. Upon completion of the conference, all attendees should sign the checklist to confirm concurrence. In addition to design details, potential issues such as troublesome soils, cultural resources, utilities, and equipment repair and/or maintenance should also be addressed. (See Appendix E on page 54 for an example checklist.)

Staking out (laying out) the project is a critical step before construction activities commence. During this step, structures, reference points, and elevations are marked with stakes to guide construction. At a minimum, levee and berm centerlines, toes (outside boundary) of spoils and borrows, WCS locations, and TBMs should be marked. Staking materials should be well marked, and clearly visible and well suited to the elements. Depending on the time of year, the staked areas may require maintenance. Commonly used staking materials include wooden stakes/lathes, flags (multiple colors), iron pins, flagging tape, and fluorescent paint.

Staking Levees/Berms

Typically levee and berm locations are marked by identifying the centerline with a wooden stake (normally 4–5 feet in height). At a minimum, stakes should be placed at intervals of 200 feet, but 100-foot intervals are preferred. Also, all curves in the alignment should be identified. The following information should be written on each stake with a permanent marker:

- **Levee Stations**
  Mark the footage of the levee from beginning to end. Place stakes at 100-foot intervals and record each station as 1+00, 2+00, etc. The identifying levee number should also be included. For example, if the station is at 125 feet, the station is recorded as 1 + 25.
- **Cut/Fill Heights**
  Also include the amount of cut and/or fill at each station. This can be written in feet to the tenth decimal. Whether or not to include this information is up to the individual; however, providing this figure will aid the contractor in determining the outer limits of the levee footprint. For example: Station 1+00 1.5' fill.
- **Other**
  Additional items that should be marked include levee transitions such as floodways (include station, new slope, top width, and top elevation if affected).

Staking Borrows and Spoils

Borrow and spoil locations are most easily marked by using flags to delineate the outside perimeter. Different colors should be used to identify borrow from spoil. In instances where borrow and/or spoil have uniform dimensions, then simply marking the centerline of each may be sufficient.

Staking TBMs

Temporary benchmarks should be identified with the following information: TBM number, point coordinates, and TBM elevation.

Staking WCSs

All water control structure locations should be marked with the following information: WCS number, station, and waterline elevation. Flowline of pipe and bottom elevation of WCS can also be included if desired.

Construction Monitoring and Checkout

Once the contractor is on-site and work has begun, it is a good practice to make regular visits to monitor progress, accuracy, and workmanship and to answer any questions the contractor may have. Monitoring should be more frequent in the beginning and can drop to one visit per week as you become comfortable with the contractor's abilities. Be sure to take some sort of instrument (laser level, etc.) to check elevations of completed work. Construction is a major undertaking and unchecked mistakes can be costly.

It is of major importance to be on-site when the contractor is setting WCSs to ensure they are installed properly and at the correct elevation. In addition, be sure to be on-site when construction begins and review all design details with the equipment operators. Encourage the contractor and operators to call immediately if they have questions.

Upon completion, the project will need to be checked and certified that all components were installed to the standard and specifications and that all quantities (cubic yards of earthfill, feet of pipe) were installed or moved. Typically, this task is performed by the designer or someone with job approval authority.

A Word on Wetland Management

There are many existing publications regarding the techniques of wetland management on private land; therefore this manual will offer only a few thoughts on the topic.

First, encourage landowners to focus management resources into areas where they can expect success. Most private wetland owners have limited time and resources to spend on wetland management. Assist landowners in developing achievable management objectives specific to their tract and in understanding the factors that affect that management (e.g., soils, hydrology, and vegetative components). A basic understanding of soil make-up (clay, silt, or sand), the landscape position (backswamp, alluvial fan, stream terrace, etc.), and the conditions under which the soils were developed (grass/prairie, timber, etc.) will certainly point the way to more efficient management of the wetland. Here's an example:

- *Situation:* A landowner has a waterfowl interest, and the wetland soils are comprised of 60% Wabash (silty clay, grassland soil, floodplain step) and 40% Nodaway (silt loam, timber soil, alluvial floodplain/stream levee). The site floods often from an adjacent stream.
- *Management Recommendation*: The Nodaway portions of this tract will almost always tend toward woody vegetation, whereas the Wabash portions will lean towards herbaceous vegetation. Given this situation, the manager will be wise to focus management resources on the Wabash area, simply because this area lines up with his/her objectives naturally. Trying to force an herbaceous plant community on the Nodaway soils may be possible in the short term but will be unsustainable and costly, because the soil type is better suited for timber establishment.

Second, encourage the landowner to manage by elevation and not by pool or unit. Managing in this fashion and staggering drawdowns over time can increase plant diversity and help preserve soil moisture, making fall flooding easier and more efficient.

Finally, avoid steering landowners in the direction of single species management, most specifically, waterfowl. Good, ecologically sound wetlands make good waterfowl hunting areas; however, good waterfowl hunting areas are not always good wetlands. It is easy to conflate the two, so it's up to you to stress the difference and highlight the benefits of the former.

Conclusion

Wetland restorations are not, and certainly do not have to be, complicated. In fact, the best and often most successful restorations are the simplest.

Throughout the planning process, take care to keep your restoration goals in sight.

- Set priority habitats, watershed objectives, target species.
- Restore the site to the historical conditions to the extent practical.
- Reintroduce landscape features.
- Work with the existing topography and do not "overpower" it.
- Provide floodplain connectivity where possible.
- Recognize the capabilities of a site and plan accordingly.

Keep in mind that wetlands come in many forms and no two restorations will be the same. Every site is unique.

Under natural conditions wetlands exhibit a high degree of variability when it comes to wetness. Some will be wetter, some drier, etc. It's our job as planners to recognize this variability and strive to include it to the extent practicable on every restoration. Doing so will provide the species richness, both plant and animal, that we are shooting for.

Finally, remember to always plan for a result that is achievable. In other words, work with the strengths of the tract and never attempt to force the land to do something it can't. Ultimately, success or failure of any restoration is in the eyes of the beholder, but as long as we work with nature and not against it, it is impossible to fail when the beginning condition was a soybean field.

The art of restoring wetlands will continue to evolve and improve as technology advances, just as it has over the last 30 years. Utilize this manual as a starting point and develop your own style relative to the geographic area in which you work. Most importantly, never be afraid to try new methods.

Appendix

Appendix A: Web Soil Survey Example

Appendix A: Web Soil Survey Example, continued

Soil Map–Carroll County, Missouri (Soil Exercise)

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP UNIT LEGEND

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
13507	Bremer silty clay loam, 0 to 2 percent slopes, rarely flooded	42.9	27.2%
36031	Nodaway silt loam, 0 to 2 percent slopes, frequently flooded	25.1	15.9%
36046	Wabash silty clay, 0 to 2 percent slopes, occasionally flooded	85.1	53.1%
36116	Zook silty clay loam, heavy till, 0 to 2 percent slopes. occasionally flooded	4.8	3.0%
Totals for Area of Interest		**157.8**	**100.0%**

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Carroll County, Missouri
Survey Area Data: Version 24, August 27, 2021

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

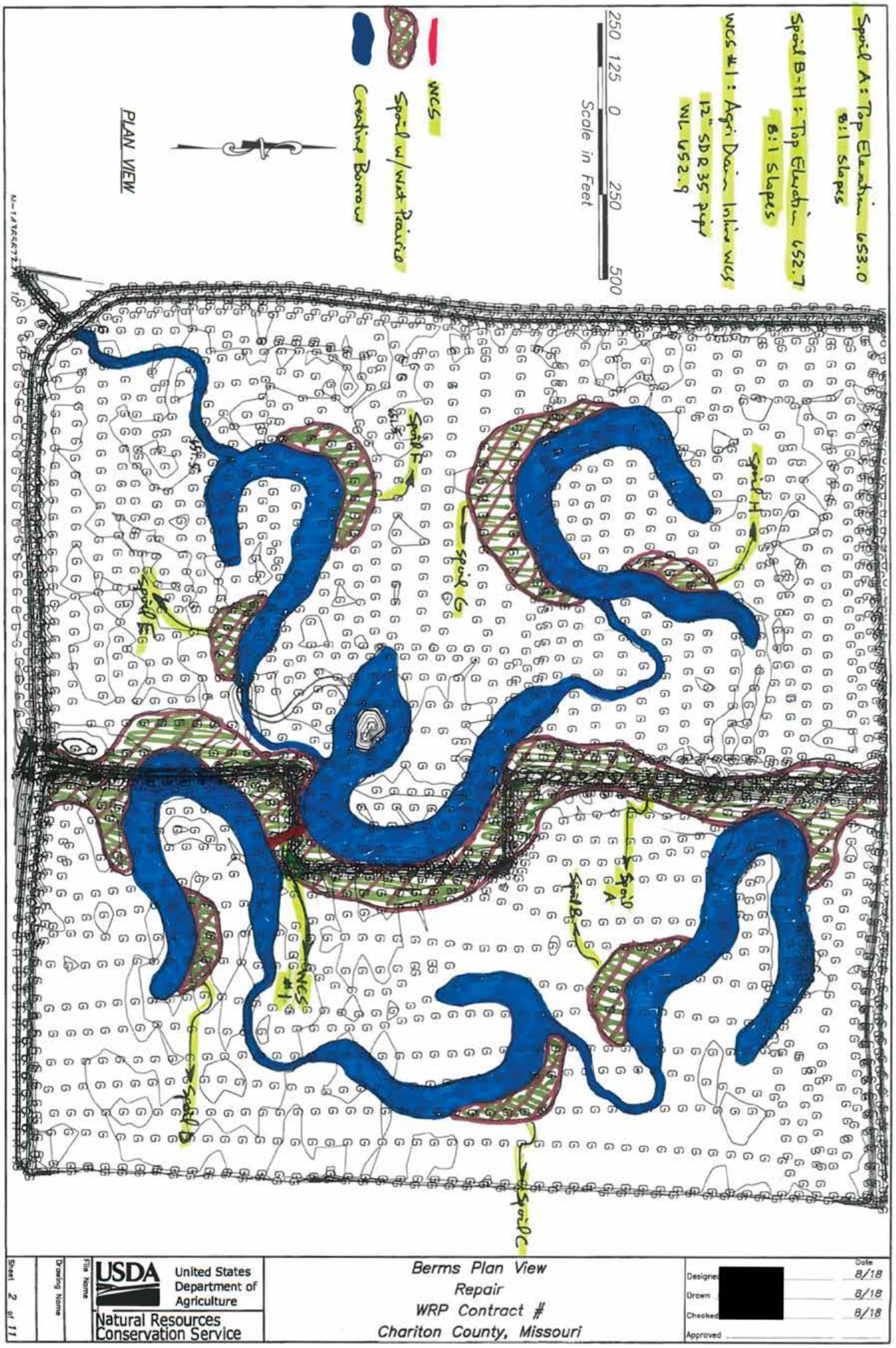
Date(s) aerial images were photographed: June 1, 2012–June 14, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Appendix B1: Topographic Survey Example

Appendix B2: Topographic Survey Example

Appendix C: Conceptual Design Example



Appendix D: Full Final Design

Personal identification information has been redacted from these pages.

[redacted] COUNTY MISSOURI

TWP [redacted] * RNG [redacted] * SECTION [redacted]

TWP [redacted] * RNG [redacted] * SECTION [redacted]

LATITUDE – [redacted]" LONGITUDE – [redacted]"

CONTRACT NUMBER: [redacted]

EASEMENT LENGTH: Perpetual

TABLE OF CONTENTS

QUANTITY SUMMARY TABLE

ITEM	DESCRIPTION	QUANTITY	UNIT
PROJECT	CLEARING LIGHT – WRE	35	AC
BERMS	EARTHFILL	2,585	CY
SPOIL BERMS	SPOIL BERM EARTHFILL	28,390	CY
SPOIL BERMS	GRADING & SHAPING SPOIL BERMS	16.0	AC
WCS	12" Pipe x 24" Wide x 4' Tall Water Control Structure	1	EA
WCS	12" SDR 35 PVC PIPE	140	FT
WCS	24" SDR 35 PVC PIPE	42	FT
PROJECT	TRACKHOE	16	HR
PROJECT	SEEDING	13.6	AC
PROJECT	Existing Tile Line Removal	1,350	FT

IN COOPERATION WITH: USDA NRCS

PROJECT LOCATION

MISSOURI ONE CALL SYSTEM

The excavator is responsible for having all utilities located at the site or on ingress road prior to beginning work. Call 1–800–DIG–RITE (344–7483) or 811 or click www.mo1call.com 3 days before you dig! The landowner shall ensure that the excavator completes the utility locate request.

Date	
Designed M [redacted]	8/19
Drawn [redacted]	8/19
Checked	
Approved	

Cover Page

[redacted]

Chariton County, Missouri

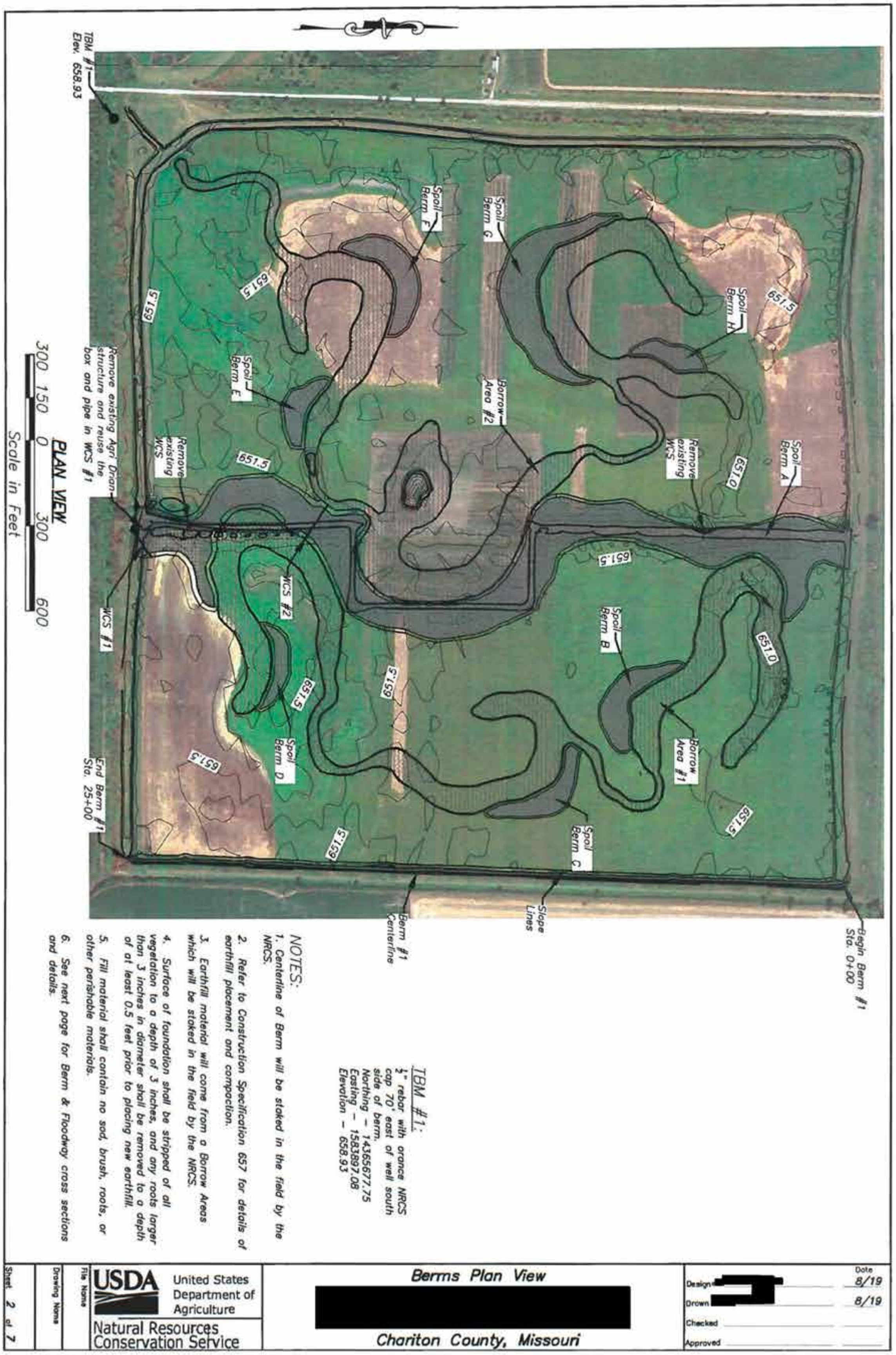
USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name

Drawing Name

Sheet 1 of 7

Appendix D: Full Final Design, continued



BORROW NOTES:

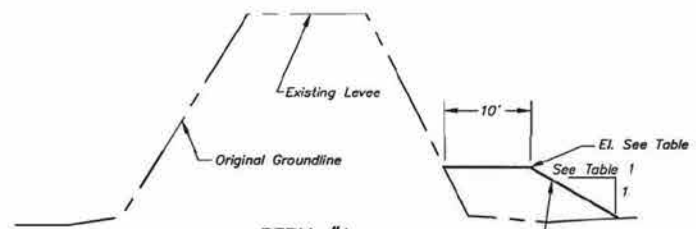
1. Outer boundary of borrow areas will be staked in the field by the NRCS.

2. Borrow areas shall be stripped of vegetation. The vegetation can be used in the back side of the Spoil Berms or for top soil on the Berms.

3. Borrow may be expanded or contracted as needed to yield the required volume of material needed to construct the spoil berm, floodway and berms. Expansion or contraction of the borrow area shall be approved by the engineer and staked in the field by the NRCS.

4. Excavated slopes shall be no steeper than 4:1 unless otherwise shown.

5. If sandy soil is encountered in borrow area contact NRCS.



BERM #1
TYPICAL CROSS SECTION

(Not to Scale)

Table 1 – Berm Elevations

Berm #	Top Elev	Top Width	Station	SideSlope–Pool	SideSlope–Back	Spoil Berm Fill (CY)	Seeding (AC)
1	653.0	10	0+00 – 25+00	8:1	8:1	2,585	1.3
					Total:	2,585	1.3

NOTES:

1. Centerline of Berm will be staked in the field by the NRCS.

2. Toes of Spoil Berms will be staked in the field by the NRCS. Top width will vary and will be determined by projecting the fill slope from the toe location.

3. Refer to Construction Specification 657 for details of earthfill placement and compaction.

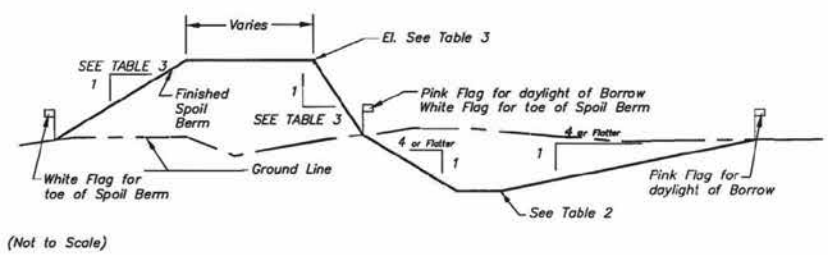
4. If sand or sandy looking material is encountered in any borrow area stop with that borrow area immediately and contact NRCS.

	Date
Design [redacted]	8/19
Drawn	8/19
Checked	
Approved	

Ben Details
[redacted]
Chariton County, Missouri

USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name
Drawing Name
Sheet 3 of 7



SPOIL BERM with ADJACENT BORROW AREA
TYPICAL CROSS SECTION

Table 3 – Spoil Berm Elevations

ID	Top Elev	SideSlope Borrow	SideSlope	Spoil Berm Fill (CY)	Grading & Shaping (AC)	Seeding (AC)
A	653.0	8:1	8:1	19,565	10.3	10.3
B	652.7	8:1	8:1	1,175	0.8	
C	652.7	8:1	8:1	965	0.7	
D	652.7	8:1	8:1	715	0.4	
E	652.7	8:1	8:1	875	0.5	
F	652.7	8:1	8:1	1,460	0.9	
G	652.7	8:1	8:1	3,025	2.0	
H	652.7	8:1	8:1	610	0.4	
			Total:	28,390	16.0	10.3

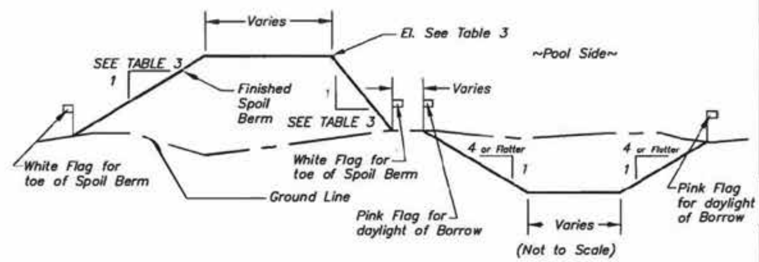
NOTES:

1. Centerline of Berm will be staked in the field by the NRCS.

2. Toes of Spoil Berms will be staked in the field by the NRCS. Top width will vary and will be determined by projecting the fill slope from the toe location.

3. Refer to Construction Specification 657 for details of earthfill placement and compaction.

4. If sand or sandy looking material is encountered in any borrow area stop with that borrow area immediately and contact NRCS.



SPOIL BERM without ADJACENT BORROW AREA
TYPICAL CROSS SECTION

Table 2 – Borrow Area Elevations

ID	Bottom Elev	SideSlope	Available Borrow
1	650.5	4:1	15,050 CY
2	650.7	4:1	14,385 CY
		Total:	29,435 CY

BORROW NOTES:

1. Outer boundary of borrow areas will be staked in the field by the NRCS.

2. Borrow areas shall be stripped of vegetation. The vegetation can be used in the back side of the Spoil Berms or for top soil on the Berms.

3. Borrow may be expanded or contracted as needed to yield the required volume of material needed to construct the spoil berm, floodway and berms. Expansion or contraction of the borrow area shall be approved by the engineer and staked in the field by the NRCS.

4. Excavated slopes shall be no steeper than 4:1 unless otherwise shown.

5. If sandy soil is encountered in borrow area contact NRCS.

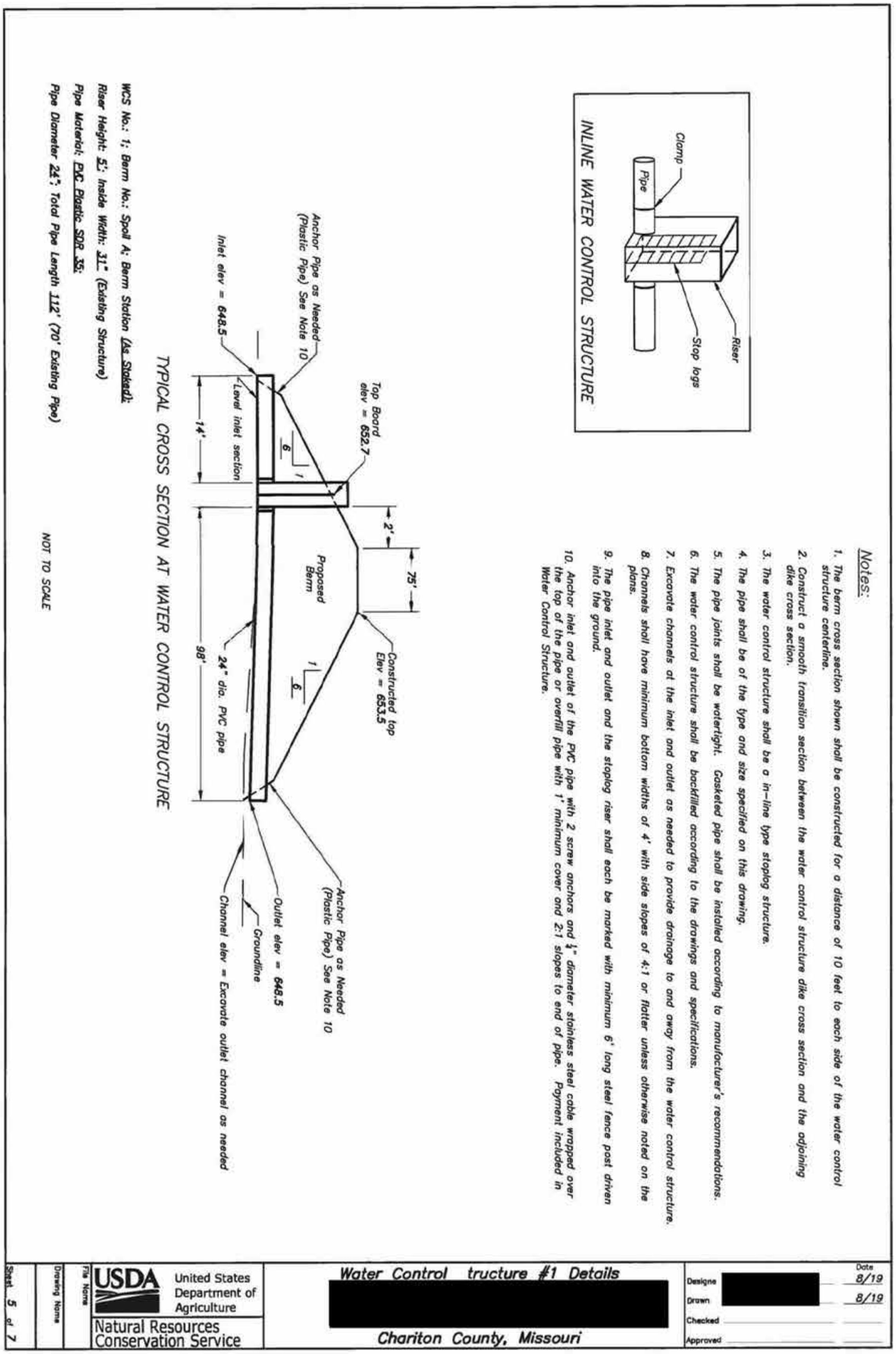
	Date
Designed [redacted]	8/19
Drawn	8/19
Checked	
Approved	

Spoil & Borrow Sections
[redacted]
Chariton County, Missouri

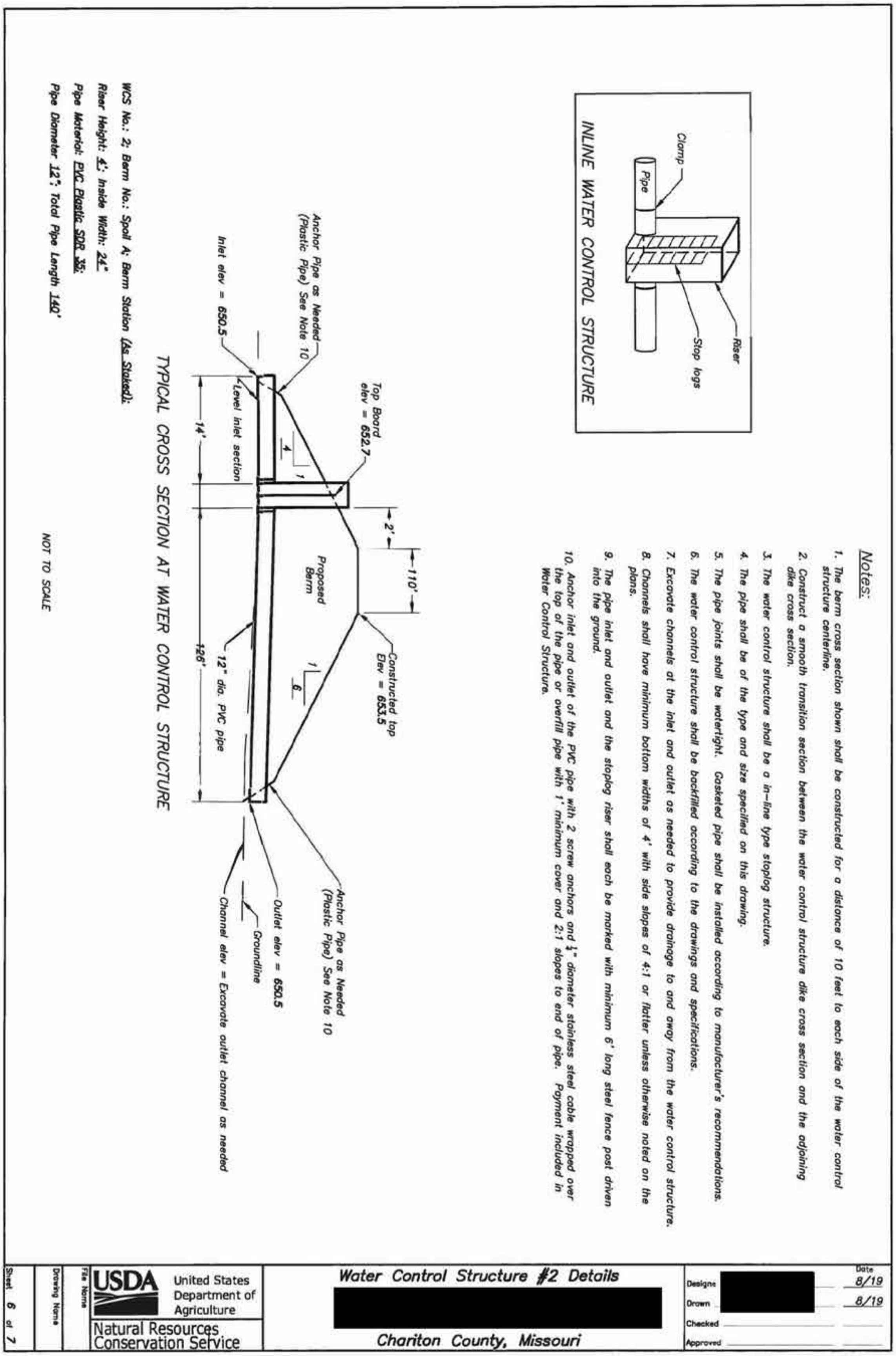
USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name
Drawing Name
Sheet 4 of 7

Appendix D: Full Final Design, continued



Appendix D: Full Final Design, continued



Appendix D: Full Final Design, continued

Appendix E: Preconstruction Checklist for Missouri

PRE-CONSTRUCTION CONFERENCE CHECK SHEET FOR WETLAND RESTORATION

Pre-construction conferences will take place on site between the landowner, contractor and NRCS person with appropriate Job Approval Authority. Check each item discussed, both sides of sheet. Provide a copy for the landowner and contractor.

SAFETY

☐ Easements Secured or permits (Neighbors, Public Road, 404,401.)
☐ MO-1-CALL contacted
☐ Non-member Utilities contacted
☐ Conduct construction according to OSHA requirements

CONSTRUCTION PLANS

☐ Landowner and Contractor provided a copy
☐ Bench mark location(s) and elevation(s)
☐ Layout stake locations
☐ Shape of levee (side slopes, top width, top elevations, seeding)
☐ Emergency spillway location and elevation
☐ Location of Water Control Structure
☐ Water Control Structure Exit Channel
☐ Rock Protection Blanket Around WCS
☐ Pipe and WCS type, wall thickness, straps, height, length
☐ Pipe and WCS back filling (hand tamping or water packing)
☐ Top Soiling
☐ Repair Staging Area and Ingress-Egress Route
☐ Location for spoiling of trees, brush, rocks, debris (habitat mounds, etc.)
☐ Site Cleanup
☐ Trash Racks and Animal Guards
☐ Removal of any old pipes

SPECIFICATIONS

☐ Foundation preparation
☐ Cutoff trench
☐ Borrow area
☐ Moisture content of fill material
☐ Maximum layer of fill prior to compaction
☐ Compaction shall be two passes when soil is at proper moisture No LGP Dozers
☐ Seeding, Mulching, etc.

OTHER

☐ Call NRCS @ (573) 221- 0180 if cultural resources are unearthed and halt construction in that area
☐ Call Utility owner, MO- I-CALL & NRCS if utility is found during excavation
☐ Landowner understands they will be paid based on actual cost not to exceed allowed dollars for that component or practice

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INSPECTION ROLES DURING CONSTRUCTION

It is NRCS role and responsibility to certify components and the entire system when it meets standards and specifications. NRCS may make periodic inspections to determine whether construction meets construction specifications.

The landowner's role and responsibility is to serve as the general contractor (hire, direct and manage contractor's activities), keep NRCS informed of progress, follow federal/state/local laws, zoning regulations, notify utility companies (& MO 1 CALL) prior to excavation, ensure that construction product conforms to the construction plans and specifications and complete necessary forms. It is important that the contractor not make any changes in construction prior to concurrence with NRCS. Work performed or materials that differs from the construction plans and specifications may need to be modified or replaced. The landowner is ultimately responsible for proper construction and maintenance.

It is the contractor's role and responsibility to read and follow the construction plans, keep a set of plans on site, designate a foreman on site, know construction specifications, use materials that conform to the specifications and plans, construct the improvements according to the shape planned, notify MO 1 CALL and utility companies prior to excavation, practice safety at all times, document materials used, notify NRCS of any discrepancies or errors in the plans or specifications and repair improper construction or materials.

Inspection is an important role of NRCS. NRCS needs to inspect certain items in order to be able to certify the structures have been constructed according to plans and specifications. It is the landowner's responsibility to notify NRCS when the site is ready for the appropriate inspection items below. If any item is temporarily covered, the cover (fill) will need to be removed before NRCS can certify correct installation.

- ☐ Core trench prior to backfill
- ☐ Subgrade prior to fill placement
- ☐ Water control structure placement
- ☐ Backfill around pipes and water control structure
- ☐ Moisture condition of fill
- ☐ Unannounced spot check inspections may be performed by NRCS

List of people attending this meeting covering items marked on both sides of this sheet.

Authorized NRCS Employee	Landowner/Operator
Contractor	Date

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Appendix F: Missouri NRCS Standards and Specifications for Wetlands

NRCS Standards and Specifications Commonly Used in Wetland Restoration

(327) Conservation Cover

(342) Critical Area Planting

(420) Wildlife Habitat Planting

(587) Structure for Water Control

(612) Tree and Shrub Establishment

(644) Wetland Wildlife Habitat Management

(657) Wetland Restoration

(658) Wetland Creation

(659) Wetland Enhancement

NRCS standards are available on the NRCS Field Office Technical Guide website at **efotg.sc.egov.usda.gov.** The website allows you to search by state for state-specific standards.

Online Resources

Resources for Synthetic Aperture Radar (SAR) images

FLOOD OBSERVATORY

floodobservatory.colorado.edu

GLOBAL SURFACE WATER EXPLORER

global-surface-water.appspot.com

NASA WORLDVIEW

worldview.earthdata.nasa.gov

THE GLOBAL FLOOD DATABASE

global-flood-database.cloudtostreet.ai

USGS GLOBAL VISUALIZATION VIEWER

glovis.usgs.gov/app

NRCS Resources

NRCS EDIRECTIVES-PART 650-ENGINEERING FIELD HANDBOOK

directives.sc.egov.usda.gov/viewerFS.aspx?hid=21429

NRCS EDIRECTIVES-PART 650-ENGINEERING FIELD HANDBOOK,
CHAPTER 1-SURVEYING

directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=47739.wba

NRCS FIELD OFFICE TECHNICAL GUIDES

efotg.sc.egov.usda.gov

WEB SOIL SURVEY

websoilsurvey.sc.egov.usda.gov/App

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