IN SEARCH OF THE WETLAND BOUNDARY[1]

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Abstract. Implementation of Section 404 of the Federal Water Pollution Control Act of 1972 and the "swampbuster" provisions of the Food Security Act of 1985 require identification and delineation of wetlands in accordance with applicable statutes and regulations. While a considerable amount of work has gone into characterizing wetlands, very little has gone toward delineating the boundary between unregulated uplands and regulated wetlands. We attempted to delineate this boundary in a tidal saltmarsh and a wooded swamp and along an intermittent stream in North Carolina. Comparisons were based on contour maps of wetland index values. The locations of boundaries derived from Corps of Engineers and Soil Conservation Service indices differed little. However, inclusion of "facultative" species within the aggregate of wetland plants produced a much larger area of "wetland" than hydrographic or soils indicators. Elimination of facultative species brought the three indicators into much closer agreement. The procedures described are appropriate for calibrating and verifying boundaries determined by professional judgment and in situations where the high cost is otherwise warranted, but are not suitable for routine boundary determinations.

Key words: wetland boundary, Section 404, land use regulations, wetlands, Corps of Engineers, Soil Conservation Service.

INTRODUCTION

Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) as amended (33 U.S.C. 1344 (1982)) built upon precedent provisions of the River and Harbor Act of 1899 (30 Stat. 1151) to require permits for certain activities in waters and wetlands. Under Section 10 of the earlier act (33 U.S.C. 403 (1982)), construction in navigable waters of the United States is unlawful unless permitted by the Secretary of the Army; under Section 13 (The Refuse Act), deposition of waste material where it may enter such waters is proscribed. Section 404 of the Clean Water Act largely superseded The Refuse Act, enacting in its stead a requirement for a U. S. Army Corps of Engineers (Corps) permit for deposition of dredged and fill material in "waters of the United States." Since its passage in 1972, the applicability of Section 404 to specific ecological situations has been contested repeatedly (e.g., *Natural Resources Defense Council, Inc. v. Callaway*, 329 F. Supp. 685, 686 (D.D.C. 1975); *Bob Jones University v. United States*, 461 U.S. 574 (1983); *Avoylles Sportsmen's League v. Marsh*, 715 f. 2d 897 (1983); *United States v. Riverside Bayview Homes, Inc., et al.*, 54 U.S.L.W. 4027 (1985)). Today, at least for practical purposes, 404 may apply to

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any area "inundated or saturated by surface or ground water at a frequency and duration to support, and that under normal circumstances do[es] support, a prevalence of vegetation typically adapted for life under saturated soil conditions" (33 C.F.R. 323.2 (c)).

Passage of the Food Security Act of 1985 (P.L. 99-198) involved the Soil Conservation Service (SCS) in wetland indentification and delineation under generally the same definition. Persons who produce an agricultural commodity on converted wetland are ineligible for price supports, loans, crop insurance, and other subsidies during that crop year.

A considerable amount of effort has gone into characterizing, describing, and classifying wetlands (e.g., Cowardin *et al.* 1979, Shaw and Fredine 1956, Michener 1983, Wentworth and Johnson 1986), but being able to recognize a wetland is not the issue. The issue is *"Where, for the purposes of these statutes, do regulated wetlands end and non-regulated uplands begin? Where is the wetland boundary?"* This imaginary line across the wet-dry continuum must be established rationally, based upon uniform methods, independent of personal bias and geographical/ecological variation, in a manner that will be admissible and defensible in court. Very little published work has addressed this issue.

We attempted to locate the wetland boundary in a tidal saltmarsh, a coastal wooded swamp, and along a Piedmont intermittent stream, under a number of assumptions and hypotheses. We a) delineated the Section 404 permit boundary without an *a priori* boundary definition, b) fitted current Corps and SCS boundary definitions to two areas in which the boundary had previously been delineated and to one in which it had not, and c) fitted modified Corps and SCS definitions to the same areas.

The rigorous procedure described here is not appropriate for boundary delineation under most field conditions because it is far too expensive. It is useful, however, in calibrating and verifying boundaries determined by field inspection and professional judgment, in providing evidence for litigation, and in establishing the permit boundary in areas where high land values and development potentials warrant such precision.

METHODS

Delineation Without a Definition

In 1982, we attempted to delineate the Section 404 permit boundary in a saltmarsh and a wooded swamp based upon the following assumptions:

1. Boundaries subjectively established by agency personnel were being accepted as valid and thus became so.
2. Such boundaries were based upon some set of unstated criteria which existed in the perception of the delineators and could be identified through statistical procedures.

With these assumptions in mind, the following procedures were followed:

1. Personnel from the Wilmington District, Corps of Engineers, marked a preestablished permit boundary in a wooded swamp near Aurora,

Beaufort County, North Carolina and a tidal saltmarsh near Carolina Beach, New Hanover County, North Carolina.

2. A research team collected ecological data at vertices along the boundary and along transects perpendicular to it.
3. Discriminant analysis of the ecological data was used to separate boundary from non-boundary conditions.

Wooded Swamp. The following data were obtained at each of 17 points (vertices) along the wooded swamp permit boundary (Figure 1):

1. Depth to water table (inches).
2. Species and percent coverage of vegetation <2 ft tall in a 1 m^2 circular plot.
3. Species and number of woody plants >2 ft in height and <2 in. in diameter in a 25 m^2 circular plot.
4. Number of trees by species located from the plot center by a BAF 10 prism (each tree representing 10 sq. ft basal area per acre).

Two sets of four parallel transects about 25 ft apart and perpendicular to the boundary line were established from a random beginning point and 5 plot centers at 25 ft intervals were located on each transect, providing one set of data for model development and another for validation. The information described above was collected from each plot center.

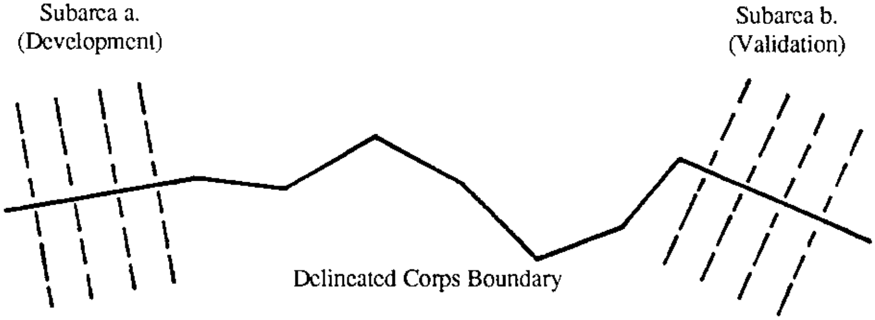

Figure 1. Sampling pattern in wooded swamp and tidal saltmarsh areas (conceptual).

Tidal Saltmarsh. Twenty sample points were selected on the pre-established permit line and two sets of parallel transects were established as at the swamp site. Data collection was the same as in the swamp except for trees (which were absent) and shrubs (which were recorded as percent coverage on a 25 m^2 plot). At both sites, North Carolina Plane Coordinates and the elevation of each point were determined.

Analysis. We expected that two populations, "wet" and "dry," separated by the boundary, would exist at both sites. With this type of hypothesized division among the data points, discriminant analysis may be used to delineate populations and predict membership in a given population. On both sites, percentage data were transformed by the arc-sin-square-root transformation to stabilize variance, and a discriminant analysis was performed to separate line plots from wet and dry combined (non-line). If the separation were successful, the Mahalanobis' distance (Morrison 1976) of the wet and dry plots from the centroid of the line population could be calculated and plots farther from the line on the ground should be farther away in Mahalanobis' distance.

Fitting the Definitions

Several new tools for wetland identification and delineation have appeared since 1982. The Corps has prepared a "Wetlands Delineation Manual" (Sanders *et al.* 1984). The Fish and Wildlife Service (U. S. Department of the Interior, Fish and Wildlife Service 1986) has prepared a "National List of Plant Species that Occur on Wetland," and comparable state lists are available (e.g., Reed 1986). The Soil Conservation Service (U. S. Department of Agriculture, Soil Conservation Service 1985) has published a description of "Hydric Soils of the United States." Regulations implementing the "swampbuster" provisions of the Food Security Act of 1985 (The 1985 Farm Act) contain a formula for determining the "Prevalence Index," based upon plant species classifications in the Fish and Wildlife Service list (Wentworth and Johnson 1986), which may be used to "indicate that an area exhibits a prevalence of hydrophytic vegetation" (51 F.R. 23507 (June 27, 1986)).

The tools now exist, but their emphasis is on characterizing an area, a spot, a point, or a sample location as wetland. That is not the problem. The problem is to determine where the wetlands begin so that a landowner can avoid applying for a permit and/or violating the law and so that regulatory personnel can determine the extent of a transgression. It is not possible to take sufficient samples to assure that contiguous wetland-upland pairs are obtained, and even if it were, the samples would have area. This kind of problem has been solved in other situations. Isometric lines on maps are used to indicate elevation, salinity, barometric pressure, temperature, frost-free days, flood hazards, and other continuous varibles. Rarely is a precise value determined directly on a line shown, yet the results are accepted because they are logical, reproduceable, based on known and accepted functions, and are not subject to personal bias. With the tools now available, a similar approach may be used to determine the wetland boundary for 404 permit purposes.

In 1986, we reanalyzed the 1982 data using the new tools. We also added a site along an intermittent stream in the lower Piedmont near Raleigh, NC in which the permit boundary had not previously been established.

Regardless of the data set developed, it must be used to generate a line across the wet-dry continuum. We therefore determined the prevalence of wetland indicators at each sample point, using as nearly as possible the proposed Corps (Sanders *et al.* 1984) and SCS (51 F.R. 23507 (June 27, 1986)) systems. Connecting points corresponding to the Corps boundary value (0.50) and the comparable SCS value (3.00) (determined by linear interpolation along and between transects) produced a simple contour map of the various "wetland boundaries." We then compared the boundaries determined by these procedures with those previously delineated on the ground at the coastal sites and with the depth to water table. At the Piedmont site, we compared the boundary locations and areas which would have been determined 1) under each component of the Corps proposal -- vegetation, soil, and hydrology and 2) between the SCS vegetative proposal and the Corps soil and hydrology components. All approaches and components allege to delineate areas meeting the same statutory definition, i.e., all are indicators of the same condition. If so, reasonable concurrence should exist among the various boundaries and areas.

Analysis. Data from each sample point in the tidal marsh and wooded swamp were combined to form Corps and SCS wetland vegetative indices as follows:

Corps: the sum of the proportions of the 1) herbaceous stratum coverage, 2) shrub frequency, and 3) tree basal area composed of obligate and facultative wetland species and facultative species, divided by the number of strata present (Sanders *et al.* 1984).

SCS: (the prevalence of wetland obligates) + (2 x the prevalence of wetland facultatives) + (3 x the prevalence of faculatives) + (4 x the prevalence of upland facultatives) + (5 x the prevalence of upland obligates), divided by the sum of prevalences (51 F.R. 23507 (June 27, 1986)). [Note: SCS measures "prevalence" as "frequency of occurrence." Our botanical data were collected as described earlier by stratum prior to issuance of the SCS regulations. We therefore applied their formula to the herb, shrub, and tree stratum (where present) and averaged across strata.]

No detailed soils map existed for the wooded swamp. The saltmarsh soil was listed as "Tidal Marsh" (U. S. Department of Agriculture, Soil Conservation Service 1977), an old term which does not appear in "Hydric Soils of the United States" (Soil Conservation Service 1985). In one subarea at Carolina Beach the water table at all sample points was within 1 ft of the surface at the time sampled; in all other Coastal Plain areas, the location of the -1 ft water table contour was plotted.

Vegetative data from the Piedmont study area were treated similarly, except that shrubs were expressed as (frequency x height (by class intervals)), vines were treated as frequency (by class intervals) in a separate stratum, and relative tree basal area was determined from a 30 ft radius circular plot around each sample point. In addition to the vegetative data, the area on this site in which the water table was within 1 ft of the ground surface and exhibiting a soil color value ≥ 4 and soil color chroma ≤ 2 was delineated.

Vegetative wetland indices were plotted by Plane Coordinates and contour lines corresponding to 50 percent wetland species (Corps) and a weighted mean of 3.0 (SCS) were drawn.

Modified Definitions

Inclusion of facultative species within the wetland vegetation component creates logical, ecological, and legal problems. If all versions of the wetland definition are indeed measuring the same entity, they should concur. They did not. The area comprised of wetland species, by current definition, was much greater than that meeting soil and hydrology and the area previously delineated as "wetland" by Corps personnel. Facultative species are no more indicators of wetland than of upland, and are certainly not "typically adapted for life under saturated soil conditions" (33 C.F.R. 323.2 (c)).

This inconsistency can be alleviated by omitting facultative species from the definition of wetland vegetation.

The same analyses described in the preceding section were repeated, except that 1) the Corps vegetative wetland index consisted only of obligate and facultative wetland species, and 2) the SCS vegetative wetland/upland boundary index was 2.5, the midpoint between facultative wetland and facultative species. [Note: Wentworth and Johnson (1986; p. 59, 60) recommended "provisional adoption of 3.0 as a 'break-point' separating wetlands from uplands" but regarded the region "between 2.5 and 3.5 as a 'gray zone,' where designations would be unreliable." SCS failed to heed this caution in their proposed regulations.]

RESULTS AND DISCUSSION

Delineation Without a Definition

Wooded Swamp. All validation points were correctly classified as "wet" or "dry" by the discriminant function. However, the minimum Mahalanobis' distance was adjacent to the marked Section 404 boundary on only one-half of the transects and no trough of minimum distances coincident with the boundary existed.

Tidal Saltmarsh. Discriminant analysis did not distinguish between "line" and "other" points nor between wet and dry points.

While discriminant analysis was useful in classifying line and non-line points in the wooded swamp, it was no help in the tidal saltmarsh and probably was a poor choice in either case. "Wet" and "dry" were the closest zones to "line" along the hydric to xeric continuum. Although not evident in the data, discrimination could have been enhanced by extending the sampling transects to include "wetter" and "drier" conditions; the function simply may have represented the length of the transect lines relative to the degree of environmental change per unit distance. In the tidal saltmarsh, the entire study area could have been considered 1) an upper tidal marsh community consisting of intermixed small areas of marsh and upland, or 2) a broad ecotone within which environmental conditions changed very gradually.

Discriminant analysis did not help to separate line from non-line conditions. In both study areas, grouping wet and dry conditions into an "other" category may have masked differences which were attributable to either but not to both.

Fitting the Definitions

Tidal Saltmarsh. The Corps vegetative index value at 16 of the 17 points on the previously established boundary was 1.00; the mean was 0.99. The corresponding SCS mean value of the same points was 1.87, with a maximum of 2.55.

Little coincidence appeared between the marked boundary and those which would have been established by current Corps or SCS procedures. By either system, almost all of the roughly 75 ft x 100 ft area sampled by the transects lay in wetlands, but above (at a higher elevation than) the previously established boundary. Derived Corps and SCS boundaries were parallel and within 25 ft of each other. All boundaries, delineated or derived, lay well below (at a lower elevation) the line representing the water table at 1 ft depth.

Wooded Swamp. The mean value of the Corps vegetative index derived from 15 points along the delineated boundary was 0.92; extremes were 0.99 and 0.76. Comparable SCS values were 2.49, 2.69, and 2.26.

The delineated line was again at a lower elevation than the derived ones, and all were more parallel than in the tidal marsh. The line representing the water table at a depth of 1 ft was generally parallel to vegetative boundaries, but was at a lower elevation than the derived Corps boundary and crossed the SCS and delineated Corps boundaries.

In all cases, the derived vegetative boundaries would have included more land under regulation than did the delineated boundary, and the SCS boundary more closely approximated the delineated boundary than did the derived Corps boundary, but differences were relatively small. In three out of the four examples the derived boundary was within 14 ft or less of the delineated boundary and areal differences were less than about one-third acre per 1000 linear ft of boundary (Table 1).

Subarea	Boundary	Ft	Ac/1000 Ft
a.	Corps	26	0.60
	SCS	12	0.26
b.	Corps	14	0.32
	SCS	7	0.17
	Mean	15	0.34

Table 1. Average differences between delineated and derived vegetative boundaries in wooded swamp.

Intermittent Stream. Only about 300 ft^2 (within which lay the intermittent stream channel) met Corps soils and water table criteria (i. e, soil color value ≥ 4, chroma ≤ 2, and water table within 1 ft of the surface). The soil series was "Mantachie" (U. S. Department of Aqriculture, Soil Conservation Service 1970), which does not appear in "Hydric Soils of the United States" (U. S. Department of Agriculture Soil Conservation Service 1985). SCS hydric soils characteristics contained in the same publication (e.g., "water table at less than 1.0 ft. from the surface at some time during the growing season if permeability is equal to or greater than 6.0 in/hr in all layers within 20 inches ... water table at less than 1.5 ft from the surface at some time during the growing season if permeability is less than 6.0 in/hr in any layer within 20 inches ....") were unobtainable during the field time available. The SCS vegetative model covered more than 20 times as much land as the area meeting Corps soils and water table criteria, and almost the entire study area supported wetland vegetation by the Corps vegetative model (Figure 2).

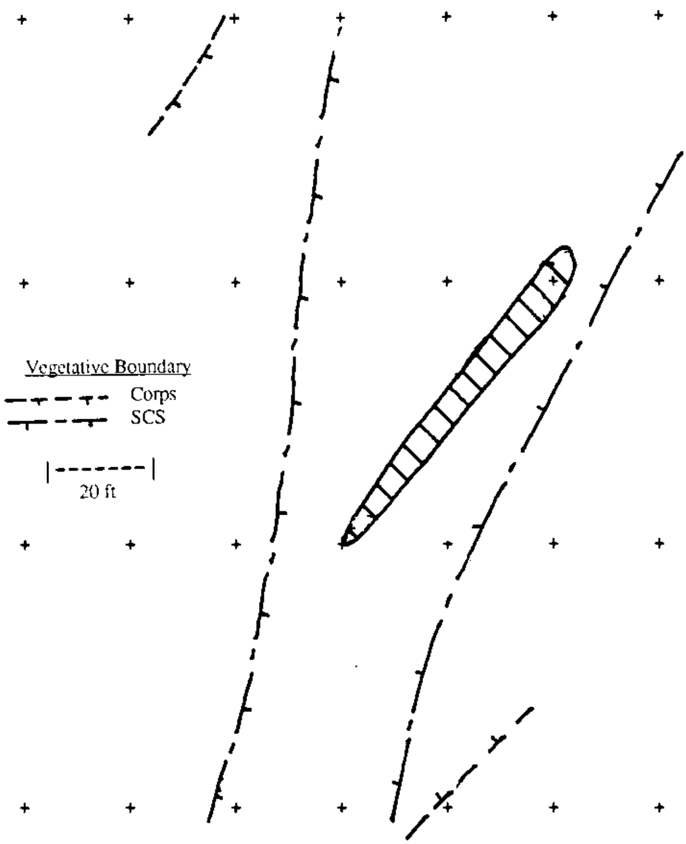

Figure 2. Lower Piedmont wetland along intermittent stream. (Shaded area meets Corps wetland soils and hydrology criteria; hachures are on the wetland side of boundary lines.)

In this Piedmont study area, the tree stratum was composed primarily of loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and tulip poplar (*Liriodendron tulipifera*). The shrub stratum consisted largely of smaller specimens of the hardwood species listed above, and the vines were mostly muscadine grape (*Vitis rotundifolia*), Japanese honeysuckle (*Lonicera japonica*), common greenbrier (*Smilax rotundifolia*), and poison Ivy (*Toxicodendron radicans*). All these species are classified as "facultative" by the Fish and Wildlife Service (1986) and contribute to the wetland vegetation component by both Corps and SCS standards.

Modified Definition

Wooded Swamp. Mean vegetative values along the designated boundary corresponded almost exactly to expected values, 0.48 vs. 0.50 for the Corps index and 2.49 vs. 2.50 for the SCS measure. Lines derived from the modified definitions were more parallel to the delineated boundary than under the previous definition and more closely in agreement with each other (Table 2). Better agreement with the line representing the water table at 1 ft depth was also achieved, although both derived boundaries were downhill from the water table line.

Subarea	Boundary	Ft	Ac/1000 Ft
a.	Corps	-11	-0.25
	SCS	-14	-0.32
b.	Corps	-20	-0.47
	SCS	-15	-0.34
	Mean	-15	-0.35

Table 2. Average differences between delineated and derived vegetative boundaries in wooded swamp under the modified definitions.

Overall, the fit was about the same, but in the opposite direction. Under both modified systems, less land would have been regulated than under the delineated boundary.

Tidal Saltmarsh. Under the modified definition, the mean value for points on the previously established boundary was 0.83 under the Corps system, 17 percentage points closer to the expected vegetative index value of 0.50 than under existing standards (0.99). While the SCS value of 1.87 did not change under the proposed system, it was obviously closer to 2.50 than to 3.00. As in the analysis of the current definition, the location of the water table at 1 ft depth was some distance shoreward of all vegetative boundaries, indicating that the vegetative boundary was conservative (i.e., encompassed a minimum area) even under this alternative.

Intermittent Stream. The greatest coincidence among indices was achieved in this system (Figure 3). When the modified vegetative criteria were applied, about 190 ft^2 were defined as wetland by Corps standards and about 290 ft^2 by the SCS formula. About 64% of the Corps vegetative wetland lay within the area meeting their soils and hydrology criteria, and it encompassed about 38% of the latter area. By the modified SCS standards, 57% of the vegetative wetland lay within the area meeting wetland soils and hydrology criteria, comprising about 51% of that area.

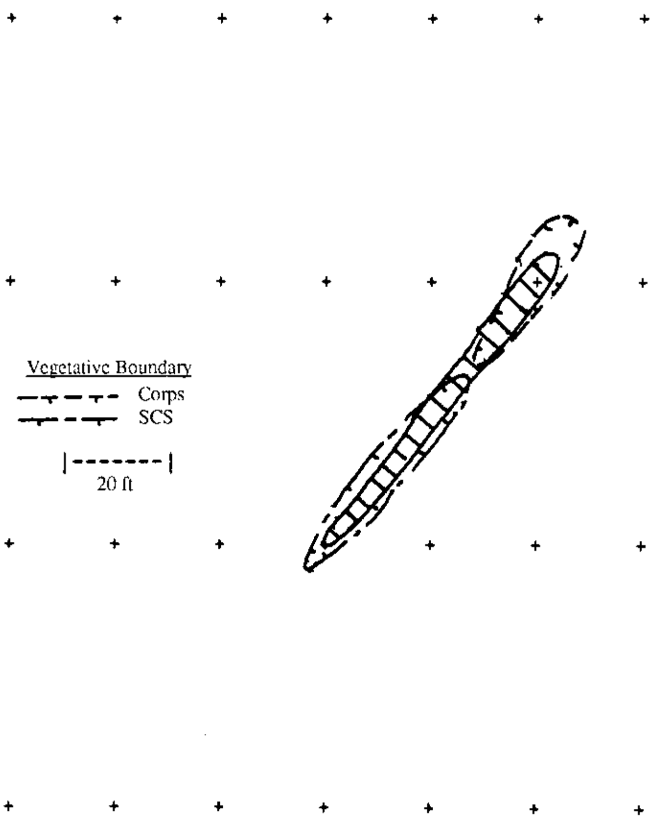

Figure 3. Lower Piedmont wetland along intermittent stream under modified definitions. (Shaded area meets corps wetlands soils and hydrology criteria; hachures are on the wetland side of boundary lines.)

CONCLUSIONS

1. When facultative species are included within the aggregate of wetland vegetation, as proposed by Sanders *et al.* (1984) and in regulations promulgated by the SCS (51 F.R. 23507), vegetation becomes virtually useless as an indicator of wetland conditions in the Piedmont. The vegetative wetland boundary is almost invariably upslope from the wetland boundary as defined by soil and/or water table criteria, and the regulatory boundary would almost always be limited by the latter. While differences between inclusion and exclusion of facultative species under the definition of wetland vegetation are less pronounced in wooded swamp and tidal saltmarsh, vegetative boundaries under themodified criteria (excluding facultative species) more closely match permit boundaries previously delineated by Corps of Engineers personnel.

2. The wetland boundary problem is a linear problem; its solution depends upon constructing a legally and ecologically defensible line across the wetland-upland continuum. Contouring provides a means of accomplishing this task.

3. Commonly used vegetation analysis methods, applied to points on a 25-to-50 ft sampling grid, provide an adequate data base for calibrating and/or validating boundaries established through less rigorous methods and for boundary delineation in small areas of high value land. When the definition of "wetland vegetation" is limited to obligate and facultative wetland species, the proposed Corps and SCS systems produce generally comparable results, and their delineation of the wetland boundary will be roughly compatible with delineations based on soil color and hydrology criteria.

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