Wetland Repair and Renovation Project
Cane Ridge Wildlife Management Area
Patoka River National Wildlife Refuge

Least Tern

Thomas R. Biebighauser

May 11, 2015

Abstract

A prescription for repairing five-wetlands not holding water as planned was prepared by Tom Biebighauser for the Cane Ridge Unit of the Patoka River National Wildlife Refuge. Water was found to be leaking from the wetlands by flowing under the dams, and by soaking into the ground. The wetlands may be rebuilt by coring and building groundwater dams, and by placing thick layers of compacted clay over scattered patches of sand. Repairing the wetlands offers great opportunity to improve habitat for rare species of wildlife by adding features such as ephemeral wetlands, mounds, peninsulas, large woody debris, and snags.

Introduction

The Cane Ridge Unit was acquired by the U.S. Fish and Wildlife Service in 1999 as part of the Patoka River National Wildlife Refuge. Cane Ridge is located in Gibson County, Indiana. The 464-acre area is two miles east of the Wabash River. Cane Ridge is on the south side of the 3,000-acre Gibson Lake, used to cool water for Duke Energy's Gibson Generating Station.

Four moist-soil management units (A-D) totaling 193-acres and one 59-acre deep water wetland (Tern Pool) were constructed on the Cane Ridge Unit in 1994. The wetlands were created by building dams around agricultural fields. The units hold water for a short time after a flood, or while water is being added by pumping. They basically lack hydric soils and hydric plants.

Duke Energy pumps water into the most uphill unit, the Tern Pool, at a rate of 1,500 gallons/minute from the Wabash River, located two-miles away. The pump was designed to fill the Tern Pool first, with water gravity fed into the four lower units via a canal system.

Two large islands were constructed in the Tern Pool to provide safe nesting areas for the Interior Least Tern. The Tern Pool produces a large number of Least Terns each year. Despite their problems, the Cane Ridge Wetland Units provide some of the best habitat for waterfowl and shorebirds in the region. Over 12,000 ducks were counted feeding and resting in the wetlands in 2006. Twenty-eight species of shorebirds and 21-species of ducks, geese, and swans have been documented to use the area.

Objectives

The primary objectives for managing the Cane Ridge Units include providing:

1. Migratory habitat for waterfowl including the Mallard, Pintail, Blue-winged Teal, and Northern Shoveler.
2. Migratory habitat for shorebirds including the Pectoral Sandpiper, Black-necked Stilt, Dunlin, Greater Yellowlegs, and Lesser Yellowlegs
3. Nesting habitat for the Least Tern

4. Wildlife viewing opportunities

Since construction of the Cane Ridge it has been determined that Units A-D and the Tern Pool are not holding water as planned. In 2012 there was a drought. Numerous deep cracks, averaging 12-inches wide and over 4-feet deep developed in the Tern Pool. Since the drought, it has not been possible to fill the Tern Pool, even though the cracks are no longer visible and the pump is operated full time.

Duke Energy and the U.S. Fish and Wildlife Service contracted with Wetland Restoration and Training LLC to identify how to repair the Cane Ridge Units. The Cane Ridge Units and surrounding areas were field examined by Tom Biebighauser from March 31 to April 3, 2015. Biebighauser was assisted by Heath Hamilton (U.S. Fish and Wildlife Service), John Pike (Duke Energy), Trevor Shepard (Natural Resources Conservation Service), Michael Sertle (Ducks Unlimited), and Jeff West (G.J. Rode & Son).

The observation deck at Cane Ridge offers the public unparalleled opportunities for bird watching.

Methods

The Cane Ridge Units were examined by Tom Biebighauser to identify why they are not holding water as planned.

The field investigation involved the following:

1. Using a laser level to determine if water in ditches surrounding the wetlands could be directed into the wetlands
2. Digging test holes by hand using a soil auger to determine soil texture and groundwater elevations
3. Using tile probes of different lengths to determine soil texture and ground water elevation

4. Digging deep test holes using a backhoe
5. Searching for outlets for possible buried drainage systems
6. Examining water control structures for leaks
7. Examining constructed dams for burrows dug by beaver, muskrat, and other mammals
8. Interviewing personnel who were involved with the design and construction of the wetlands
9. Examining the engineering design prepared for wetlands A-D
10. Interviewing individuals who once farmed the land

An eight-foot long tile probe was used to hand test for the presence of sand and gravel.

A series of shallow and deep holes were dug in the wetlands, and along the dams of the wetlands, to determine soil texture and the elevation of groundwater. The holes were dug by hand using a 52-inch long soil auger, and by using a backhoe with an extend-a-hoe attachment that allowed for digging 13-feet deep. In addition, two tile-probes, one 4-feet long and another 8-feet long were used to estimate soil texture and the elevation of groundwater.

The test holes showed similar layers of soil texture and groundwater elevations between the units. All of the Cane Ridge Unit Wetlands were built from agricultural fields. The fields contain thick layers of sandy-clay and clay-texture soils near the surface. Each unit contained an average of 14-inches of topsoil. The topsoil contained a mixture of organics, sand, silt, and clay. The topsoil generally contained enough clay that thin ribbons averaging 1.25-inches long could be made. Sandy-clay or clay-texture soil was generally found beneath the topsoil. The sandy clay and clay layer was approximately 4-feet thick on Unit A, from 5-8 feet thick in the Tern Pool, and from 5-8 feet thick in Units B, C, and D. The amount of clay found in the sandy-clay and clay are high enough to compact for wetland success using the surface water/groundwater dam and surface-water/compacted clay liner techniques described by Biebighauser (2011)[1].

[1] Thomas R. Biebighauser. *Wetland Restoration and Construction - A Technical Guide*. Upper Susquehanna Coalition, 186 pages, 2011

Sand with some fine gravels were found beneath the sandy-clay and the clay layers. The sands and gravels were more than 6-feet thick. The backhoe did not reach deep enough to dig below the sand layer. Conversations with local contractors found that the sand layer can be very thick, with it not being possible to dig beneath it to form a solid foundation for a groundwater dam. The sand was very liquid and collapsed rapidly into the holes. The sand and gravels were saturated, and under positive water pressure. Water generally rose to within 12-inches of the surface when the test holes were dug into the sand and gravel layer.

Table 1. Shallow test-hole results (inches)

Hole #	Wetland Unit	Topsoil[2]	Sandy-Clay[3]	Clay[4]	Sand & Gravel[5]	Comments
4	A	0-14	12-60		60+	
8	B	0-10	10-80		80+	
9	B	0-10	10-80		80+	
3	C	0-12	12-60		60+	In standing water, borrow area
6	C	0-6		6-100	100+	
7	C	0-12	12-80		80+	
1	D	0-12	12-60		60+	
2	D	0-12	12-60		60+	
5	Tern Pool	0-6	6-60		60+	
10	Tern Pool	0-12			12+	Sand lens found by John Pike

[2] Contains organics, sand, silt, and clay. Generally forms a thin ribbon 1.25-inches long. Not compacted. Moist, not gleyed.
[3] Forms a thin ribbon at least 2-inches long. Easily compacted.
[4] Forms thin ribbon over 3-inches long. Easy compacted.
[5] Saturated. Not able to compact.

This photo shows the hand tools used to measure soil texture and the elevation of groundwater in the Cane Ridge Wetland Units. The photo also shows how the vegetation in the units is typical of well-drained fields.

This long and thin ribbon shows a soil texture that is high in clay. The ribbon is typical of soil textures found within the Cane Ridge Wetland Units.

Figure 1. Soil test hole and petroleum well locations. Cane Ridge Unit Wetlands.

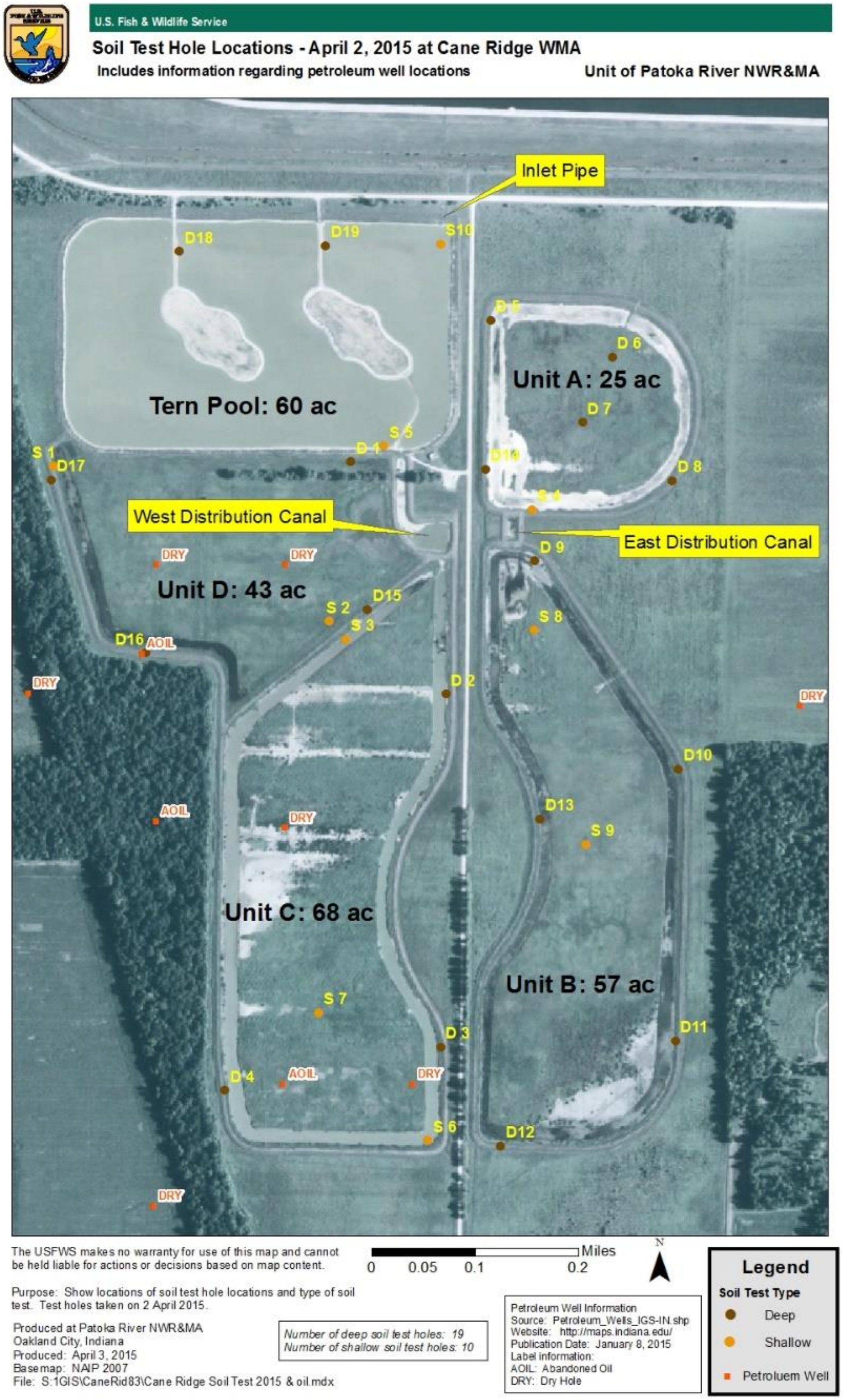

Table 2. Deep test-hole results (inches)

Hole #	Wetland Unit	Topsoil	Sandy-Clay	Clay	Sand & Gravel	Comments
5	A	0-24	24-84		84+	
6	A	0-14	14-75		75+	
7	A	0-14	14-72		72+	Possible sand patch
8	A	0-14	14-60		60+	
14	A	0-21	21-84		84+	
9	B	0-14		14-84	84+	
10	B	0-12	12-84		84+	
11	B	0-14		14-108	108+	
12	B	0-14		14-108	108+	
13	B	0-14	14-66		66+	
2	C	0-24	84-108	24-84	108+	
3	C	0-24	24-84		84+	
4	C	0-24	24-96		96+	
1	D	0-12	12-60		96+	60-96 Sandy-loam
15	D	0-15	15-84		84+	
16	D	0-14	14-84		84+	
17	D	0-12		12-96	96+	
18	Tern Pool	0-16		16-96	96+	
19	Tern Pool	0-15		15-96	96+	

A backhoe was used to dig deep test holes in the Cane Ridge Units to determine soil texture and the elevation of groundwater.

The type and texture of soil layers and the elevation of groundwater was measured in each test hole.

Crayfish

Crayfish appear to be rare at Cane Ridge with only two of their burrows being seen while field work was taking place. Crayfish may impact wetlands because their burrows can extend into the ground 26-feet or more. Crayfish burrows can end in permeable layers of soil or gravel containing water. Water can flow down crayfish holes and under the dam, causing wetlands to leak. However, crayfish are not able to burrow into clay soil that is compacted. Therefore, it is important to compact the clay soil placed in core trenches, and the clay soil used to cover sand patches when building and repairing wetlands.

Buried drain lines

Buried drain lines are likely present in the Cane Ridge Units. The wetlands were built on land that was intensively farmed in row crops for years. Actions were most likely taken to drain the fields to raise corn and soybeans. The topsoil and mineral soil found in the old fields, now surrounded by dams, is high in clay. The land is almost level, with slopes less than one-half of one-percent. Land that is both level and high in clay should have saturated soil, and areas with water standing on it. However, the Cane Ridge Units appear to be well-drained, with most areas resembling dry, fallow fields. In addition, no basins or shallow drainages were observed in the old fields, indicating they were filled and leveled for farming. Signs of historic wetlands can also be seen on old aerial photographs of the fields that were made into wetland units. These *ghosts* of drained wetlands are no longer visible and were mostly drained using clay tiles and plastic drain lines.

Another sign that buried drainage structures were used to drain the old fields prior to wetland construction is the low density of shallow ditches within and around the Cane Ridge Units. A high density of shallow and deep ditches should be seen if buried drainage structures were not used. The Cane Ridge Units contain few shallow ditches, and are bordered by deep drainage ditches. These deep ditches would have provided the outlet needed for installing a system of buried drainage structures, which are far superior to farming compared to a network of shallow ditches.

It is likely that buried drainage structures are now draining the Cane Ridge Units. The wetland dams were not built on a foundation made by digging a core trench and building a groundwater dam. No actions were designed or taken to identify or disable buried drain lines during construction of the wetlands. Any buried drain lines that were present are likely still functioning, even though topsoil was scraped off the surface to make the dams. The author was unsuccessful in contacting Mr. Phil Almon, Mr. Phillip Almon, or Ms. Angie Almon who used to farm the land to discuss their knowledge of drainage practices on the lands.

The dams should be cored to locate and disable buried drainage structures. Soil that is high in clay should be placed in the core trenches and compacted to form groundwater dams. The groundwater dams would greatly reduce water flowing under the dams, allowing water to fill and remain in the wetlands.

Permeable soil layers

Water is leaving the units by flowing under the dams. This is known from these observations:

1. Heath Hamilton notices that water begins flowing in shallow ditches outside of the dams after water is pumped into the wetlands. Water does not flow in these ditches when water is not being added to the units.
2. Test holes dug along the base of the dams found water traveling under the dams via layers of loose sandy-loam, sandy-clay, and sand.
3. The dams were built on topsoil. Topsoil acts like a sponge, allowing water to flow under the dams. The flow of water under the dams would be greatest when water levels are highest in the units.

Layers of sand and loose clay are allowing water to leave the wetlands by traveling under the dams. This problem can be expected to worsen when the wetlands are temporarily filled with water. The permeable layers should be blocked by constructing groundwater dams beneath the above ground dams.

Sand patches

Patches of sand and gravel found near the surface are most likely contributing to the drainage of the Cane Ridge Units. The contractor and heavy equipment operators who built the Tern Pool remember finding areas of sand near the surface during construction. Jeff West says that he covered sandy areas with soil that was high in clay using a dozer. However, it is very possible that other patches of sand were missed, that some of the sand patches had a thin layer of clay over them, and that the clay placed over the sand was not adequately compacted. It is important to note that the tracks of the dozer are capable of compacting soil to approximately 150lbs/square inch. Clay placed over a permeable layers should be compacted to over 300lbs/square inch to hold water. It is also possible that sand was exposed when the islands in the Tern Pool were constructed.

This field investigation identified one patch of sand in the Tern Pond, and another in Cane Ridge Unit A. The soil at these locations was loose and saturated, indicating that water was moving into the ground. The problem of water leaking out of units through sand layers becomes worse when the wetlands are filled with water. This is because increased water pressure produced by deeper water forces its way out of wetlands at a much greater rate.

The bottom of each unit including the Tern Pool should be carefully examined for areas where sand or gravel are near the surface. It was not possible to search for permeable layers near the surface because water was present in the wetlands at the time of this investigation due to flooding. Searching for sand or gravel would involve walking the bottom of each wetland in a systematic, grid-like pattern. A tile probe and small diameter soil auger should be used regularly test for the presence of sand or gravel near the surface. Other clues to the presence of sand or gravel should be used such as plant species composition, and soil moisture. The perimeter of each sand and gravel patch should be mapped with a GPS, and marked using stakes.

Patches of sand and gravel should be covered with at least 24-inches of clay that is compacted. Sand may be removed and piled to provide habitat for shorebirds and turtles. The clay used to cover the sand may be obtained from the bottom of the wetlands. However, the thickness of original, non-compacted clay remaining should be monitored closely to make certain that it is not reduced to less than 4-feet.

Water control structures

The water control structures placed in the Units at Cane Ridge were manufactured by:

Fiberglass Utility Supplies, Inc.
1465 - 250th St.
Libertyville, IA 52567

Phone: 641-693-3311
Fax: 641-693-4131

Factory- installed rubber gaskets were are used to seal the moveable plates in the water control structures. These gaskets should be replaced. The gaskets are compressed and torn, causing water to leak from the Units. The amount of water leaving the Units can be expected to be much greater when water levels are higher in the wetlands.

The water control structures placed in Units A-D were manufactured by Fiberglass Utility Supplies, Inc. They contain plates for adjusting water levels in the wetlands.

The gaskets on the plates are torn and flattened, causing the wetlands to leak.

Topsoil placed in dams

The dams were made from topsoil which is not an acceptable practice with pond or wetland construction. The topsoil contains pockets of sand and organic material that is allowing water to seep out of the wetlands. The amount of water leaving the wetlands can be expected to increase when water levels rise in the wetlands from pumping or from floods. A layer of clay at least 24-inches thick should be placed over the inside slope of each dam to prevent water from seeping through the dams. This clay should also be compacted.

Oil wells in wetlands

Oil wells are located in the units. Fortunately, records show these oil wells were plugged. The oil well casings were cut off below the plow zone in the fields before they were plugged. However, the oil wells may be causing the wetlands to leak if they were not plugged to standard. Efforts should be taken to find the oil wells in the Units. Clay should be compacted over the plugged oil wells as a precaution if they are found. Care should also be taken during reconstruction not to disturb the oil wells with heavy equipment.

Topsoil sponge effect

The majority of precipitation now entering the wetlands could be simply soaking into the ground. The wetlands were agricultural fields that had been plowed for years. The plow zone contains loose soil that is not compacted, and is made from sand, silt, clay, and organic material that is permeable. The Cane Ridge Units do not receive runoff from streams or ditches, so most of the precipitation entering the wetlands may be soaking into the topsoil. To reduce this problem the topsoil should be interrupted by a number of constructed shallow basins. These shallow basins should contain little, if any topsoil, and be based on soils that are high in clay. The clay soils in the basins should be compacted. Evidence of this concept working is found throughout the Cane Ridge Units. Areas where topsoil was removed to build the dams contain water much longer than the wetland basins where topsoil was not removed.

Adding runoff

One of the most effective ways of increasing the amount of time water stays in a wetland is to add more water to the wetland. This is generally done by moving a ditch or stream so that runoff flows into the wetland. What is unusual about the Cane Ridge Units is that no ditches or streams enter the wetlands. Unless water is pumped, direct precipitation from rain or snow is the only way the Units receive water. Annual precipitation in the region should be adequate to develop and maintain wetlands that meet the management objectives, *providing the water entering the* *wetlands is not being carried away by buried drainage structures or soaking into the permeable topsoil.*

An abandoned railroad borders the Cane Ridge Unit Wetlands on the west side. A deep ditch was dug along either side of the railroad when it was built. The deep ditch provides the outlet needed by farmers to install buried drainage structures at Cane Ridge. The ditch is now largely plugged, and has filled with water. However, the ditch still dries in the summer, meaning water is still flowing out from the ditch.

The dams on the Tern Pool, Unit C and Unit D may be modified to join the old railroad grade, adding runoff now being carried along one side of the railroad ditch into the wetlands. However, the land near the Railroad and Railroad ditch is not owned by the U.S. Fish and Wildlife Service, so this modification may not be possible.

Blair Ditch borders the Tern Pool and Unit A to the north. Blair ditch was constructed in the 1970s to replace another ditch that was modified by Duke Energy. Blair Ditch carries a large volume of water. Elevations taken by this investigation show that the bottom of the Tern Pool and Unit A are more than 6-feet higher than the elevation of water in Blair Ditch. A dam would need to be built across Blair Ditch to divert water into the wetlands. This action is not feasible, as it would likely inundate private property. A more feasible option may be to lower the elevation of the high bank along Blair Ditch paralleling the wetlands. Water could then flow from the ditch into the wetlands under flood conditions. However, this action may not be feasible because it may flood Duke Energy property, and a portion of a County Road.

Table 3. Recommended Actions for Cane Ridge Wetland Units A-D, and the Tern Pool

Observation	Problem	Recommended Actions
Water in Units A, B, C, and D and the Tern Pool must be maintained by pumping. It is currently not possible to fill the wetlands by pumping.	Water is leaking into the ground, and under the dams	Repair the wetlands so they hold water as planned.
The dams were not cored for construction	Drain lines are present that are moving water under the dams	Dig a core trench and build a groundwater dam along the inside slope of each dam
The dams are made from topsoil. The topsoil contains organics and sand	Water is leaking through and under the dams	Cover the inside slope of each dam with at least 24-inches of compacted clay
Permeable layers of sand, topsoil, and loose layers of sandy-clay are present under the dams.	The permeable layers are allowing water to leave the wetlands by flowing under the dams. Leakage increases	Dig a core trench and build a groundwater dam along the inside slope of each dam

Observation	Problem	Recommended Actions
	when water levels are high in the wetlands.	
Sand and gravel patches are present near the surface	Water can flow directly into the ground, leaving the wetlands	Identify and mark all areas of sand and gravel near the surface of the Units Cover permeable patches with 24-inches of compacted clay.
The plates on the water control structures are loose and portions of gasket material are missing	Water is leaving the Units via leaks in the water control structures	Replace the gaskets in the water control structures.
The dams are high with steep slopes	Muskrats can tunnel into the dams, causing leaks The dams require mowing to prevent trees and shrubs from causing leaks Once repaired the water would be too deep to meet management objectives for waterfowl and shorebirds Wave action can cause damage to high dams with steep slopes	Lower the elevation of the dams on Units A-D by approximately 1.5-feet. Modify the slopes on each dam to be no steeper than 5-percent Set the elevation of the water control structures 0.5-feet below the top of the dams on Units A-D.
Water stands in areas where topsoil and clay have been removed	The topsoil is absorbing precipitation over most of the wetland basins	Excavate a series of shallow depressions where topsoil is removed and clay is compacted in the bottom of the depressions
The Units lack structural diversity	Low quality habitat is provided to waterfowl and shorebirds	Vernal pools, ridges, peninsulas, sand bars, islands, large woody debris, and snags should be added to the wetlands
Runoff from surrounding land does not enter the wetlands	The wetlands rarely contain water	Modify the dams on the Tern Pond, Units C and D so they intercept the water flowing in the ditch along the old railroad grade
Oil wells are located in the Units. These are supposed to be plugged	The oil wells may be allowing water to leave the wetlands. The oil wells may be accidently exposed and opened during soil moving operations.	Identify oil well locations Place mounds of compacted clay soil over each oil well

Observation	Problem	Recommended Actions
While repairs are being made		
Soil conditions may be different than expected during construction of the core trench	Permeable layers are missed	Government Project Manager is on site full time monitoring the construction of the core trench
Buried drain lines are not seen during construction of the core trench by heavy equipment operators	Wetland will fail to hold water as planned	Government Project Manager is on site full time monitoring the construction of each core trench
The clay placed in the core trench is not compacted	Water will continue to leak under the dam	Government Project Manager is on site full time monitoring compaction using a penetrometer
Soil high in clay is not placed over sand and gravel lenses	Wetland will fail to hold water as planned	Government Project Manager is on site full time monitoring the clay content of soil used
Too much clay is removed from the surface during construction	Additional leaks are created	Government Project Manager is on site full time monitoring the thickness of clay layers where clay is removed
Following repairs		
Driving on top of the dams	May leave ruts and cause erosion	The tops of the dams are graveled, or people do not drive on the dams

Wetland renovation

Features may be added to the wetlands while repairs are taking place that increase biodiversity. These features will help the wetlands meet their management objectives. The features may include ephemeral wetlands, ridges, peninsulas, sand bars, islands, large woody debris, and snags.

Shallow depressions

Water stands in areas where topsoil and sandy-clay were removed to build the dams. This water can remain until the end of summer. At the same time there is little if any water in the constructed wetlands. The thick layer of topsoil where soils were loosened by plowing appears to be absorbing the majority of rainfall entering the wetlands. A series of depressions may be dug in the bottoms of the units to restore natural ephemeral and emergent wetlands. The shallow depressions should extend under the topsoil and into the clay layer below. The sandy-clay or clay texture soil should be compacted in these depressions. A thin layer of topsoil may be spread over the compacted clay. The remaining topsoil can be used to make mounds. These depressions should not be dug over historic oil wells.

Peninsulas

Peninsulas provide loafing sites for waterfowl and foraging habitat for shorebirds. They can be made from sand, sandy clay, or topsoil. Peninsulas can also be used by turtles for nesting. The features greatly improve opportunities for viewing wildlife.

Islands

Island provide loafing sites for waterfowl and foraging habitat for shorebirds. They can be made from sand, sandy clay, or topsoil. Islands can be used by turtles for nesting, and are great places to view wildlife.

Large woody debris

Large logs and tree limbs may be placed in the wetlands to provide perches for birds and basking sites for turtles. Waterfowl will make great use of fallen trees in wetlands for roosting and preening. The logs should be anchored using soil so they do not float away during floods. The large woody debris should not contain chainsaw cuts that appear unnatural and provide poor habitat.

Snags

Snags are used by birds for perching and for foraging. Bats use snags for roosting, and for maternity sites. The Bald Eagle and Osprey make great use of snags in wetlands. Snags of various diameters and heights should be set in the wetlands. The snags should not contain chainsaw cuts that appear unnatural and provide poor habitat.

Specifications for repairing and rebuilding the wetland units

Specifications were prepared for repairing and rebuilding the Cane Ridge Unit Wetlands. These specifications should apply under a Service Contract, or a Construction Contract:

Dam rebuilding

A. Dam lowering:

1. The elevation of the top of the dam will be lowered to the elevation marked on the ground by the Project Manager, which will be approximately 1.5-feet lower than the existing elevations.
2. The soil removed from lowering the dam will be used to: 1) form more gradual slopes on the backside of the dam so the dam will not require mowing, 2) make islands and peninsulas, or 3) spread thinly over areas of compacted clay.
3. The finished top of the dam will be a minimum of 12-feet wide.

B. Core & Groundwater Dam:

1. A core trench will be dug along the entire length of the dam. The core trench will be located by the Project Manager so that it is beneath the inside slope of the dam.
2. The inside slope of the dam will be removed prior to digging the core trench. The soil removed from the inside slope of the dam will be used to: 1) form more gradual slopes on the backside of the dam, 2) make islands and peninsulas or, 3) spread over the completed groundwater dam and inside slope of the dam.
3. The core trench for the groundwater dam will be 12-feet or wider.
4. The core trench will extend into the ground below the clay and sandy-clay soil. The core trench will extend into the sand and gravel layer approximately 1-foot. The final depth of the core trench will be determined by the Project Manager.
5. Soil removed to dig the core trench that is low in clay will be kept separate from soil that is high in clay. Soil that is high in clay is defined as clay, sandy-clay, or silt-clay. One can make a thin ribbon at least 2-inches long from soil that is high in clay. The Project Manager will make the final determination on what soil is high in clay.
6. Soil that is high in clay will be placed in the core trench after it is dug. The soil high in clay will be placed in layers averaging 6-inches thick, with each layer being compacted to 300lbs/square inch or more. A penetrometer will be used to measure compaction. The entire surface of soil placed in the core trench will be compacted using a large rubber-tired Skid steer (large), or equivalent. The Project Manager will determine when soils are adequately compacted.
7. The soil placed in the core trench to form the groundwater dam will be the right soil moisture content to obtain compaction. Soils that are high in clay may be mixed with other soil that is high in clay of various moisture contents to obtain moisture content for compaction.
8. Water that enters the core trench will be removed prior to filling with soil high in clay to obtain compaction.
9. The final elevation of the groundwater dam and the above ground dam will be determined by the Project Manager.

C. Inside slope of dam:

1. The inside slope of the dam will be made from soil that is high in clay.

2. The inside slope of the dam will be made from soil that is high in clay, that is placed in layers averaging 6-inches thick, with each layer being compacted.
3. The inside slope of the dam must contain at least 24-inches of soil that is high in clay and compacted.
4. The finished slope on the inside of the dam will average 5-percent so it will no longer require mowing, and not be damaged by muskrats.

Dam rebuilding estimated progress rates:

a) Dozer 25 linear feet/hour
b) Excavator = 25 linear feet/hour
c) Skid steer (large) with rubber tires = 25 linear feet/hour

Clay Sources:

1. Soil that is high in clay will be needed to build the groundwater dam, and to complete the inside slope of the dam.
2. Soil that is high in clay may be obtained by removing it from the basin of the wetland unit being repaired.
3. Care must be taken to avoid removing too much clay from one place. A layer of clay at least 4-feet thick must be maintained over the bottom of each wetland unit. The Project Manager will work with the Contractor to monitor the thickness of the clay layer. This will be done by periodically digging and filling test holes using hand tools and heavy equipment provided by the Contractor.

Sand Patches

1. Areas of sand and gravel will be marked by the Project Manager. These will be covered with compacted clay at least 24-inches thick.
2. Topsoil will be removed from each area of sand or gravel before covering with clay.
3. The perimeter of the clay patch will be connected with surrounding clay soils so that water does not flow from the surface and under the clay patch. The clay soil will be compacted to at least 300lbs/inch^2, as measured by the Project Manager using a penetrometer.
4. A thin layer of topsoil will be spread over the completed clay patch as directed by the Project Manager.
5. Ephemeral wetland depressions will be shaped in areas where soil is removed to cover sand and gravel patches

Average size estimated to be 60-foot diameter, round or oval shape, 3,000 ft^2. The actual sizes and locations will be determined by the Project Manager.
Average density estimated to be 4 sand patches per wetland unit. The actual number will be determined by the Project Manager.

Sand and gravel patch repair estimated progress rates

a) Dozer = 550 ft^2/hour, or 6 hours/sand patch
b) Wheel Loader = 550ft^2/hour, or 6 hours/sand patch

Ephemeral Wetland Depressions

1. Topsoil will be removed to a depth determined by the Project Manager (ranging from 12 to 24-inches deep) from within each area to be made into an ephemeral wetland, as marked by the Project Manager.
2. The soil that is high in clay from under where topsoil is removed will be shaped into a shallow depression, from 8 to 20-inches deep, with slopes 5-percent or less.
3. The top 12-inches of the soil that is high in clay in the depression will be compacted by using a wheel loader or equivalent to at least 300lbs/$inch^2$
4. A thin layer of topsoil (4-inches or less), as determined by the Project Manager, will be spread over the depression.
5. Ephemeral wetland depressions would also be shaped in areas where soil is removed for covering sand and gravel patches
6. Remaining topsoil will be shaped into islands or peninsulas.

Average size estimated to be 60-foot diameter, round, oval, or irregular shapes, 3,000ft^2
Average depth estimated to be 24-inches
Average density to be built = 1 for every 2-acres within wetland unit basin

Ephemeral wetland construction estimated progress rates

a) Dozer = 550 ft^2/hour or 6 hours per ephemeral wetland
b) Wheel Loader = 550 ft^2/hour or 6 hours per ephemeral wetland

Islands

Islands of various size, shape, elevation, and soil texture will be made within the wetland unit basins. The approximate locations of these islands is shown on the map of each wetland to be rebuilt. The final location, shape, and size of each island will be determined by the Project Manager. The islands will generally be made from topsoil, sand, or gravel that is available on site.

Average size estimated to be 60-foot diameter, round or oval shape, 3,000ft^2
Average height estimated to be 24-inches
Average density estimated to be 1 for every 2-acres within wetland unit basin

Island construction estimated progress rates:
Dozer = 600 ft^2/hour or 5 hours per island

Peninsulas

Peninsulas of various size, shape, elevation, and soil texture will be made within the wetland basins. The approximate locations of each Peninsula is shown on the map of each wetland to be rebuilt. The final location, shape, and size of each Peninsula will be determined by the Project Manager. The Peninsulas will generally be made from topsoil, sand, or gravel that is available on site.

Average top width estimated to be 12-feet
Average length estimated to be 100-feet
Average height estimated to be 24-inches
Average density estimated to be 1 per every 4-acres of wetland basin

Peninsula construction estimated progress rates:
Dozer = 600 ft^2/hour or 5 hours per peninsula

Large Woody Debris

Logs, trees, and root masses will be placed in the wetland units to improve habitat for wildlife and plants. This material will be delivered to designated staging areas by the Government. The large woody debris will be anchored by burying portions of logs and branches with soil.

Average density = 4/acre
Large woody debris placement estimated progress rates
Dozer = 1-log placed/15 minutes = 4 logs/hour

Snags

Dead trees of various height and diameter will be placed vertically in the wetland units. The end of each tree will be buried so that the snag will not fall over.

Average density = 1/acre
Snag placement estimated progress rates
Excavator = One snag placed/30 minutes = 2 snags/hour

Wheat

Wheat of any variety should be spread on the exposed soil of rebuilt dams for erosion control. Wheat can be expected to germinate within 3-days of rain. Wheat should be sown at an estimated rate of 1-50lb bag/100-feet of dam repaired. Wheat is estimated to cost $20.00/50lb bag.

Native Seed

Native species of grasses and wildflowers may be sown on exposed soil for erosion control, and to provide habitat for pollinators. Native seed may be applied at a rate of 1-lb/100-feet of dam repaired. Native seed is estimated to cost $20/lb.

Heavy Equipment Needs & Estimated Rates

For all work described:
Excavator, 200-Series (one needed with operator)
148 HP minimum
47,000lbs minimum
Bucket that is 60-inches wide
On tracks, not wheels
$180.00/hour[6]

For all work described:
Dozer with 6-way blade
Rated net power = 115 HP or greater
Operating weight = 32,000 lbs. or greater
$160.00/hour
(It is recommended that two dozers with operators be working on the site at the same time)

For placing clay over sand and gravel patches, and for compacting ephemeral wetland depressions:
Wheel Loader, Komatsu WA320, 4 cubic yard bucket, rubber tires, 166HP, 30,754lbs or equivalent
$160.00/hour

For filling core trenches to build groundwater dams:
Large Skid steer (large) with rubber tires or equivalent
$120.00/hour

[6] Prices listed are estimates for planning purposes

Project Manager

The estimated budget for the Project Manager = $799/day. This price includes salary, travel, and per-diem. Tom Biebighauser is interested in serving as the Project Manager, and would train agency personnel how to do this job with future wetland projects.

Contract Types

A Service Contract should be used to complete the Cane Ridge Wetland Project. Under a Service Contract the Contractor provides the heavy equipment and skilled operators needed to accomplish the job. The work is directed by the Project Manager. Under a Construction Contract a detailed design, set of plans, and specifications are prepared. The Contractor submits a bid for completing the project. Prices are much higher because one cannot see underground. The thickness of clay and sand layers may vary, and there is no certainty how far one must travel to find clay to cover sand and gravel patches. The Contractor would inflate the bid to cover costs that are difficult to estimate.

The award of the Service Contract (where the work is completed by the hour) should be based on the following criteria:

1. Type, year, and size of heavy equipment available for use
2. The performance of each individual heavy equipment operator
3. Price

The U.S. Fish and Wildlife Service would determine the starting and ending date of the project, along with number of hours worked each day. Using a Construction Contract would greatly increase the cost of completing the project, and would not reduce the need for a Project Manager to be on site during construction.

Project Management

A project manager should be onsite at all times to direct and monitor construction operations. This person must be highly skilled with wetland restoration techniques. The Project Manager should monitor:

1. Soil moisture
2. Soil texture
3. Clay layer thickness
4. Location of sand and gravel patches
5. The shape, size, depth, and location of wetland basins restored
6. The thickness of clay layers being placed or left overlaying subsurface permeable layers
7. Compaction by using a penetrometer
8. Construction of the core trench and groundwater dam
9. The placement of excess soils

10. Topsoil storage and spreading
11. Large woody debris placement
12. Snag placement

Work Progression

It is recommended that the wetland units be repaired over a number of years. Consider beginning the project by repairing the Tern Pond, or Cane Ridge Unit D. This way techniques can be fine-tuned and contractors trained to meet the stated management objectives before other wetlands are repaired. One can expect to learn much by first rebuilding one wetland that can be applied to renovating the other wetlands.

Table 4. Estimated Budget for Repairing and Rebuilding Wetland Units
Tern Pool (60 acres, length of dam = 6, 066-feet)

Item	**Units**	**Excavator hours**	**Dozer hours**	**Wheel Loader hours**	**Skid Steer hours**	**Project Manager days**	**Wheat** 50lb. bags	**Native seed** lb.
Dam Rebuilding	6,066 feet	243	243		243	25	60	60
Sand patch repair	4 each		24	24		2		
Ephemeral wetland	0							
Islands	0							
Peninsulas	4 each		20			2		
Large woody debris	30 each		8			1		
Snags	10 each	5						
Total		248	295	24	243	30	60 bags	60lbs
Price/Unit		$180	$160	$160	$120	$799	$20/bag	$20/lb
Cost		$44,640	$47,200	$3,840	$29,160	$23,970	$1,200	$1,200
Total Cost	**$151,210**							

Table 5. Estimated Budget for Repairing and Rebuilding Wetland Units
Wetland Unit A (25 acres, length of dam = 3,818-feet)

Item	**Units**	**Excavator hours**	**Dozer hours**	**Wheel Loader hours**	**Skid Steer hours**	**Project Manager days**	**Wheat** 50lb bags	**Native seed** lbs.
Dam Rebuilding	3,818 feet	153	153		153	15	38	38
Sand patch repair	6 each		36	36		3		
Ephemeral wetland	12		72	72		7		
Islands	12		60			6		
Peninsulas	6		30			3		
Large woody debris	100 each		25			2		
Snags	25 each	12				2		
Total		165	376	108	153	38	38	38
Price/Unit		$180	$160	$160	$120	$799	$20/bag	$20/lb.
Cost		$29,700	$60,160	$17,280	$18,360	$30,362	$760	$760
Total Cost	**$157,382**							

Table 6. Estimated Budget for Repairing and Rebuilding Wetland Units
Wetland Unit B (57 acres, length of dam = 7,528-feet)

Item	**Units**	**Excavator hours**	**Dozer hours**	**Wheel Loader hours**	**Skid Steer hours**	**Project Manager days**	**Wheat** 50lb bags	**Native seed** lbs.
Dam Rebuilding	7,528 feet	301	301		301	30	75	75
Sand patch repair	4 each		24	24		3		
Ephemeral wetland	28		168	168		16		
Islands	28		140			14		
Peninsulas	14		70			7		
Large woody debris	228		57			5		
Snags	57	28				2		
Total		329	760	192		77		
Price/Unit		$180	$160	$160	$120	$799	$20/bag	$20/lb.
Cost		59,220	121,600	30,720	36,120	61,523	1,500	1,500
Total Cost	**$312,183**							

Table 7. Estimated Budget for Repairing and Rebuilding Wetland Units
Wetland Unit C (68 acres, length of dam = 7,744-feet)

Item	**Units**	**Excavator hours**	**Dozer hours**	**Wheel Loader hours**	**Skid Steer hours**	**Project Manager days**	**Wheat** 50lb bags	**Native seed** lbs.
Dam Rebuilding	7,744 feet	309	309		309	30	78	78
Sand patch repair	4 each		24	24		3		
Ephemeral wetland	34		204	204		19		
Islands	34		170			15		
Peninsulas	17		85					
Large woody debris	272		68			5		
Snags	68	34				3		
Total		343	860	228	309	75	78	78
Price/Unit		$180	$160	$160	$120	$799	$20/bag	$20/lb.
Cost		61,740	137,600	36,480	37,080	59,925	1,560	1,560
Total Cost	**$335,945**							

Table 8. Estimated Budget for Repairing and Rebuilding Wetland Units
Wetland Unit D (43 acres, length of dam = 4,094-feet)

Item	**Units**	**Excavator hours**	**Dozer hours**	**Wheel Loader hours**	**Skid Steer hours**	**Project Manager days**	**Wheat** 50lb bags	**Native seed** lbs.
Dam Rebuilding	4,094 feet	164	164		164	16	40	40
Sand patch repair	3 each		20	20		2		
Ephemeral wetland	21		126	126		12		
Islands	34		170			10		
Peninsulas	10		50			4		
Large woody debris	172		43			3		
Snags	43	20				2		
Total		184	573	146	164	49	40	40
Price/Unit		$180	$160	$160	$120	$799	$20/bag	$20/lb.
Cost		33,120	91,680	23,360	19,600	39,151	800	800
Total Cost	**$208,511**							

Grand Total for repairing the Tern Pool and Cane Ridge Wetland Units A-D = $1,165,231.00

Table 9. Estimated progress rates used to estimate the budget for repairing and renovating the Cane Ridge Wetland Units[7]

Dam rebuilding:
Dozer 25 linear feet/hour
Excavator = 25 linear feet/hour
Skid steer (large) with rubber tires = 25 linear feet/hour

Sand and gravel patch repair:
Dozer = 550 ft^2/hour, or 6 hours/sand patch
Wheel Loader = 550ft^2/hour, or 6 hours/sand patch

Ephemeral wetland construction:
Dozer = 550 ft^2/hour or 6 hours per ephemeral wetland

[7] Used to prepare the Estimated Budget for Repairing and Rebuilding Wetland Units

Wheel Loader = 550 ft^2/hour or 6 hours per ephemeral wetland

Island construction:
Dozer = 600 ft^2/hour or 5 hours per island

Peninsula construction:
Dozer = 600 ft^2/hour or 5 hours per peninsula

Large woody debris placement:
Dozer = 1-log placed/15 minutes = 4 logs/hour

Snag placement:
Excavator = One snag placed/30 minutes = 2 snags/hour

Wheat: 1-50lb bag/100-feet of dam repaired.

Native seed: 1-lb/100-feet of dam repaired.

Photographs

Photographs showing how wetlands can be made from deep ponds are available for viewing at:
https://picasaweb.google.com/105985116543820569589/WetlandConstructionFromDeepPonds#

Photographs showing restored wetlands are available for viewing by visiting:

Wetlands Restored and Created
https://picasaweb.google.com/105985116543820569589/WetlandsRestoredAndCreated#

Dix River Stream and Wetland Restoration Project
https://picasaweb.google.com/105985116543820569589/DixRiverStreamAndWetlandRestorationProject#

Queens Wetland Restoration Project
https://picasaweb.google.com/105985116543820569589/QueensWetlandRestorationProject#

Slabcamp Creek and Stonecoal Branch Stream and Wetland Restoration Project
https://picasaweb.google.com/105985116543820569589/SlabcampCreekStonecoalBranchStreamAndWetlandRestorationProject#

Wetlands Restored in Autumn
https://picasaweb.google.com/105985116543820569589/WetlandsRestoredInAutumn#

The Cane Ridge Units can be transformed into naturally appearing and functioning wetlands that require little, if any maintenance.

Summary

The constructed units on the Cane Ridge Wildlife Management Area of the Patoka River National Wildlife Refuge can be repaired so they appear and function like natural wetlands. The units can be made to hold the water entering them from precipitation by controlling how water soaks into the ground and travels under the dams. The units can be renovated to greatly improve habitat for migratory waterfowl, shorebirds, and wading birds by adding ephemeral wetlands, islands, peninsulas, large woody debris, and snags. The wetlands can be improved so they require little, if any maintenance.

Prepared by:

Thomas R. Biebighauser
Wildlife Biologist and Wetland Ecologist
Wetland Restoration and Training LLC
3415 Sugar Loaf Mountain Road
Morehead, KY 40351

Email: tombiebighauser@gmail.com
Website: www.wetlandrestorationandtraining.com
606-784-6175 (phone)
606-356-4569 (cell)