USDA FOREST SERVICE
SOUTHERN RESEARCH STATION

ASSESSING WETLAND RESTORATION PRACTICES ON SOUTHERN AGRICULTURAL LANDS:
The Wetlands Reserve Program in the Southeastern Coastal Plain

FINAL REPORT to the U.S. Department of Agriculture
Natural Resources Conservation Service, CEAP–Wetlands

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November 14, 2011

ACKNOWLEDGMENTS. Many thanks to CEAP–Wetlands Science Coordinator Diane Eckles for critical support of this study. We greatly appreciated the very helpful cooperation from NRCS State and Field Office staffs in South Carolina, Mississippi, and Georgia, especially WRP Coordinators Glenn Sandifer (SC), Mike Oliver (MS), and Keith Wooster (GA). We also thank the private landowners for facilitating access to their WRP sites. Steven Hughes assisted in field work, plant identification, data compilation, and GIS work, with additional help from Kristi Wharton (GIS data) and from Kristie Burr, Cody Clark, and Anne Cubeta (data entry, plant i.d.). Ray Souter provided statistical advice. The study was supported by USDA NRCS–CEAP and the U.S. Forest Service Southern Research Station, including a Forest Service Joint Venture Agreement with The Citadel Graduate College.

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SYNOPSIS

Wetlands provide significant ecosystem services that include floodwater storage, water-quality improvement, biodiversity support, and wildlife habitat. Under U.S. Farm Bill programs, numerous defined conservation practices may be installed to reduce the impacts of agriculture on environmental quality. Certain practices are aimed specifically at maintaining or restoring wetland ecosystem services. The Wetlands National Component of the NRCS Conservation Effects Assessment Project (CEAP–Wetlands) is conducting region-based studies to assess and model the ecological benefits of such wetland practices (see Duriancik et al. 2008, Eckles 2011). Wetland restoration, a core practice applied mainly under the Wetlands Reserve or Conservation Reserve Programs, has received considerable study in agriculture-dominated areas such as the Northern Prairie Pothole (PPR) and Mississippi Alluvial Valley (MAV) regions (Gleason et al. 2011, Faulkner et al. 2011). However, in the forest-dominated Southeastern Piedmont–Coastal Plain region, information on the nature and outcomes of Farm Bill program wetland restorations was found to be scarce or non-existent (De Steven & Lowrance 2011).

Two features of the Southeastern region have important implications for assessing the ecosystem services provided by wetland practices and programs. First, agriculture comprises only about 20% of land use (USDA 2006; see Fig. 1), which potentially limits the landscape extent of program activity compared to agriculture-dominant regions. Second, most wetland hydrogeomorphic (HGM) classes are frequent in the region, despite historical wetland losses to both agricultural and forestry activities (Hefner & Brown 1985, Hefner et al. 1994). High wetland diversity complicates assessment because HGM types differ in hydrodynamics and thus in their relative contributions to various ecosystem services (Brinson & Reinhardt 1998, NRCS 2008, Smith et al. 2008). In a region of diverse wetlands, understanding the wetland types restored and their interaction with restoration practices can enhance the ability to assess gains in ecosystem services (De Steven & Lowrance 2011). It can also identify relevant variables to incorporate into regional assessment models.

Principal freshwater wetland HGM types of the Southeastern Piedmont–Coastal Plain and their relative contributions (from lower to higher) to provision of regional ecosystem services

Ecosystem Service	Riverine	Mineral-soil flat	Organic-soil flat	Depressional
Floodwater attenuation	high	low	low	low
Rainwater storage	medium	high	high	medium to high
Water-quality improvement	high	low	low	low to medium
Soil carbon sequestration	medium to high	low	high	low to high
Biodiversity and habitat	high	high	high	high

This study establishes a baseline foundation for ecosystem services assessment by describing the key characteristics of wetland restoration projects on Wetlands Reserve Program

(WRP) lands in three states (South Carolina, Georgia, Mississippi) spanning the Southeastern Piedmont and Coastal Plain. Following from a preliminary report on South Carolina projects (De Steven 2009), this final report summarizes the region-wide findings to: 1) identify the wetland HGM types being restored, 2) document the restoration practices used and whether the practices establish original or modified HGM functions/services, and 3) determine if restored sites show positive wetland condition indicators as a measure of restoration success. Based on a robust sample of 109 projects enrolled in the WRP from 1996 to 2004, this survey provides the first comprehensive picture of WRP restorations in the Southeast region.

Findings. The WRP projects were unevenly distributed geographically, reflecting different state-level activity, but they encompassed diverse wetland types and prior habitat conditions. Nearly half the projects were prior-converted wetlands retired from active agriculture, whereas the remainder were vegetated wetlands or bottomlands formerly degraded by ditching or by timber harvesting. Repairing altered hydrology or retaining natural hydrology was a primary emphasis in all projects. The hydrology practices used were partly adapted to wetland type, with varying functional implications. Restoration of vegetative cover generally relied on natural succession, with tree planting used more actively on prior-agriculture sites. Based on field surveys of selected sites, most project wetlands had positive indicators of functional wetland hydrology, vegetation, and faunal use. In the Southeastern WRP, the wide variation in wetland types, prior habitat conditions, and tract sizes has landscape-level implications for ecosystem services gained from individual projects. Enrollment of degraded forested floodplains was a distinctive feature of the WRP in South Carolina, where floodplain easements now total nearly 48,000 acres to date.

METHODS

The NRCS National Conservation Planning Database (NCPD) was queried initially for all practice records of Wetland Restoration (#657) and Wetland Creation (#658) reported as applied during 2000–2008 on privately-owned program lands in the five Southeastern states of South Carolina, Georgia, Alabama, Florida (excluding the Everglades), and "Coastal Plain" Mississippi (excluding the MAV). Nearly all records were in the Wetlands Reserve Program (WRP). The query yielded minimal records of wetland creation, so we focused the study on WRP wetland restorations in three states (SC, GA, MS) with the most reported activity (Fig. 1). We worked with the respective NRCS State Offices to link practice records to completed WRP projects, and supplemented the dataset with some projects not reported in the NCPD. The result was a sample of 109 wetland projects enrolled in WRP during 1996–2004 and completed by 1998–2008 (Table 1). For purposes of this study, a "project" is a defined wetland or tract with coordinated planning that may involve multiple landowner contracts and data records. The sample represented nearly all GA and MS contracts and ~55% of the more numerous SC contracts for the 9-year enrollment period, with some under-sampling of the earliest SC projects. Projects spanned all physiographic sub-regions, and 95% were either 30-year or permanent easements (Table 1).

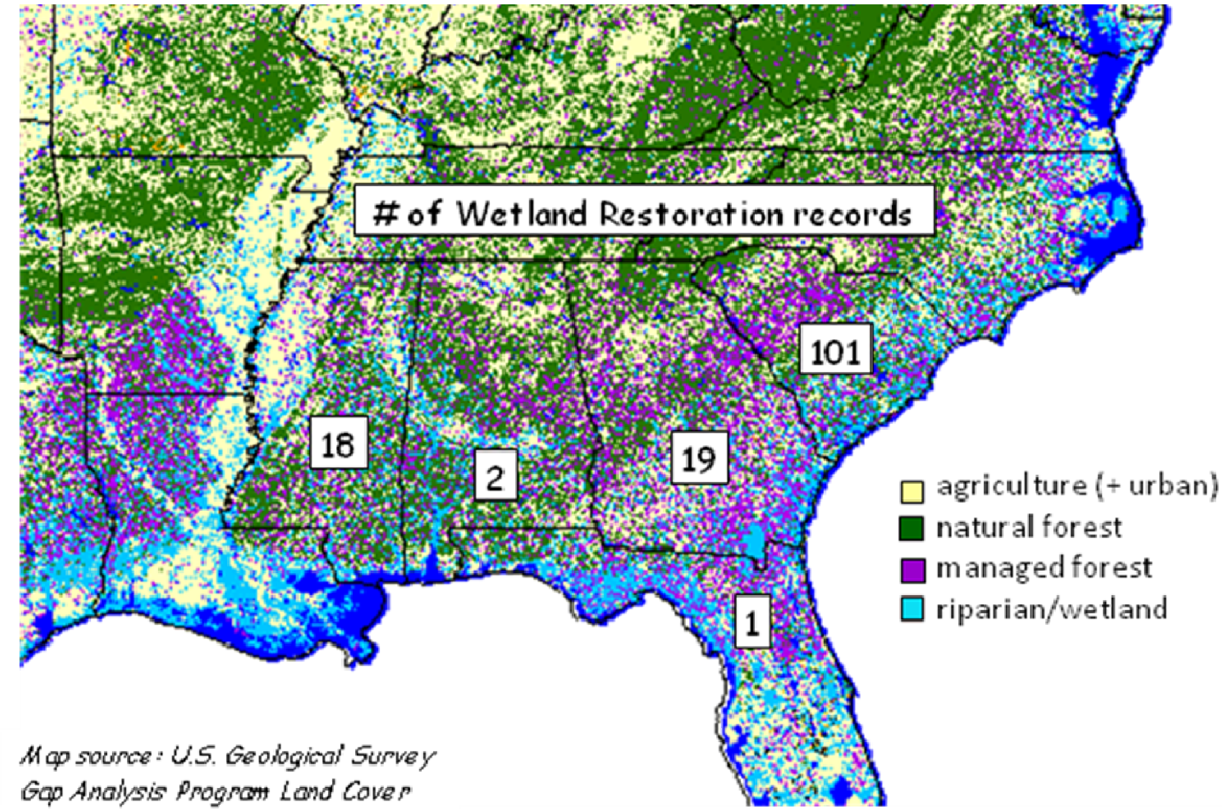

Figure 1. Southeast U.S. land cover, with relative frequency of the Wetland Restoration practice reported in the Piedmont–Coastal Plain of five states during 2000-06 (preliminary NCPD data).

To describe the basic features of the restorations, each project was characterized as to wetland HGM type restored, habitat condition prior to restoration, extent of mapped hydric soils, tract size (area), and the NRCS conservation practices used in the project plan (Appendix 1). Relevant data were compiled from USGS 30′x60′ and 7.5′ topographic maps, aerial photos, NRCS Web Soil Survey maps, the written conservation plans, and other information in the project files. For the main restoration practices, 3-way contingency analyses (log-linear models) were used to test if practice frequency differed with project HGM type or prior habitat condition. Differences would indicate whether restoration methods were adapted to wetland characteristics, and also whether hydrology practices would establish original or modified hydrologic function.

Detailed quantitative field assessments were beyond the scope of the study, so we evaluated whether restoration projects successfully established functional wetland conditions at a qualitative level. A subsample of 53 projects (Table 1) was selected for a one-time visit to score for field indicators of wetland hydrology, vegetation, and faunal presence. Nearly all GA and MS projects were visited (24 of 31), excluding a few that were redundant or completed too recently

Table 1. Features of 109 Southeastern WRP restoration projects evaluated, by state and overall.

	South Carolina	Georgia	Mississippi*	All
Number of projects†	78	17	14	109
Number of WRP contracts	87	19	12	118
Number of projects by physiographic sub-region:				
Piedmont	9	0	–	9
Hilly Coastal Plain, incl. MS Silty Uplands	41	15	14	70
Coastal Flats	28	2	0	30
Number of projects by agreement type:				
10-year cost-share	5	0	0	5
30-year easement	23	3	6	32
permanent easement	50	14	8	72
Total project area enrolled, in acres (hectares)	26,416 (10,690)	7,200 (2,914)	2,381 (964)	35,997 (14,568)
Range of WRP enrollment years	1996-2004	1996-2004	1997-2002	1996-2004
Range of project completion years ‡	1998-2009	1998-2009	2000-2007	1998-2009‡
Number of projects field-surveyed in 2010	29	13	11	53

* Coastal Plain portion only (excludes the "Delta"/Mississippi Alluvial Valley sub-region)
† a "project" is a distinct planned wetland or contiguous wetland tract that may have >1 associated WRP contract
‡ excepting 2 projects completed in 2009, the overall range for completion year was 1998–2008

for valid field assessment. In SC, we chose a random subsample of 29 projects stratified by HGM type and prior habitat condition. Time since completion of restoration for all 53 projects averaged 6 years (range 2–11 yr). All sites were visited during July–August 2010, a year in which all three states experienced below-normal rainfall and summer drought (NOAA 2010). One to four wetland survey locations per site (number scaled to tract size and cover types) were assessed with a modified Corps of Engineers method for routine wetland determinations (ACOE Environmental Laboratory 1987), omitting soil indicators because WRP site eligibility is based on presence of hydric soils. We traversed the general area of each survey location to score for 15 primary and secondary hydrology indicators (Appendix 2), including presence of aquatic or wetland-dependent animals in 7 general taxon groups (waterfowl, wading birds, fish, aquatic insects, amphibians, reptiles, mammals). We also recorded all "dominant" plant species in four strata (tree, sapling/shrub, herb, woody vine), where a dominant was any species comprising ~20% or more of total stratum cover by visual estimation. Plant species were classed as to wetland indicator category (Reed 1997), native/non-native status (USDA Plants Database), and (if non-native) "invasiveness" status (see Appendix 4). Indicator data were compiled to site level. Differences in field indicator metrics with respect to project HGM type and prior condition were tested with 2-way ANOVA or 3-way contingency analyses, as appropriate to the metric.

RESULTS

Characteristics of Restored Wetlands

The restoration projects collectively represented four HGM types: isolated *depression*, wet *flat*, and two riverine sub-classes, riparian *headwater* and mainstem *floodplain* (Fig. 2a). Depressions were distinct topographic features. Flats were areas with no apparent topographic relief, often with irregular patterns of hydric soils; very large "Carolina bays" (200–1900 ac) were classed with flats based on similar topographic and hydrologic traits. Riparian headwater sites were narrow banks or incipient channels of small (1st- to 3rd-order) creeks. Mainstem floodplain sites were wide and topographically heterogeneous first bottoms or braided channels on large (4th-order and higher) rivers. A few near-coastal riverine sites (headwater and floodplain) were tidally influenced. Projects in SC and GA included all four HGM types, whereas MS projects were headwater or floodplain types only (Fig. 2a).

Prior habitat status varied substantially. While many sites were still in active agriculture at the time of WRP enrollment (including all MS sites), many others appeared naturally vegetated before restoration (Fig. 2b). Excluding SC floodplains, 95% of sites (whether vegetated or not) had records of ditching, tile drainage, or stream channelization. The prior condition of mainstem floodplains diverged between states: all MS floodplains (n=10) were agricultural, whereas all SC floodplains (n=24) were naturally vegetated, with only 33% of the latter noted as having been ditched. The SC floodplains represented a Special State Initiative begun in ca. 2002 to enroll degraded wetlands with "problem" soils (i.e., lacking some hydric indicators) that normally would experience frequent flooding (NRCS-SC 2003). In effect, these were forested bottomlands where water flows, movements of aquatic biota, and other floodplain functions were altered by past timber-harvest activities such as logging-road and culvert construction, clear cutting, soil rutting, and debris accumulation. Of the GA floodplain sites (n=3), two were also timbered bottomlands (plus one agricultural).

Project size varied substantially within and between HGM types (Table 2). Wet-flat and particularly floodplain easements were larger, on average, than depression and headwater easements. The forested floodplain tracts in SC and GA averaged nearly 4 times larger than the agricultural floodplain tracts in MS, with the largest bottomland easements ranging to a maximum of 2,700 ac (1,100 ha).

All project wetlands were represented by mapped hydric soils; across all sites, these soils collectively represented 73 soil series of mineral, histic, or organic types. WRP easements may also include upland areas, but the extent can be difficult to determine, especially on low-relief floodplains with a complex mosaic of wetland and upland soils. For non-floodplain project types, the estimated percentage of easement area that was upland habitat ranged from 0 to 69% (based on extent of non-hydric soils or planned upland practices).

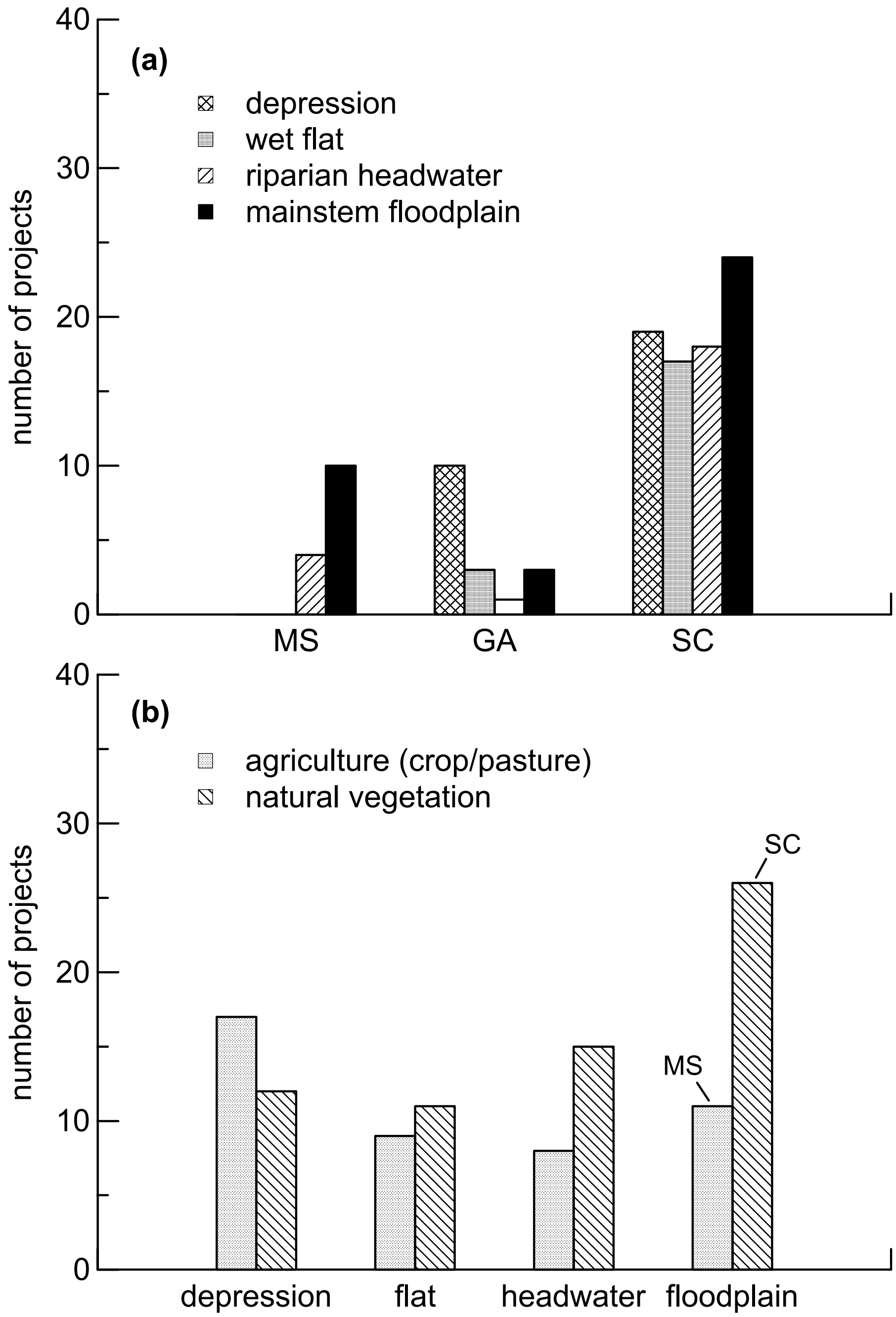

Figure 2. Wetland HGM type and pre-restoration habitat condition for 109 Southeastern WRP projects. (**a)** Frequency distribution of HGM types by state. **(b)** Frequency distribution of prior habitat condition (agriculture or natural vegetation) by HGM type; for floodplains, see text.

Table 2. Easement size and estimated wetland area of 109 Southeastern WRP projects, by wetland HGM type. Mean easement area differed among HGM types ($P < 0.001$), and mean area of floodplain easements differed between contrasting states ($P < 0.01$) (ANOVA tests on log-transformed data).

Wetland HGM Type	***no. of projects***	**Mean easement area†, in acres (range)**	**Mean wetland area‡, in acres (range)**
depression	*29*	112 (5–615)	66 (4–414)
flat	*20*	374 (13–1925)	282 (9–1848)
riparian headwater	*23*	83 (9–412)	60 (7–334)
mainstem floodplain (all)	*37*	632 (10–2700)	517 (9–2189)
SC/GA floodplain easements	*27*	788 (29–2700)	635 (24–2189)
MS floodplain easements	*10*	208 (10–545)	199 (9–523)

† includes tract areas of 10-year cost-share projects
‡ wetland area is estimated from the % of total easement area with mapped hydric soils (NRCS Web Soil Survey)

Planned Restoration Practices

Hydrology restoration methods differed between wetland HGM types and in relation to prior habitat condition (Table 3). Ditch plugging or tile-drain removal ("unmanaged" hydrology restoration) was used mainly on flats and depressions. Installing some form of water-level management (control structure + associated dike) was common across all wetland types, but was especially frequent (>70%) on headwaters and on prior-agricultural floodplains. Semi-enclosed managed impoundments, a sub-category of water management, were also very frequent on agricultural headwaters and floodplains. On headwater sites, water-management practices either impounded creek flows directly or created diked "depressional" ponds on adjacent creek banks. On agricultural floodplains, impoundments typically were modified from existing flood-prevention dikes/levees. In contrast, common practices on vegetated (forested) floodplains were breaching roads or dikes ("obstruction removal") and installing rock-fill crossings or stream-crossing structures (Table 3), all with the aim of improving water flows and animal movements across the floodplain and to the river. Small managed waterfowl ponds or green-tree reservoirs could be established on forested floodplains; often these were pre-existing from earlier land use.

Landowners' interests in wildlife were a strong influence on project planning. Nearly 60% of project files indicated an explicit or implicit goal of managing restored wetlands for waterfowl habitat; possible the actual percentage was higher. This goal was evidenced in the choice of restoration practices favoring water management or impoundments. A few projects represented conservation efforts related to wildlife species of concern (wood stork, bald eagle).

Table 3. Percent frequency of typical conservation practices in 109 Southeastern WRP projects classed by HGM type and prior habitat condition (agriculture or natural vegetation). For a given practice, values are the % of projects in each category using the practice, with P values from a 3-way contingency analysis for effects of HGM type (P_{HGM}) and prior condition (P_{pc}). Boldface highlights the principal differences between wetland types or prior conditions for a given practice.

Conservation Practice	**depression**		**flat**		**riparian headwater**		**mainstem floodplain**			
	Agric	**Veget**	**Agric**	**Veget**	**Agric**	**Veget**	**Agric**	**Veget**	**P_{HGM}‡**	**P_{pc}‡**
Hydrology Restoration Practices										
ditch plug/tile break	**24**	**25**	**56**	**64**	†	†	†	†	**	n.s.
water-control structure (plus dike)	53	50	44	36	**88**	**73**	**82**	38	*	*
diked impoundment	29	†	22	27	**88**	33	**45**	27	*	*
road breach/rock ford	†	†	†	†	12	**33**	18	**54**	**	**
macro-/microtopography	**35**	†	**78**	18	12	†	27	19	*	**
Auxiliary Practices										
tree planting, on easement/in wetland	**47/35**	25/17	**78/56**	18/9	**50/50**	20/13	**100/82**	†	n.s.	**
Wetland Wildlife Habitat Management	88	100	78	73	88	87	100	85	n.s.	n.s.
Upland Wildlife Habitat Management	47	75	67	82	**38**	**40**	91	62	*	n.s.
Use Exclusion	53	58	56	54	50	53	82	62	n.s.	n.s.
number of projects	*17*	*12*	*9*	*11*	*8*	*15*	*11*	*26*		

† practice uncommon (frequency < 10%)
‡ likelihood ratio chi-square tests: ** $P \leq 0.01$; * $0.01 < P \leq 0.05$; n.s. = not significant

Excavated macro/microtopography (ridge-and-swale, pothole) was generally not a primary practice for restoring hydrology, but was used to enhance water-depth variety in sites restored by other methods. The practice was most frequent on agricultural flats (Table 3). In a few cases where a primary method proved infeasible (e.g., because of potential for off-site flooding), swales or potholes were constructed to provide some water storage in lieu of other hydrologic restoration. Finally, 13% of all projects had no hydrology practices installed; typically the reasons were that the site was protected to enhance the conservation value of existing adjacent WRP tracts, or that a planned hydrologic repair later proved to be unneeded (e.g., because site drainage was no longer effective).

Tree planting was used to restore wetland vegetation or to improve the upland habitat on an easement. The general practice was frequent on agricultural tracts (47–100%) but not on naturally vegetated sites (Table 3). Use of the practice also differed by state. Planting of bottomland hardwood trees (except in impounded areas) was a typical practice on MS easements (93%), all of which were prior-agriculture headwater and floodplain sites. In GA and SC, wetland vegetation was generally restored by natural succession, but was variably supplemented with planted bottomland trees (47% of GA projects and 12% of SC projects). Timber-harvested floodplains were not actively reforested. Appendix 3 lists the tree species typically planted in each state.

Most project plans also included a group of more generalized auxiliary practices (Table 3). Wetland Wildlife Habitat Management partly represented active water management (moist-soil units, green-tree reservoirs), but also included other wildlife-oriented activities. Upland Wildlife Habitat Management (UWHM) was typically used to establish small food plots for wildlife, but in SC and GA the practice could also represent actions to restore longleaf pine (*Pinus palustris*) forest or early-succession vegetation on upland buffer areas. Lower frequency of UWHM on riparian headwater projects (Table 3) likely reflected the limited extent of upland area on these smaller tracts. The Use Exclusion practice generally restricts the kinds of activities allowed on a WRP easement, but it was also a "restoration" practice when it involved removing livestock grazing from a wetland tract.

Field Condition of Restored Wetlands

Fifty-three project sites were visited in the late summer of 2010. Irrespective of wetland type, most restored sites had multiple positive indicators of hydrology function, wetland vegetation, and faunal use (Table 4, Appendix 2). Few indicators differed with prior habitat status, and none were correlated with time since restoration. Overall, 38 sites (72%) had water-saturated soil or surface water present despite summer drought conditions, and an additional 7 sites (13%) with no visible water had several other primary hydrology indicators. The total number of hydrology indicators averaged 4–5 per site (Table 4), but two sites had no primary indicators at all, and four other dry sites had only 1 or 2 "non-water" indicators. Implementation of water-level management was variable. In 28 sites where water-control structures or partial impoundments had been installed, an estimated 57% were being actively managed, 18% were not managed, and the rest (25%) could not be determined.

Table 4. Selected indicators of wetland hydrology, vegetation, and faunal presence in 53 Southeastern WRP project sites visited in July–August 2010. Data are either frequency (number) of sites or the mean per site, with P values from χ^2 or ANOVA tests as appropriate. ** $P \leq 0.01$; * $0.01 < P \leq 0.05$; n.s. = not significant.

Indicator	depression	flat	riparian headwater	mainstem floodplain	P
Hydrology Indicators					
Frequency (no.) of sites with water present	8	7	10	13	n.s.
Frequency (no.) of sites with water present or with ≥ 3 other primary (1°) hydrology indicators	10	8	12	15	*
Mean no. of hydrology indicators (1° and 2°)	3.8	4.0	4.9	5.5	n.s.
Vegetation Indicators					
Mean number of dominant plant species	21.1	20.9	29.5	30.9	**
Mean % hydrophytic species†	86.2	89.9	86.5	90.5	n.s.
Mean % wetland species†	63.5	59.5	59.0	68.6	n.s.
Mean % native species	95.0	94.7	93.0	95.5	n.s.
Frequency (no.) of sites with 1 or more "invasive" non-natives present	6	3	9	9	n.s.
Mean no. of "invasive" non-native species	0.4	0.5	1.1	0.7	n.s.
Aquatic/Wetland Fauna Indicators					
Mean no. of animal taxon groups seen‡	2.1	2.3	2.4	3.1	n.s.
Number of sites visited	*14*	*11*	*13*	*15*	

† hydrophytic species are OBL, FACW, FAC+, and FAC (ACOE 1987); wetland species are OBL and FACW
‡ of 7 groups, for GA and MS sites only; animal taxa were not recorded consistently in SC sites

Vegetation of the project wetlands ranged from open-water or grass/sedge communities to shrub-scrub and aggrading or mature forests, with nearly 380 plant species recorded in total. The dominant vegetation of restored sites averaged 88% hydrophytic species, 63% wetland species, and 95% native species, with no differences among wetland types (Table 4). An apparent difference in species richness was likely an artifact of differing numbers of survey locations per site (mean of ~2 in depressions/flats versus ~3 in headwaters/floodplains). Seven sites had <40% wetland (OBL/FACW) species as dominants, which could be indicative of shorter hydroperiod duration. Non-native species were detected more often in prior-agriculture sites (Appendix 4); however, many were naturalized species of early-succession habitats or species of adjacent uplands with limited spread into wet areas. Some non-natives may have been planted as part of moist-soil management for waterfowl habitat. Roughly a third of the observed non-natives were potentially "invasive" (Appendix 4), some of greater concern than others. Projects averaged <1 invasive species detected per site, either as an occasional species or abundant locally. Frequency (presence) of invasive species did not differ with prior habitat condition (χ^2 tests, n.s.).

Data on faunal use of restored wetlands was necessarily limited in scope, since systematic surveys could not be conducted. Roughly 30% of the sites had no standing water by late summer, which precluded detection of aquatic taxa. However, wetland-dependent or aquatic animals were observed as present at 47% of all project sites. In GA and MS, where faunal observations were more complete, one or more of the 7 taxon groups was seen in >75% of those sites, with the number of detected groups averaging 2–3 per site (Table 4). Wading birds or waterfowl were seen at 60% of the GA and MS sites.

Success of tree planting in the wetlands was not measured specifically; however, as part of the vegetation sampling we surveyed planted areas, particularly on prior-agricultural floodplains. At eight such sites where evaluation was possible (7 in MS, 1 in GA), large saplings of both planted trees and naturally recruited (volunteer) species were detected frequently (Table 5). The naturally recruited trees were almost all light-seeded, wind-dispersed species. On most sites, limited to no active ground-cover management between rows of planted trees may have allowed natural colonization to enhance the tree diversity of these areas.

Table 5. Planted and volunteer tree species seen in the sapling stratum of 8 prior-agriculture floodplain sites in the Southeastern WRP.

Tree Species	Name	frequency (in 8 sites)	no. of sites where planted	no. of planted sites where seen
Planted				
Carya illinoensis	pecan	1	2	1
Diospyros virginiana	persimmon	1	3	1
Fraxinus pennsylvanica	green ash	5	5	4
Quercus lyrata	overcup oak	1	1	1
Q. michauxii	swamp chestnut oak	0	4	0
Q. nigra	water oak	5	5	4
Q. pagoda	cherrybark oak	4	5	2
Q. phellos	willow oak	4	6	3
Q. shumardii	Shumard oak	2	5	1
Q. texana (Q. nuttallii)	Nuttall oak	4	6	4
Taxodium distichum	baldcypress	2	5	1
Volunteer				
Acer negundo	box elder	1	–	–
A. rubrum	red maple	2	–	–
Betula nigra	river birch	1	–	–
Juniperus virginiana	red cedar	1	–	–
Liquidambar styraciflua	sweetgum	5	–	–
Pinus taeda	loblolly pine	2	–	–
Platanus occidentalis†	sycamore	5	†	–
Populus deltoides	cottonwood	2	–	–
Salix nigra	black willow	3	–	–
Ulmus americana	American elm	1	–	–

† possibly planted in some sites (file records incomplete)

DISCUSSION

Southeastern wetlands restored under the Wetlands Reserve Program were characterized by diverse HGM types, tract sizes, and restoration methods. Another unusual feature was a wide range of pre-restoration habitat conditions that included agricultural sites, drained wetlands with natural vegetation, and timber-harvested bottomlands with no contemporary cropping history. In part, this variety reflected an opportunity to enroll "non-typical" sites owing to a more limited agricultural land base compared to other U.S. regions. South Carolina's initiative for forested floodplains appears to be a novel utilization of program scope. In contrast to other project types, the forested floodplain tracts are typically large, and it has been possible to assemble adjacent tracts into larger corridor habitats, with potential landscape-scale benefits for floodwater storage and other ecosystem services. Total enrolled area of all SC floodplain projects was 25,000 ac by 2004 and almost 48,000 ac by 2010, with nearly all in permanent easements (SC NRCS State Office data). The success of the SC floodplains initiative has generated interest in neighboring states for possible use within their WRP programs (G. Sandifer, pers. comm.).

The WRP is aimed broadly at recovering wetland functions, but projects also reflected a traditional program emphasis on wildlife benefits. This emphasis influenced the planned restoration methods, with varying functional implications. Nearly 60% of projects installed some form of water management. All hydrologic practices were considered "restoration"; however, in the context of wetland hydrogeomorphic (HGM) type, practices may restore hydrology to the natural pattern or modify hydrology to favor particular ecosystem services over others. Ditch plugging or tile-drain removal would recover original hydrodynamics and related services, as would practices to restore natural water flows on timbered floodplains. Conversely, constructing managed impoundments across creek channels, or on creek banks and floodplains, modifies those sites to enhance a specific function (water retention for waterfowl) while reducing original functions related to surface flow, overbank flooding, and river connectivity. From this perspective, ca. 37% of projects had created some form of modified ("enhanced") hydrology, although the Wetland Enhancement practice was generally not used to represent this outcome (Appendix 1, Notes). While the scope of the WRP allows for a variety of desired conditions for wildlife habitat, consideration of wetland type would enable the benefits of a planned condition to be weighed explicitly relative to other ecosystem services or regional resource concerns.

Ecological monitoring reports were found in about half of the project files, but report format was mainly qualitative (yes/no questions). Our field surveys were a preliminary technical assessment of whether planned practices successfully established wetland ecological conditions. Actual hydroperiods could not be determined from single site visits, but approximately 85% of project wetlands had evidence of hydrology function (presence of late-summer water or multiple hydrology indicators). With respect to the dominant vegetative cover, nearly 87% of projects, whether hydrologically managed or not, had high values for three metrics (proportions of hydrophytic, wetland, and native plant species) that are indicative of functional wetland vegetation and floristic "quality" (Ervin et al. 2006). Potentially invasive species occurred locally in some sites, but non-natives generally appeared to be less frequent in Southeastern restorations when compared to program wetlands in other regions (e.g., Gleason et al. 2008). One reason may be that the Southeastern WRP enrolled many sites with degraded hydrology but pre-existing natural vegetation. Finally, wetland and aquatic fauna were observed at many project wetlands, although frequency of habitat use or species-specific habitat quality could not be assessed.

Based on our initial surveys, a majority of Southeastern WRP sites are supporting native wetland plant diversity and faunal habitat, particularly where hydrology restoration was effective. However, a small percentage of sites (11–17%) appeared to be less successful hydrologically. Consideration of wetland HGM type during project planning could help to identify the potential for unsuccessful outcomes. For example, it may be difficult to increase water retention in certain depressions and flats with inherently temporary or saturation-driven hydroperiods. Failure to recognize such limitations may be a reason that several projects did not achieve the desired goal of a floodable waterfowl pond. In a few sites where macrotopography was excavated into the subsoil, the result was sometimes a stagnant pond with turbid water, anoxic sediments, and depauperate biota. Historic channelizing of a first-order stream feature may have been interpreted as ditching, thus leading to use of a ditch plug as "restoration". A better understanding of inherent site hydrodynamics could aid in identifying compatible restoration approaches in light of overall project goals.

The variety of Southeastern wetland restorations suggests several site variables that would be relevant for regional models to estimate the ecosystem services delivered by wetland conservation practices. Wetland HGM type identifies the key services for assessment in relation to the applied practices. Prior habitat status may influence the degree of "gain" in services relative to the pre-restoration condition, since vegetated sites have likely retained or recovered some wetland functions in comparison to more degraded and younger agricultural sites. Mapped hydric soil types that vary from mineral to organic may be a coarse indicator of hydrologic duration and potentially different levels of soil carbon storage. Relative proportions of non-hydric/hydric soils can estimate the amounts of upland/wetland habitat (and services) on an easement, perhaps in conjunction with remote sensing methods to estimate wetness extent. Tract size is directly relevant for floodplains, where floodwater storage is provided in some proportion to easement area (adjusted for topography and flooding elevations). This study provides a foundation for exploring the utility of these variables in ecosystem services estimation.

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Appendix 1. NRCS conservation practices used in 109 WRP project conservation plans in the Southeastern Coastal Plain and Piedmont. Data are the number of projects using each practice, with practices ordered by overall count within each group (primary or operational). The list omits 15 other practices used rarely.

Practice Name (NRCS practice number)	South Carolina	Georgia	Mississippi*	All
Principal Restoration and Management Practices				
Wetland Restoration (657), for the project tract	78	17	14	109
Wetland Wildlife Habitat Management (644)	65	16	14	95
Upland Wildlife Habitat Management (645)	45	11	11	67
Dike (356)	52	3	12	67
Water-Control Structure (587)	45	3	12	60
Tree/Shrub Establishment (612)	17	9	13	39
ditch plug (657, 356, 410) or drain-tile removal (657) ‡	24	11	1	36
macro/microtopography (657, 659, 646)† ‡	18	5	3	26
no-net-fill ford or stream crossing (561, 657, 395, 728)‡	16	2	0	18
Wetland Enhancement (659)	10	0	0	10
Shallow-Water Development and Management (646)	7	1	2	10
road/dike breach (500, 657)‡	7	0	1	8
Associated Operational Practices				
Use Exclusion/Access Control (472)	40	13	11	64
Access Road (560)	24	10	5	39
Critical Area Planting (342)	29	6	0	35
Forest Stand Improvement (666)	7	6	9	22
Prescribed Burning (338)	13	8	0	21
Tree/Shrub Site Preparation (490)	2	6	10	18
Land Clearing (460)	15	1	0	16
Firebreak (394)	4	7	2	13
Early Successional Habitat Development (647)	3	6	0	9
Pest Management (595)	0	9	0	9
Conservation Cover (327)	2	4	1	7
Fence (382)	1	5	0	6
Total number of projects evaluated	*78*	*17*	*14*	*109*

* MS data exclude projects in the "Delta"/Mississippi Alluvial Valley area
† macro-/microtopography refers to excavated swales and potholes
‡ various NRCS practices (including Wetland Restoration, 657) were used for this general practice

Technical Notes on reported practice data: On average, there were 2.3 NCPD records (range 1–17) of practice 657 (Wetland Restoration) per project plan. Records exceeded the number of plans partly because of local variability in how projects are planned and reported (*e.g.*, for the entire tract *vs.* by sub-fields). The 657 practice also serves a dual purpose: it is used mainly for reporting WRP easement area (including uplands), but also for restoration actions lacking a formal NRCS practice number. Consequently, the incidence of "unmanaged" hydrology-restoration methods (ditch plug, drain tile removal, road/dike breach) was not easily quantifiable from practices reporting. Likewise, practice 659 (Wetland Enhancement) is one of several used to report within-wetland macro/microtopography installation; it is not typically used to indicate wetland-scale modifications of hydrology such as construction of managed impoundments on low-order streams.

Appendix 2. Field indicators of hydrology function scored as present or absent in 53 Southeastern WRP project sites visited in July-August 2010.

Primary hydrology indicators (10)

Surface water present
Soil saturation (in upper 12 inches)
High water table present (in upper 12 inches)
Water marks
Sediment deposits
Drift deposits
Algal mat or crust
Water-stained leaves
Oxidized root channels
Aquatic or wetland fauna observed

Secondary hydrology indicators (5)

Surface soil cracks
Sparsely vegetated concave surface
Drainage patterns
Moss trim lines
Crayfish burrows

Reference: ACOE 2008

Appendix 3. Typical bottomland and wetland tree species planted on Southeastern WRP easements.

Species Name	Common name	Wetland indicator†	Where used		
			MS	GA	SC
Betula nigra	river birch	FACW			x
Carya illinoensis	pecan	FAC+	x		
Celtis laevigata	sugarberry/hackberry	FACW	x	x	
Diospyros virginiana	persimmon	FAC	x		x
Fraxinus pennsylvanica	green ash	FACW	x		x
Nyssa spp. (aquatica, biflora)	water tupelo, swamp tupelo	OBL	x	x	x
Platanus occidentalis	sycamore	FACW-		x	x
Quercus laurifolia	laurel oak	FACW			x
Quercus lyrata	overcup oak	OBL	x	x	x
Quercus michauxii	swamp chestnut oak	FACW-	x		x
Quercus nigra	water oak	FAC	x	x	x
Quercus pagoda	cherrybark oak	FAC+	x	x	x
Quercus phellos	willow oak	FACW-	x	x	x
Quercus shumardii	Shumard oak	FACW-	x		
Quercus texana (Q. nuttallii)	Nuttall oak	OBL	x	x	
Taxodium ascendens	pond cypress	OBL		x	x
Taxodium distichum	baldcypress	OBL	x	x	x

†Reference: Reed 1997

Appendix 4. Non-native species recorded in plant surveys of 53 Southeastern WRP project sites visited in July–Aug 2010, ordered by potential invasiveness and growth form.

Scientific Name	Common Name	Wetland Indicator	Considered invasive?†	Growth form	No. of sites, by site prior condition, where recorded as a dominant	
					agriculture (*n = 27 sites*)	natural vegetation (*n = 26 sites*)
Lygodium japonicum	Japanese climbing fern	FAC	yes	fern	1	0
Alternanthera philoxeroides	alligatorweed	OBL	yes	forb	3	1
Microstegium vimineum	Nepalese browntop	FAC+	yes	grass	2	2
Miscanthus sinensis	Chinese silvergrass	UPL	yes	grass	0	0
Sorghum halepense	Johnsongrass	FACU	yes	grass	2	0
Ligustrum sinense	Chinese privet	FAC	yes	shrub	3	3
Rosa multiflora	multiflora rose	UPL	yes	shrub	1	0
Melia azedarach	chinaberry	UPL	yes	tree	2	0
Triadica sebifera	Chinese tallow	FAC	yes	tree	0	3
Lonicera japonica	Japanese honeysuckle	FAC-	yes	woody vine	7	6
Pueraria lobata	kudzu	UPL	yes	woody vine	0	0
Wisteria sinensis	Chinese wisteria	UPL	yes	woody vine	1	0
Colocasia esculenta	coco yam	FACW+	no	forb	1	0
Cuphea carthagenensis	Columbian waxweed	FACW	no	forb	0	1
Glechoma hederacea	ground ivy	FACU	no	forb	1	0
Ipomoea hederacea	ivyleaf morning-glory	FAC-	no	forb	1	0
Ipomoea purpurea	tall morning-glory	FACU	no	forb	0	1
Verbena brasiliensis	Brazilian vervain	FAC-	no	forb	2	0
Agrostis gigantea	redtop	FACW	no	grass	1	0
Bromus japonicus	field brome	FACU	no	grass	1	0
Cynodon dactylon	Bermuda grass	FACU	no	grass	4	0
Echinochloa crus-galli	barnyard grass	FACW-	no	grass	1	1
Festuca pratensis	meadow fescue	FACU	no	grass	1	0
Oryza sativa	rice	OBL	no	grass	1	0
Paspalum notatum	bahiagrass	FACU+	no	grass	2	1
Paspalum urvillei	Vasey's grass	FAC	no	grass	3	3

Appendix 4. continued.

Scientific Name	Common Name	Wetland Indicator	Considered invasive?†	Growth form	No. of sites, by site prior condition, where recorded as a dominant: agriculture (*n = 27 sites*)	natural vegetation (*n = 26 sites*)
Sorghum bicolor	sorghum	FACU	no	grass	1	0
Cyperus difformis	variable flatsedge	OBL	no	sedge	1	0
Cyperus iria	ricefield flatsedge	FACW	no	sedge	3	0
Cyperus pumilus	low flatsedge	FACW	no	sedge	1	0
Lespedeza bicolor	shrub lespedeza	UPL	no	shrub	1	0
Rubus bifrons	Himalayan berry	UPL	no	shrub	0	1
Pyrus calleryana	Bradford pear	UPL	no	tree	1	0
Sum of occurrences					49	23

† Based on data from Miller et al., *Invasive Plants of the Thirteen Southern States* (www.invasive.org/south/), and from University of Georgia & National Park Service, *Invasive Plant Atlas of the United States* (www.invasiveplantatlas.org)