Wetland Habitat Improvement Project
Robert C. Corby Arboretum and Wildlife Sanctuary
Village of Pittsford, New York

Vernal Pond Wetland built 2,000-years ago

Thomas R. Biebighauser
Wetland Restoration and Training LLC
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Introduction

This plan describes how three vernal pond wetlands may be built in the Robert C. Corby Arboretum and Wildlife Sanctuary in the Village of Pittsford, New York to improve habitat for amphibians and to increase wildlife viewing opportunities.

The wetlands may be built to provide habitat for vernal pond obligate species including the wood frog, spotted salamander, and fairy shrimp. Vernal Pond Wetlands are not found in the Arboretum or the adjacent Erie Canal Nature Preserve.

Vernal ponds would be built to appear and function as natural wetlands. The wetlands would improve viewing opportunities for Mallards, Wood Ducks, Canada Geese, Great Blue Herons, Egrets, Red-wing Blackbirds, painted turtles, spring peepers, chorus frogs, and gray tree frogs.

The vernal ponds would be built shallow with gradual slopes so that students may safely use the habitats for outdoor learning. Flat rocks would be placed near the water's edge to provide children with places to stand while exploring vernal pond life.

Logs may be placed in the vernal ponds to provide birds with perches and turtles with basking sites. Branches may be placed in the wetlands to provide salamander with egg attachment sites.

Compacted soil surrounding the wetlands may be loosened using the rough and loosen technique. A diversity of native plants may be seeded and planted within and surrounding the wetlands to add beauty to the vernal ponds.

The wetland project would improve habitat for pollinators. A diversity of flowering plants may be seeded and planted in and around each wetland to improve the habitat for butterflies, moths, bees, and hummingbirds. Pollinators would also obtain minerals from the moist soil along the edge of the wetlands, and shorebirds would forage on the exposed mud flats.

Detailed specifications are contained in this plan that can serve as a guide in the construction of the designed wetlands. Measures are described for building the wetlands to control erosion and to provide habitat for a diversity of native animal and plant species. The project is designed and shovel-ready, with the author being available to be on the ground directing the implementation of the project.

The author gave a PowerPoint Presentation on Vernal Ponds to community members in the Village of Pittsford on April 18, 2024. Community members learned about the value of vernal ponds and reviewed the locations of the designed vernal ponds during field trips lead by the author on April 19, 2024.

Goal and Objectives

The goal of this project is to improve the environment.

The objectives of this project are to:

1. Provide breeding habitat for frogs, toads, and salamanders.

2. Build naturally appearing and functioning vernal pond wetlands.
3. Provide habitat for a diversity of wildlife and plant species.
4. Improve habitat for pollinators.
5. Reduce the need for future maintenance.
6. Increase wildlife viewing opportunities.
7. Reduce nonnative invasive plant species.

Design Process

Three vernal pond wetlands were designed by the author and Margot Fass on April 18 and 19, 2024. The design process began by examining aerial photos, property ownership maps, and NRCS Soil Survey maps showing the Arboretum. The land area was then carefully examined on the ground to identify projects that could be implemented to meet objectives.

The vernal ponds were designed so they would not affect adjoining property, dwellings, buried utilities, roads, parking lots, or the existing trail system. Each wetland would be built without dams, berms, diversions, pipes, water control structures, or pumps that require maintenance. The wetlands would fill naturally with runoff and precipitation.

Vernal pond wetland construction sites were chosen in forest openings on level areas of land. Building the vernal ponds would not affect existing wetlands. The vernal ponds would be built on slopes no steeper than 2-percent, on sandy-loam texture soil, and where trees would not be removed. Each area where wetlands would be built has been disturbed in the past by heavy equipment.

Soil texture was measured outdoors at each site by using the ribbon test. Soil test holes were dug using a 52-inch long-2.5-inch diameter open-face soil auger. A 48-inch-long tile probe was used to test for the presence of rock and groundwater. A long-range laser-level and receiver were used to record elevations for each wetland that was designed. Each designed project was mapped using a smartphone with an external GPS. Photographs were taken showing each designed wetland.

The most effective technique for building each wetland was identified by the author.
The techniques to be used are described in this document, and in the following books:

1. *Wetland Restoration and Construction – A Technical Guide,* a book by Thomas R. Biebighauser.
2. *Wetland Drainage, Restoration, and Repair,* a book by Thomas R. Biebighauser

Design Factors

The vernal pond wetlands would be built using aquatic-safe liners that are buried in the ground. The aquatic-safe liner controls water soaking into the ground, which is the major reason constructed wetlands fail that are built on sand and gravelly soil. The author has found it is

always more economical to use aquatic-safe liners compared to clay liners due to the high costs associated with transporting large quantities of clay needed to build a liner that is 2-feet thick over an entire basin.

The steps involved with installing an aquatic-safe liner are described in the books written by the author. The topsoil on the site is first removed and set aside for later spreading in the finished wetland. A naturally appearing basin is dug that is from 10-16-inches deep in the center. An aquatic-safe liner is installed that is protected on both sides with geotextile fabric and then covered with at least 6-inches of soil. The saved topsoil is then spread over the aquatic-safe liner and geotextile in the completed basin.

Designed Wetland Projects

Table 1. Summary of designed wetland projects.

Wetland Name	Size (feet²)	Wetland Type to be built	Maximum water depth (inches)
1	1,600	Vernal Pond	10
2	1.600	Vernal Pond	12
3	1,600	Vernal Pond	16

Map Showing Designed Wetland Projects

Location of vernal pond wetlands designed for construction at the Robert C. Corby Arboretum and Wildlife Sanctuary.

Photos Showing Designed Wetland Projects

Vernal Pond 1 may be built at this location.

The site where Vernal Pond 1 may be built is covered with gravel.

Vernal Pond 2 may be built at this location.

Vernal Pond 3 may be built at this location.

This photo shows the plants currently growing in the area where Vernal Pond 3 may be built.

Waterfowl Habitat

Habitat for waterfowl would be improved by building vernal ponds. Wetland perimeters would be built to contain points, peninsulas, and shallow water bays. Wetland basins would be shaped to contain pits, mounds, ridges, and islands of various shapes and sizes. Compacted soils would be loosened to provide invertebrates with places to live and plants with unrestricted root

growth. Logs may be placed in the wetlands to provide waterfowl with loafing sites, and turtles with basking sites.

The wetlands would contain a diversity of amphipods, gastropods, worms, mussels, clam shrimp, and fairy shrimp. The seasonally inundated shoreline would be rich in invertebrates used by waterfowl for food.

Bat Species

The wetlands would be built with features to provide habitat for bat species. The water contained in the wetlands would be of critical importance to female bats while lactating. The author has built hundreds of wetlands that are being used by the Indiana bat and the Northern long-eared bat.

Areas of open water would be featured in the wetlands to provide bats with access to water. A diversity of flowering plants would be established within and surrounding the wetlands to support insects used by the bats for food.

Amphibians and Reptiles

The vernal ponds would support a diversity of amphibian and invertebrate species because they would not contain fish. Shallow water bays in full sunlight would be created in the wetlands to serve as staging areas for amphibian larvae and juveniles. Compacted soils within and surrounding the restored wetlands would be loosened using the rough and loosen technique to facilitate burrowing along with plant survival and growth. Large woody debris would be placed in and around the restored wetlands to provide hiding cover for frogs, toads, and salamanders.

Monarch Butterfly

Habitat for the Monarch Butterfly would be improved by building the wetlands. The Monarch Butterfly would use saturated soil along the edges of wetlands that contain high mineral concentrations. Swamp milkweed, Common Milkweed, and buttonbush may be planted in and around the restored wetlands.

Shorebirds

The vernal ponds would provide foraging habitat for shorebirds during migration. The wetlands would contain a diversity of amphipods, gastropods, worms, mussels, clam shrimp, and fairy

shrimp. Water levels would fluctuate in the wetlands being restored with compacted soil being loosened, thereby allowing water to soak into the ground. Water levels would rise when runoff from storms and snowmelt enters the wetlands. The fluctuating water levels would expose and maintain mudflats that are rich in invertebrates used by shorebirds for food. The author has successfully restored wetlands to provide shorebirds with migratory habitat that do not involve the use of pumps or water control structures. Ornithologists have been amazed by the species of shorebirds that use these restored wetland habitats.

Soil Disposal

The wetlands were designed so that the excavated soil is kept on site, and not moved to another location. The soil that is removed would be spread on higher ground, and not placed in existing wetlands.

Compacted soil surrounding the finished wetlands would be prepared for planting and seeding using the rough and loosen technique. Compacted soils would be loosened to realize these benefits:

- Water would soak into the ground and not runoff.
- Trees, shrubs, and wildflowers could germinate and grow.
- Plant and animal diversity would be increased.
- Turtles, small mammals, and toads can burrow into the ground. Snakes, frogs, and toads may live in these burrows.
- The loosened soil would retain moisture and not erode.

Mosquitoes and Wetlands

The vernal ponds can be expected to lower mosquito populations in the surrounding community. The dragonfly larvae, damselfly larvae, water boatman, water striders, frogs, toads, and salamander larvae living in the wetlands can be expected to control mosquitoes in as little as one year. Swallows, bats, and adult dragonflies flying near the wetlands would consume adult mosquitos. The wetlands can be expected to become population “sinks” for mosquitoes.

Dragonfly larvae living in the restored wetlands can be expected to control mosquito larvae.

Salamander larvae can be expected to control mosquitoes in the restored wetlands.

Wetland Construction Specifications

The wetlands were designed to be built using aquatic-safe (fish-grade) liners. Aquatic-safe liners are needed because clay texture soil is not present, and the elevation of groundwater is far below the surface. The following steps are used to build wetlands with aquatic-safe liners:

1. Wire flags are used to mark the perimeter of the wetland to be built prior to construction.

2. An aquatic-safe liner (30-mil PVC, 30-mil RPE, or 45-mil EPDM) is installed that is protected on both sides by geotextile (16-ounce environmental grade, non-woven).
3. The author is onsite directing construction.
4. The wetland is made to be deepest in the center, with slopes no steeper than 20-percent. Soil may slip off the liner if slopes are steeper than 20-percent.
5. 6-inches (15 cm) of soil is placed over the liner and geotextile.
6. An excavator is used to move soil for construction.
7. Heavy equipment is not allowed to travel on the liner and geotextile before or after it is covered with soil.
8. Excess soil may be spread downslope or uphill from the wetland being built.
9. Logs and branches may be placed in the finished wetland to improve wildlife habitat.
10. The wetland is supplied with water from rainfall and snowmelt.
11. Native species of plants are seeded and planted within and surrounding the completed wetland.

The recommendation that an aquatic-safe liner is needed to build a wetland is based on the authors' experiences building wetlands, and after examining hundreds of ponds and wetlands other people have built that have not held water as planned. The author has used liners to successfully repair hundreds of failed ponds that other people have attempted to build on permeable soils.

Wetlands built using aquatic-safe liners would not leak and can be expected to contain 100-percent of the water that is placed in them, with surprisingly low losses from evaporation. The author has used fish-grade, aquatic-safe RPE, PVC, and EPDM liners with success in building over 400 wetlands across North America.

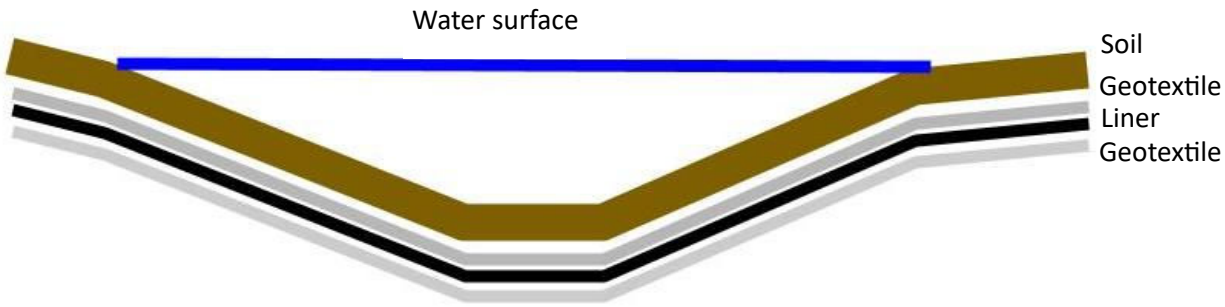
This table describes wetland construction techniques that the author has used without success.

Construction Technique	**Reasons not chosen**

Bentonite	Not effective. The author has not seen successful use of this product for building or repairing wetlands. Bentonite cannot be compacted. Bentonite is not fish grade or aquaticsafe. Bentonite would stay in solution and kill aquatic-life. Very expensive
Bentonite liner	Not effective. The author has not seen successful use of this product for building wetlands. Not labeled for building ponds with standing water. One is not able to seam panels, so leaks occur where sheets overlap. Not labeled as aquatic safe. Proven to kill aquatic-life by the author. Specialized equipment is needed to load onto a large trailer and to install.
ESS-13 (Spray Polymer)	Not effective on gravelly, rocky, or sand texture soils Only reduces water loss by seepage from 60-90-percent on soil textures that are not gravelly, rocky, or sandy. Not labeled for use on sites with sand and gravel Not aquatic-safe Specialized heavy equipment is needed to transport and install. Can be very expensive.

Liners should be made from material that is certified fish-grade & aquatic safe. Most liners available are treated with fungicides and algaecides, and if used, would kill aquatic life in a new wetland. This is why it is critical that an aquatic-safe liner be purchased for the project.

Geotextile fabric is used to protect the top and bottom of the liner. Thick geotextile would be placed over and under the liner. The geotextile should be factory-seamed and measure the same size as the liner.



Profile view showing liner and geotextile placement (not to scale). This drawing does not show the depressions, mounds, rocks, and wood to be placed in the basin to improve habitat.

The following companies manufacture fish-grade aquatic-safe liners. These companies would prepare one-piece, factory seamed fish-grade aquatic-safe liners and matching Environmental Grade 16oz geotextile.

Fab-Seal Industrial Liners, Inc.
6121 Highway 177
Shawnee, OK 74804
405-878-0166 Phone
405-878-0209 Fax
sales@fabseal.com

DAKK Mfg., LLC
14102 Highway 177
Shawnee, OK 74804
O:405-395-2139
C:405-765-6771
sales@dakkmfg.com

The liner and matching set of geo-textile pads are packaged on wood pallets, with the size of the liner labeled on the outside and delivered by a large semi-truck. One must let the company know in advance if a large semi-truck cannot access your delivery location when ordering. It is critical you know in advance and inform the manufacturer when ordering if a full-size semi-truck can access your delivery location. The liner manufacturer can request from the trucking

company that delivery be made using a smaller truck, with a lift gate. Expect the cost of delivery to be higher with a small truck, compared to a semi-truck.

The liner and set of geo-textile pads can weigh up to 2,000lbs, so it is important to use a fork-lift to unload the pallets from the semi-truck. The materials would be wrapped in geotextile and bound by metal or plastic straps.

The liner and geotextile should be kept wrapped on the pallet and stored indoors, or in a shelter where animals cannot cause damage. Mice and squirrels can be expected to build their homes in liners and geotextile pads when stored outdoors. Once these mammals move into the package, they quickly chew holes in the materials. Fortunately, this has not been a problem after the liners and geo-textile pads are installed.

A 4WD pickup may be used to transport the liner and geotextile pads to the worksite. A forklift may be used to load the pickup truck with the liner and geotextile needed for the project. The pickup truck is backed to the edge of the wetland being built, and the materials are unloaded, by hand, one piece at a time. It is very difficult to move the liner and geotextile any distance by hand, making it important that the materials are brought to the construction site at the time they are ready to be placed.

The excavator would be transported to the project site by a large truck and trailer. The truck and trailer must travel on high quality roads, over bridges with high weight limits. The truck and trailer require a large area to turnaround.

Here a tractor with a forklift attachment is used to move a pallet containing a liner and set of geotextile pads to the wetland construction site.

The liner and geotextile are delivered to the project site by pickup truck and trailer so they may be installed.

A group of 10 or more individuals are needed to install the liner and geotextile pads. There is a considerable amount of hand raking, shoveling, lifting, and pulling needed to build a wetland using a liner.

Tom Biebighauser is available to direct construction and would work with individuals to place the liner and geotextile pads. It is extremely difficult to install a liner and geotextile pads with a small number of people helping. *The importance of organizing a large enough crew to help cannot be overemphasized.*

It takes careful measuring and takes time to prepare a site for placement of the liner and geotextile pads. A person familiar with wetland construction and survey techniques must always be onsite monitoring and assisting with the construction of the wetland.

The basin is dug deepest in the center, with slopes no steeper than 20-percent.

It is essential that a laser level, tripod, and survey rod, made for use with a laser level, be used to monitor elevations for installing the liner and geo-textile pads. A 100-foot tape measure, along with wire flags are also needed for marking and dry-fitting the liner and geotextile pads.

The liner and geotextile pads should be anchored by driving 12-inch landscape spikes and washers along the top edge before covering with soil. This prevents the materials from shifting when covered with soil. The corners and excess liner and geo-textile fabric should be trimmed before covering with soil. The materials should not be anchored by rolling them over and placing them in a narrow trench.

The landscape spikes used to anchor the liners can be twisted or smooth. They must be 12-inches long. Landscape spikes are available for purchase from major hardware stores such as Lowes and Home Depot. *Shorter nails would not work*. One washer is needed for each landscape spike. Please make sure the washers fit over the spikes before purchasing. Purchase small diameter washers, not the more expensive, larger diameter washers.

A large excavator is used to dig the basin for the wetland.

Here a group of Forest Service Wildland Fire Fighters place the liner over a layer of geotextile. The placement of a large liner and geotextile requires the help of at least 15 strong individuals.

Here excess liner and geotextile are trimmed by hand before covering with soil.

The excavator is used to place soil over the liner and geo-textile pads. Heavy equipment must always be kept off the liner to protect it from damage.

A considerable amount of hand labor is required to cover the liner and geotextile with soil. Heavy equipment must not be allowed to travel over the liner and geotextile.

Here the excavator is covering the liner and geotextile with soil. The long reach of a large machine saves time and the need for hand labor.

Immediately following installation of the liner and geotextile, the surface of the materials would be covered with 6-inches of soil using a medium size excavator. Heavy equipment or any part of heavy equipment should not be allowed on the liner under any circumstances.

Here are the main reasons soil is placed over the liner and geotextile:

- Protects materials from being damaged by the sun, livestock, deer, elk, and falling trees.
- Provides a substrate used by frogs, toads, and invertebrates.
- Supports the growth of plants.
- Provides for the safety of individuals walking in and around the wetland so they don't slip and slide into deeper water.
- Prevents a hot surface from forming at the water's edge that kills animals using the wetland.

Here the excavator places large woody debris in the wetland. Note the thumb attachment on the excavator that allows the operator to pick up and place trees and boulders.

Recently completed *80-Wetland* on the Coronado National Forest built using a 30-mil fish-grade liner and 16oz geotextile. The rock was placed over portions of the liner to provide diverse habitat for rare amphibians.

Bentonite

People often suggest using bentonite to build or repair ponds on permeable soils. Their suggestion is based on hearsay and tradition, not from experience. *The use of bentonite to build or repair ponds is not recommended.* The author has had no success using bentonite to build or repair leaking wetlands and ponds. He has examined hundreds of sites where other people have tried to repair leaky wetlands and ponds using bentonite, and never with success. Bentonite is very expensive, and almost impossible to mix with water and compact on the large scale needed for pond construction. Tom Biebighauser recently examined a failed wetland near Amado, Arizona where an individual spent over $30,000 on bentonite in an attempt to repair a leaky wetland, unfortunately, without success.

A major problem associated with using bentonite is how it causes and maintains high turbidity in the water. The author has spread bentonite in wetlands and has observed how the water becomes gray with suspended particles. It is likely that the turbid water is toxic to fish and aquatic animals.

Bentofix® Thermal Lock GeoSynthetic Clay Liners and Bentomat® Geosynthetic Clay Liners combine geo-textile outer layers and a core of high swelling powdered sodium bentonite clay, or

high-density polyethylene (HDPE) geomembrane with a spun-bonded geotextile and powdered sodium bentonite clay to form a *low-permeable* barrier to water. Please note that the manufacture does not claim the material is impermeable to water, or aquatic-safe.

The bentonite liners are sold in rolls that are 17-feet 8-inches wide by 210-feet long. One roll can weigh 2,650lbs. A roll can be expected to cost $5,000.00, plus shipping. The liner is placed in a constructed basin in strips, with overlapping edges. The material is very difficult to unload and install. The manufacture does not recommend using the material for ponds containing water more than 12-inches deep, due to leakage along the seams. The material is also not recommended for ponds that may dry. The material is not labeled as Aquatic-Safe or Fish-Grade.

The author performed a biological toxicity test of Bentomat® Geosynthetic Clay Liner material by filling two, 5-gallon buckets with water from a wetland (built from soils high in natural clay) on the author's farm. Green frog tadpoles (6), and dragonfly larvae (4) were placed in each bucket. The animals had been captured in the same wetland where water was removed to fill the buckets. A piece of Bentomat® Geosynthetic Clay Liner material, measuring 4 x 4-inches, was placed in one of the buckets. The buckets were placed in the shade, near the edge of the wetland.

The contents of the buckets were examined 24 and 48-hours after preparation. One-half of the green frog larvae died in the bucket containing the Bentomat® Geosynthetic Clay Liner material after 24-hours. All the green frog larvae died in the bucket containing the liner material within 48-hours. Two of the dragonfly larvae died in the bucket containing the liner material after 24-hours, a third dragonfly larva died the next day. None of the green frog larvae or dragonfly larvae died in the bucket that did not contain liner material after 48-hours.

It should be assumed that any liner is toxic to fish and aquatic-life unless it is specifically labeled and tested to be fish grade and aquatic-safe. The author has found that if a liner is fish-grade, then the liner is advertised as being fish-grade and safe for aquatic organisms. *One should assume that liners contain toxins if they are not specifically labeled as fish grade, or aquaticsafe. This information comes from the Engineers that work at liner companies.* The author has observed wetlands where non-fish-grade/aquatic safe liners were used in their construction at schools. These wetlands did not support fish or aquatic life.

The author recommends that liner materials made with Bentonite not be used to build ponds that would be used by animals. It is very possible the bentonite liner material is manufactured for landfills and industrial waste containment and would poison amphibians and invertebrates.

This photo shows a roll of bentonite liner material being stored in a garage. It took 15 people to unroll the material 4-feet. The roll is lifted and moved using a long pipe, chain, and backhoe.

A 4-inch square piece of bentonite liner material was placed in the bucket on the left (notice the dead green frog larvae floating on the surface after 24-hours). The bucket on the right does not contain the bentonite liner material.

The author recommends using fish-grade and aquatic safe, one-piece, factory-seamed liners to build ponds instead of bentonite liners for these reasons:

1. Lower unit purchase price
2. Lower shipping cost
3. Lower cost installation
4. The materials are certified fish-grade and aquatic safe.
5. The materials would not leak if the water were deeper than 12-inches.
6. The materials would not leak if the pond dried.

Polymer Emulsions

Liquid polymer emulsions are available in some locations that may be used to reduce leakage in wetlands and ponds. The polymer functions to reduce the hydraulic conductivity of soils by filling voids as well as chemically and electrically modifying the alignment of the clay platelets in the soil.

The liquid polymer known as ESS-13 uses surfactants to reduce the electrical charges on clay platelets and vegetable oil to fill voids and lubricate the clay platelets allowing for more efficient alignment.

ESS-13 may be applied to ponds containing water that are leaking or mixed with the soil during construction and compacted in 6-inch layers to achieve a total thickness of 12-inches. The product is 60-90 percent effective in reducing water loss due to seepage. Seepage Control Inc. claims that ESS-13 is not toxic to aquatic life (www.seepagecontrol.com).

Literature provided by Seepage Control Inc. describes how the application of ESS-13 is most effective on “suitable soils.” Examples given describe how the application of ESS-13 is not effective on gravelly, rocky, or sand texture soils (www.seepagecontrol.com).

The author has not used liquid polymers to repair leaking wetlands, or to seal new wetlands built from soils containing gravel, rock, or sand. It appears that to be effective ESS-13 must be applied to soils containing some clay, and that the product must be mixed with the soil, and compacted in layers.

The author has built over 2,000 wetlands from soil containing clay without the use of polymers. This has been done by first removing topsoil from the work area, then removing and piling clay, mixing water with the clay to obtain suitable moisture content for compaction, spreading the clay in 6-inch layers in the wetland basin, and compacting each layer until a 24-inches of compacted soil is present in the basin.

Construction Supervision

A person who is familiar with vernal pond wetland construction techniques should always be on the site while heavy equipment is operating to serve as a Contract Inspector/Representative directing the implementation of the designed projects. This person should have great knowledge of wetland construction, be dedicated, and communicate effectively with the contractor and heavy equipment operators. This individual should respond to directions from agency personnel and answer all questions asked before and during construction.

The onsite Contract Inspector/Representative should monitor soil texture, groundwater elevations, surface elevations, slopes, and compaction during construction. This person makes sure that heavy equipment operators do not harm existing wetlands, rare species, cultural resources, buried utilities, or neighboring property. This person's judgment is critical in deciding if and how to modify the design based on what is found when heavy equipment begins excavation. Having the best Engineering Design and Construction Contract in the world does not excuse the critical need of having a person who knows how to build wetlands on site monitoring the construction of the project. The rewards of having a highly experienced Contract Inspector/ Representative onsite supervising the project are great. Not only is a significant amount of money saved, but much higher quality wetlands are built.

The author is available to be on site onsite every day while heavy equipment is operating to mark and stake each project area, monitor elevations using tripod and heavy equipment mounted lasers, monitor wetland size and shape, guard against disturbing or flooding neighboring properties, monitoring compaction using a penetrometer, maintaining worksite safety, directing heavy equipment operations, disabling drainage systems, shaping wetlands, recording hours worked by heavy equipment operators, photographing construction, preparing maps of completed wetlands, keeping a daily work diary, responding to public and agency concerns, and leading tours of the project area. He would also provide training to heavy equipment operators and agency personnel in the use of techniques he has developed over the past 46 years to restore wetlands and streams to provide habitat for rare animal and plant species.

Estimated Construction Budget

The following estimated budget was developed for implementing the designed wetlands (please zoom-in to view the numbers):

Wetland Name	Liner & geotextile width (ft)	Liner & geotextile length(ft)	Wetland Area (ft²)	Liner (1) & geotextile pads (2) purchase & shipping cost	# of 12-inch landscape spikes needed to anchor	12-inch landscape spikes & washers cost	Excavator Hours	Excavator Cost	Construction Supervision by Biebighauser	Wheat (50lb bags)	Wheat cost	Straw bales	Straw cost	Misc. Supplies	Native plant & Seed Purchase	Total Cost
1	40	40	1600	$3,200	84	$101	10	$2,500	$1,500	1	$35	12	$96	$100	$699.00	$8,231
2	40	40	1600	$3,200	84	$101	10	$2,500	$1,500	1	$35	12	$96	$100	$699.00	$8,231
3	40	40	1600	$3,200	84	$101	10	$2,500	$1,500	1	$35	12	$96	$100	$699.00	$8,231
Excavator Mobilization & Demobilization																$1,000
Total				$6,400	252	$302	30	$7,500	$4,500	3	$105	36	$288	$300	$2,097	$24,692
Wetlands would be built using aquatic-safe, one-piece, factory seamed liners and geotextile pads that are buried beneath approximately 6-inches of soil.																
The estimated prices listed are not based on prices of bids received from suppliers or contractors for this specific project.																
Liner and Geotextile Cost = (1) (30mil PVC liner aquatic-safe) + (2) 16oz geotextile pads + (shipping). DAKK Liners Inc. or Fab-Seal Industrial Liners are recommended sources.																
Number of landscape spikes = width of liner x 3.1456/1.5 = # 12-inch landscape spikes with equal number of matching washers																
Construction supervision by Tom Biebighauser includes consulting fee, vehicle mileage, tolls, lodging, meals, survey equipment, construction tools, and supplies.																
Wheat for erosion and nonnative plant control on higher ground surrounding the wetland, packaged in 50lb bags																
Wheat cost = $35.00/50lb bag																
Straw will be used for mulching the spillway and higher ground surrounding each new wetland.																
Estimated cost for each straw bale is $8.00.																
Misc. supplies = (wire flags + box cutters + extra blades + marking crayon + garbage bags + waterproof patching tape)																

The original Excel spreadsheet of this estimated budget is availabe by emailing tombiebighauser@gmail.com

Native Plants

A diversity of native plants and wildflowers would be sown and planted by hand within and surrounding the wetlands to improve habitat for pollinators, including the Monarch butterfly. Seeds would be sown the same day each wetland is built to take advantage of the first rain falling on the loosened soils surrounding the wetland area. Seeding would not be delayed because of the crust that can form on the surface of the ground following the first rain event. Motorized vehicles would not be used to spread seed as the rubber tires compact soil, reducing plant survival and growth and causing erosion.

Invasive Plant Species Control

Minimizing the spread of invasive species is a key concern during implementation of the designed project because the exposed soil can create conditions for non-native species to become established. The following measures would be taken to control invasive species:

1. Nonnative plants would be controlled prior to construction where feasible.
2. Heavy equipment operators would clean machines to prevent the introduction of non-native species to the site.
3. Non-native grasses and associated soil/seedbank growing in and near the wetland restoration areas would be buried onsite.
4. Thick layers of weed-free mulch (1 bale of barley or wheat straw/10 m^2) may be used to suppress weeds and retain moisture for new plantings.
5. Native plants would be seeded and planted in and around the restored wetlands and on areas where soil is spread to help control non-native plants.

Actions may be taken to prevent nonnative invasive plants, including cattails, reed canary grass, and phragmites from dominating the restored wetlands. These techniques may be used to prevent any one plant from taking over a restored wetland:

1. Cattails, phragmites, and reed canary grass would be controlled prior to construction of the wetlands if possible.
2. Heavy equipment would be used to remove unwanted plants as part of construction.
3. Nonnative plants would be buried onsite or removed so they do not spread.
4. Wetland basins would be restored to contain uneven elevations with mounds, hummocks, ridges, pits, and depressions.
5. Compacted soils would be loosened within and around the restored wetlands.
6. Ridges, mounds, tufts, and scrapes would be created within the wetlands.
7. Exposed soils would be seeded to a diversity of native plants the same day the wetland is built.
8. Exposed soils that are above the water level would be mulched using wheat straw, oat straw, or barley straw, and not hay that often contains weeds.

The restored wetlands would be monitored each week for nonnative plants following construction. Any nonnative plants that are growing in and near the wetlands would be controlled the same day they are found. This action would facilitate the establishment of an attractive diversity of native plants in the new wetlands.

Educational Opportunities

The wetlands may be built as part of a *Wetland Restoration Workshop* instructed by the author. This training would be designed to help and encourage agency personnel, nonprofit organizations, and private landowners to build and restore wetlands to increase habitat for a diversity of plant and animal species.

The author began instructing Hands-on Wetland Restoration Workshops in 2003 and has now taught these practical sessions in 28-States, Puerto Rico, 3-Canadian Provinces, Mexico, New Zealand, and Taiwan. Hands-on Wetland Restoration Workshops are well received and very effective. On a scale from 1 to 10, course evaluations consistently rate Hands-on Wetland

Restoration Workshops from 9.8 to 10.0. Senior natural resource managers have written … “It’s the best training I’ve ever received, and “I was amazed by how much I learned.”

Climate Change

Building the wetlands would sequester carbon by tying up organic material in saturated soils. The restored wetlands would slow the decomposition of organic soils and release of carbon into the atmosphere. Nonnative plants and roots would be buried in the soil that would become saturated, sequestering their carbon indefinitely. The saturated soils would also capture and hold phosphorus.

The proposed project would restore a diversity of native flowing plants that would benefit pollinators such as bees, butterflies, hummingbirds, and moths. These pollinators would help ensure the survival of a diversity of plants that convert carbon dioxide into oxygen.

Sediment and Erosion Control

The installation of silt fencing is not recommended to control erosion for this project. Erosion would be effectively controlled by the construction of each wetland basin, and by loosening compacted soils using the rough and loosen technique.

Close monitoring of wetland restoration sites by the author near Hudson, New York in 2022 following torrential rains while construction was taking place showed that the miles of silt fence that was installed did nothing to control erosion. Any erosion on the site was being controlled by the construction of numerous wetland basins that collected and held runoff, and by the loosening of compacted soils using the rough and loosen technique. The act of installing the silt fence caused erosion to occur because soil was exposed in areas growing dense vegetation. People who have used silt fences for years are amazed by how the rough and loosen technique is so effective for controlling erosion.

Erosion and sediment would be controlled by the excavation of basins that would collect and hold runoff from precipitation and snowmelt. The wetland basins would collect and contain runoff during storm events.

The land located immediately adjacent and downhill from the wetland basins to be restored would not be disturbed by this project. These areas would serve as natural fully vegetated buffers that would also help prevent water or soil from leaving the site.

The rough and loosen technique would be used to loosen all exposed soils within and surrounding the wetlands to be restored. This technique involves using the bucket of an excavator to loosen compacted soils to a depth of 3-feet. The practice has been proven across North America to control erosion. Precipitation and runoff rapidly soak into the ground instead of flowing across the surface. A diversity of native plants would rapidly grow on soil loosened by using this technique.

Wheat would be sown on exposed soils the same day as construction for erosion control. The wheat would be spread by hand using a shoulder mounted seed spreader. The wheat would geminate within 3-days and provide excellent erosion and sediment control.

Straw would be spread for mulch on sloped areas surrounding restored wetland basins for erosion control. The straw would control erosion and provide for the rapid germination of wheat and native plants on soils loosened using the rough and loosen technique.

Vehicles with wheels would not be allowed to drive over loosened soil to control erosion. We have found that erosion begins when water flows down the ruts left by rubber-tired vehicles. This is why rubber-tired vehicles would not be allowed to travel over soils that are exposed by the project.

No roads would be constructed that can cause erosion. Heavy equipment would not expose soil when traveling between wetland restoration sites.

The actual construction of the wetlands should be considered as an erosion control measure. This project would stop erosion by filling and blocking ditches, restoring shallow basins, and by loosening compacted soils.

A diversity of native plants would be planted and seeded within and surrounding the restored wetlands, and on the soil spread from restoring the wetlands. The seed mixtures would contain many species of wildflowers to improve habitat for pollinators. There are also seeds and roots of many species of native plants that are present in the topsoil to be spread within and surrounding the restored wetlands that would sprout and grow within days of construction.

Summary

Three-ephemeral wetlands may be built to provide habitat for vernal pond species including the wood frog, spotted salamander, and fairy shrimp. This type of wetland is not found in the Arboretum or the adjacent Erie Canal Nature Preserve.

Vernal ponds would be built to appear and function as natural wetlands. The wetlands would improve viewing opportunities for Mallards, Wood Ducks, Canada Geese, Great Blue Herons, Egrets, Red-wing Blackbirds, painted turtles, spring peepers, chorus frogs, and gray tree frogs.

The vernal ponds would be built shallow with gradual slopes so that students may safely use the habitats for outdoor learning. Flat rocks would be placed near the water's edge to provide children with places to stand while exploring vernal pond life.

Logs may be placed in the vernal ponds to provide birds with perches and turtles with basking sites. Branches may be placed in the wetlands to provide salamander with egg attachment sites.

Compacted soil surrounding the wetlands may be loosened using the rough and loosen technique. A diversity of native plants may be seeded and planted within and surrounding the wetlands to add beauty to the vernal ponds.

The wetland project would improve habitat for pollinators. A diversity of flowering plants may be seeded and planted in and around each wetland to improve the habitat for butterflies, moths, bees, and hummingbirds. Pollinators would also obtain minerals from the moist soil along the edge of the wetlands, and shorebirds would forage on the exposed mud flats.

Detailed specifications are contained in this plan that may serve as a guide in the construction of the designed wetlands. Measures are described for building the wetlands to control erosion and to provide habitat for a diversity of native animal and plant species. The project is designed and shovel-ready, with the author being available to be on the ground directing the implementation of the project.

The wetlands may be built in combination with a *Hands-on Wetland Restoration Workshop* where agency personnel, private landowners, volunteers, and nonprofit organizations learn how to design and build wetlands that clean runoff and improve habitat for plant and animal species.

This design was prepared by,

Thomas R. Biebighauser

Wildlife Biologist and Wetland Ecologist

Wetland Restoration and Training LLC

3415 Sugar Loaf Mountain Road

Morehead, KY 40351

Cell phone: 606-356-4569

Email: tombiebighauser@gmail.com

Website: https://wetlandrestorationandtraining.com

Appendix 1. About the author

Thomas R. Biebighauser

Wildlife Biologist
Wetland Ecologist
Wetland Restoration and Training LLC
3415 Sugar Loaf Mountain Road
Morehead, KY 40351 USA

Phone: (606) 356-4569
E-Mail: tombiebighauser@gmail.com
Website: https://wetlandrestorationandtraining.com

Tom Biebighauser graduated from the University of Minnesota with a B.S. in Wildlife Biology in 1978 and began his career with the USDA Forest Service as a Wildlife Biologist at the Superior National Forest in Minnesota, moving on to the Daniel Boone National Forest in Kentucky in 1988, retiring from the Forest Service on June 1, 2013.

Tom Biebighauser has been enthusiastically restoring wetlands and streams for 46 years. He has designed over 10,000 wetland, lake, stream, and river restoration projects and has successfully supervised the construction of over 3,000 wetlands and streams in 27 states, across Alberta, British Columbia, and Ontario in Canada, Mexico, New Zealand, Puerto Rico, and Taiwan. Tom builds over 120 wetlands each year and has developed highly successful and inexpensive techniques for constructing wetlands in urban areas, on rangeland, farmland, and in forested areas. He specializes in planning and building wetlands, lakes, streams, and rivers that provide habitat for endangered and threatened species of animals and plants.

Tom worked as a Wildlife Biologist for the U.S. Forest Service for 34-years, helping personnel from federal, state, and county agencies initiate wetland and stream restoration programs across the United States. He took the lead in completing hundreds of partnership projects for building emergent, ephemeral, forested, and wet-meadow wetlands on public lands during his career with the Forest Service.

Tom has developed highly successful and inexpensive techniques for restoring wetlands and streams that should last forever without maintenance. He cautions against using berms, dams, dikes, levees, weirs, diversions, pipes, pumps, water control structures, or wells that all require frequent and expensive maintenance. Having built over 1,400-dams, he has since decommissioned over 350-dams. He carries a deep and long-standing concern for the

environment and finds it rewarding to assist individuals who are interested in restoring wetlands and streams.

Tom has developed techniques for building wetlands in urban areas where homes have been removed, at schools, on mined land, and in timber sale areas. He has calculated how to build wetlands so they would not require maintenance, not building dams, weirs, or using pipes, pumps, diversions, or water control structures. He uses techniques that involve:

1. Restoring the historic elevation of the water table with groundwater dams
2. Loosening and reshaping compacted soils to control erosion, restore hydric soils, aquatic plants, and provide habitat for burrowing animals.
3. Using aquatic-safe liners on rocky and sandy soils
4. Creating natural clay lined basins to restore wetlands on shallow soils and in arid regions.
5. Reversing the effects of livestock and irrigation on springs and streams in arid regions.
6. Developing wetlands and streams in urban and rural areas to manage stormwater, control flooding, control erosion, increase wildlife viewing, and provide opportunities for environmental education.

He specializes in restoring wetlands, streams, and rivers that provide habitat for endangered and threatened species. Tom has developed techniques for building wetlands that improve habitat for rare species including the Blandings turtle, burbot, California red-legged frog, Chiricahua leopard frog, grizzly bear, Eastern spadefoot, Great Basin spadefoot, Indiana bat, marbled salamander, mole salamander, Northern bat, Northern leopard frog, Sandhill Crane, Trumpeter Swan, Virginia big-eared bat, Western painted turtle, white sturgeon, and the wood frog.

Tom has developed highly effective techniques for restoring wetlands in deserts, having built over 600-wetlands in arid regions of Arizona, British Columbia, California, Nevada, New Mexico, and Utah. He has discovered how to successfully restore wetlands, lakes, and streams so they would contain water forever in response to the long-term drought wrought by climate change.

Tom has designed and built hundreds of wetlands in urban areas, including the cities of Edmonton, Alberta, Vancouver and Victoria, British Columbia, Baltimore, Maryland, Washington, D.C., Greenville, North Carolina, Bowling Green, Lexington, and Louisville, Kentucky, Kansas City, Kansas, Minneapolis, Minnesota, and Cincinnati, Ohio. These projects involved removing homes in flood-prone areas, changing ditches into streams, and building naturally appearing and functioning wetlands that clean storm water runoff, attenuate flooding, and increase wildlife viewing opportunities. He has built approximately 250 wetlands at universities, high schools, middle schools, and elementary schools.

Tom has worked to develop techniques for building wetlands on mined lands. He has successfully designed and constructed over 400 wetlands on clay, coal, gravel, limestone, and sand mines. He helped the West Virginia Department of Natural Resources to prepare a guide for building wetlands on areas where drilling for gas and oil is taking place.

The construction of wetlands for managing stormwater has been a specialty of Tom Biebighauser. He has designed and built hundreds of wetlands that clean runoff at schools across North America. These wetlands are built so they are attractive, provide habitat for pollinators and shorebirds, are safe for children to explore, and require little, if any maintenance. He builds these wetlands without using concrete, water control structures, or pipes. Tom teaches classes on designing and building wetlands for managing stormwater that look and function like natural wetlands.

Tom teaches that when restoring a wetland, it is necessary to identify and disable historic drainage practices to be successful on the site. He became an expert at identifying actions taken to destroy wetlands including the use of ditches, channeling of streams, filling, and installation of buried drainage structures made from wood, rock, clay, concrete, and plastic. Tom methodically researched literature from the 1600's to learn how wetlands were changed into farmland, and development. He has interviewed hundreds of seniors who spent their lives draining wetlands and moving streams, documenting their practices so others can be successful in wetland and stream restoration.

Tom teaches over 1,000 individuals each year how to design and restore wetlands. He has developed highly effective methods, guides, and keys for helping individuals learn how they can design and build wetlands. Biebighauser instructs unique 1-7 day long Hands-on Wetland Restoration Workshops where participants learn how to restore wetlands by becoming involved in the design and construction of one or more wetlands from start to finish. These practical training sessions are responsible for empowering hundreds of individuals to restore thousands of wetlands across North America, and around the world.

Biebighauser has served as an instructor for the British Columbia Wildlife Federation Wetlands Institute since 2003. He began instructing the British Columbia Institute of Technology Wetland Restoration Course for Graduate and Undergraduates in 2013. Tom began instructing wetland restoration courses at the University of Alberta in 2020.

Tom has a passion for encouraging and helping people initiate wetland and stream restoration programs. He teaches online graduate and undergraduate-level courses explaining wetland restoration techniques at Eastern Kentucky University, the University of Louisville-Speed School of Engineering, and the State University of New York Environmental Science & Forestry Program.

Biebighauser has worked in partnership with 12-First Nations Bands in British Columbia and 10-Native American Communities in the United States to develop wetland and stream restoration programs that restore habitats for Culturally important animals and plants.

Tom is a volunteer board member with the Sheltowee Environmental Education Coalition (SEEC), a nonprofit 501(c)3 organization that assists landowners and agency personnel with the

design and restoration of wetlands for outdoor education, and to provide habitat for rare species of animals and plants. You may learn more about SEEC by visiting https://sheltowee.net.

Tom has written 4 books and numerous publications about restoring wetlands: Over 40,000 copies of his books have been distributed worldwide. His passion for restoring wetlands and streams has been recognized by receiving 45 awards, including the National Wetlands Award for Conservation and Restoration in 2015, and the Robert Lauderdale Award from the Kentucky Water Research Institute in 2023

Publications

- Thomas R. Biebighauser, *A Guide to Creating Vernal Ponds*, USDA Forest Service, 33 pages, 2003.
- Thomas R. Biebighauser, *Vernal Pond Encore*, Birdscapes, Winter 2004, page 26. 2004
- Thomas R. Biebighauser, *Wetland Drainage, Restoration, and Repair*, Lexington, KY, University Press of Kentucky, 2007.
- Thomas R. Biebighauser, *How to Build a Vernal Pond*, Outdoor America, Winter Issue, pp. 16-17, 2008.
- Thomas R. Biebighauser, *Build Your Own Wetland*, Volume 3, Issue 2, Kentucky Woodlands Magazine, pp. 12-15, 2008.
- Thomas R. Biebighauser and Arthur C. Parola, Jr., PhD, P.E. *The University of Louisville Stream and Wetland Restoration Program*, Sustain Magazine, Spring-Summer, 2011, pages 8-13.
- Thomas R. Biebighauser. *Wetland Restoration and Construction - A Technical Guide*. Upper Susquehanna Coalition, 186 pages, 2011
- Thomas R. Biebighauser and Cindy Schafer, Practical Meets Natural, Wetlands aid in storm water runoff, provide plant and animal habitat. Land Air & Water Magazine, Volume 23 Number 2, Spring 2012, pages 5 and 12.
- Thomas R. Biebighauser, Wetlands for Whitetails, Quality Whitetails Magazine, June-July 2012, pages 36-39.

Awards

- Cash Award, USDA Forest Service, January 4, 1984, I recognition of the outstanding work performed in presenting slide/talk presentations to community and civic groups.
- Cash Award, USDA Forest Service, June 20, 1985, For outstanding effort in establishing and coordinating the Environmental Education Program with the Aurora-Hoyt Lakes School System

- Quality Award Increase, USDA Forest Service, November 4, 1986, In recognition of quality work and job performance as a Wildlife Biologist.
- Conservation Award, Minnesota Deer Hunters Association Taconite Chapter, 1987
- Certificate of Appreciation from the Regional Forester, USDA Forest Service, August 15, 1988, Project Spirit Suggestions.
- Cash Award, USDA Forest Service, December 12, 1989, For exceptional duties as zone Wildlife Biologist during FY 1989.
- Certificate of Merit, USDA Forest Service, January 5, 1990, Superior Performance, Zone Wildlife Biologist
- Spot Cash Award, USDA Forest Service, March 28, 1991, Regional Forester Visit Coordination.
- Certificate of Merit, USDA Forest Service, September 1993, Ice Storm Recovery Program
- Certificate of Merit, USDA Forest Service, December 13, 1993. For outstanding performance.
- Kentucky Colonel Commission by Commonwealth of Kentucky Governor Brereton C. Jones, September 1, 1995
- Cash Award, USDA Forest Service, November 1, 1995, Morehead Storm Salvage EA.
- Certificate of Appreciation, USDA Forest Service, November 28, 1995. For Outstanding Efforts Daniel Boone National Forest Multicultural Advisory Committee.
- Cash Award, USDA Forest Service, March 3, 1996
- The League of Kentucky Sportsman Kentucky Conservation Achievement Award, 1997
- National Taking Wing Award for Leadership, 1998, USDA Forest Service
- USDA Forest Service, Whitaker Wetland Achievement Award, 1998
- Goodyear and National Association of Conservation Districts Award of Merit, 1998, Rowan County Conservation District.
- Award of Merit from The Senate of the Commonwealth of Kentucky (Senator Robert Stivers), September 20, 1999.
- Certificate of Appreciation for Fire-Fighting Efforts, USDA Forest Service, December 15, 1999
- Certificate of Appreciation, March 25, 2000, National Taking Wing Award from Mike Dombeck, Chief USDA Forest Service, Ironton Wetlands Restoration
- Cash Award, USDA Forest Service, September 24, 2000.
- Certificate of Merit, USDA Forest Service, October 30, 2001, for leadership in building and maintaining cooperative relations
- Rowan County Wildlife Club, 2001, Honorary Membership
- Certificate of Appreciation, USDA Forest Service, Dale Bosworth, Chief Forest Service, October 30, 2001, Wildlife Openings Management Environmental Assessment
- National Taking Wing Award, Licking River Wetland Restoration Project, March 26, 2002
- Certificate of Appreciation, USDA, April 3, 2002,
- Certificate of Merit, USDA Forest Service, 2003, Ranger District of the Year, Southern Region

- Kentucky PRIDE Award, 2005
- PRIDE Volunteer of the month, January 2005
- Ducks Unlimited National Distinguished Service Award, March 19, 2005
- Honor Award, April 19, 2005, Rowan County Conservation District
- USDA Regional Forester's Honor Award, Natural Resources Leadership Award, 2007
- The Garden Clubs of Kentucky, Inc. Kentucky Enrichment Award, April 11, 2007
- Certificate of Appreciation, April 26, 2007, Regional Appeal Review Team
- Lee County Conservation District Award, April 17, 2007
- Commonwealth of Kentucky Earth Day Award, Environmental Quality Commission, 2007
- Honorary Chapter Future Farmers of America Degree, 2008
- USDA Forest Service Certificate of Merit for helping to complete the Whitaker Wetland Restoration Project on the Wayne National Forest, 2008
- USDA Forest Service Certificate of Merit, Mark Twain National Forest, Long Creek Wetland Restoration Project, August 20, 2009
- USDA Forest Service Regional Forester Award, 2010, Natural Resource Award for completing the Slabcamp and Stonecoal Stream and Wetland Restoration Project
- Arlie Boggs Conservation Award, 2010
- Wings Across America National Award, March 2011, Thomas L. Tidwell, Chief, U.S. Forest Service, For Significant Contribution to the following: Bat Management and Wetland Restoration on the Lincoln National Forest
- Certificate of Appreciation, USDA Forest Service, February 28, 2012, Recognition of superior performance assisting with the restoration of wetlands for the Sacramento Ranger District, Lincoln National Forest.
- National Wetlands Award for Conservation and Restoration. May 2015.
- The Robert Lauderdale Award for outstanding contributions in water resources quality, University of Kentucky, Kentucky Water Research Institute. 2023.

Appendix 3. Examples of Wetlands Restored in the East by Thomas R. Biebighauser

Emergent wetland restored in field. Photo taken 10-years following construction. Menifee County, Kentucky

Emergent wetland in forest. Menifee County, Kentucky

Emergent wetland. Menifee County, Kentucky

Restored vernal pond near Mt. Orab, Ohio

Pine Creek Wetland Restoration, Wayne National Forest, Ohio

Superior Wetland Project, Wayne National Forest, Ohio

Superior Wetland Project, Wayne National Forest, Ohio

Superior Wetland Project, Wayne National Forest, Ohio

Pine Creek Wetland Project, Wayne National Forest, Ohio

Emergent wetland. Menifee County, Kentucky

Emergent wetland. Menifee County, Kentucky

Emergent wetland. Menifee County, Kentucky

Emergent wetland. Menifee County, Kentucky

Emergent wetland. Menifee County, Kentucky

Emergent wetland with beaver activity. Rowan County, Kentucky

Emergent wetland. Rowan County, Kentucky

Emergent wetland. Rowan County, Kentucky

Emergent wetland. Rowan County, Kentucky

Emergent wetland. Bath County, Kentucky

Ephemeral wetland. Bath County, Kentucky

Ephemeral wetland. Bath County, Kentucky

Ephemeral wetland in old field. Rowan County, Kentucky

Ephemeral wetland. Rowan County, Kentucky

Ephemeral wetland along forest edge. Rowan County, Kentucky

Wet Meadow Wetland with wildflowers. Rowan County, Kentucky

Wet-meadow wetland with burweed. Menifee County, Kentucky

Wet-meadow outlet/spillway. Menifee County, Kentucky

Wet-meadow and ephemeral wetland. Rowan County, Kentucky

Roane Jackson Technical Center, West Virginia

Queens Wetland Restoration Project, Monongahela National Forest, West Virginia

Spring restoration, Monongahela National Forest, West Virginia

Queens Wetland Restoration Project, Monongahela National Forest, West Virginia

Emergent wetland. Rowan County, Kentucky

Queens Wetland Restoration Project, Monongahela National Forest, West Virginia