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Initiating the Development of a Draft Woody Depressional Wetland HGM Model for the Coastal Plain of Virginia.

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Final Report to
U.S. Environmental Protection Agency, Region III
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Introduction

The Hydrogeomorphic (HGM) method for modeling and assessing wetlands is an emerging standard for many federal and state agencies. Implementation of this approach in Virginia is currently hampered by a lack of appropriate models. This project initiated the preliminary development of a Forested (Woody) Depressional Wetland HGM model in the coastal plain of the Commonwealth of Virginia.

Forested depressional wetlands in the coastal plain of Virginia generally consist of topographic depressions in the landscape with soil horizon confining layers and hydrologically are predominately precipitation driven. These systems generally are considered to have no discernible surface water (channel) connections to a hydrologic source. Many coastal plain sinkhole pond complexes harbor a number of rare plants and animals and are declining throughout the region. One area of particular interest, the Grafton Ponds Complex, located in the City of Newport News and York County, Virginia, consists of approximately 2,640 acres of ponds that range in size from about 12 to 30 meters in diameter. Tiner et al. (2002) reviewed selected USGS quadrangles throughout the United States and, using a GIS methodology, found 14-16.5% of the wetlands in the one selected area in Virginia to be considered isolated. A GIS analysis of all the NWI mapped wetlands in Virginia found approximately 8% (≈95,000 acres) could be considered isolated wetlands (Virginia Institute of Marine Science, 2003). Development in southeastern Virginia continues to impact these systems (Rawinski 1997). Other impacts to these systems include removal of surrounding forest cover through timbering, utility easements and maintenance, and hydrologic modification and alteration through ditching or groundwater withdrawal from the unconfined aquifer, redirection of stormwater input and runoff from agricultural fields and residential areas. Recent court cases have also cast doubt on the long-term federal regulation of these wetlands systems (see http://www.supremecourtus.gov/opinions/00pdf/99-1178.pdf.).

Woody depressional wetlands provide a variety of beneficial functions to ecosystems and society as a whole. Due to their location in landscapes, depressional wetlands tend to store precipitation which, in turn, mitigates flooding effects. Water retained in depressions provides for groundwater recharge and headwater streamflow through contributions to the unconfined groundwater aquifer.

The mosaic of depressions within the landscape, with their varying depths and water storage capacities, provides a variety of hydrologic environments from ephemeral to seasonally ponded. Fluctuating water levels in the landscape provide niches for many species of plants and animals adding to the biodiversity of the region.

In fact, fluctuating water levels are essential habitat for many amphibians. Periodic water level drawdown within depressions eliminates fish that would severely impact the reproductive success of amphibians that rely on these systems for breeding. Many amphibian species spend their adult life in the surrounding forested landscape making depressional wetlands and their forested buffers vital for the conservation of biodiversity. These systems are also utilized by migrating birds and are sometimes the only water source for animals during drought conditions.

Existing research involving the development of assessment models for depressional wetlands was reviewed and evaluated including the Natural Resource Conservation Service (NRCS) 'interim model' for Alabama, Georgia, Florida, and South Carolina. In addition, collaboration with researchers in Maryland and Delaware was conducted to initiate the identification and definition of regional wetland subclass Woody Depressional Wetlands (WDW) for model development in Virginia. This included discussions on defining the WDW reference domain, developing the WDW functional profile, and identifying model variables and the direct and indirect measures of those variables.

This report encompasses the initial development of a WDW model up to the preliminary development stage and serves as an initial framework for a WDW model for the coastal plain of Virginia. These results can serve as a foundation for subsequent studies to complete the development of the model.

Site Location

Eight sites were selected in Virginia's coastal plain for preliminary data collection and variable development (Figure 1). Seven sites were selected within the Grafton Ponds area on the Virginia Peninsula. These sites were selected because of existing research data and the combination of relatively pristine and disturbed sites. One site was selected on Virginia's eastern shore. Sites ranged in size from 0.23 hectares to 1.68 hectares (Table 15). Depressional wetland sites are shown with 200 m buffers in Digital Ortho Quarter Quad (DOQQ) aerials in Appendix V.

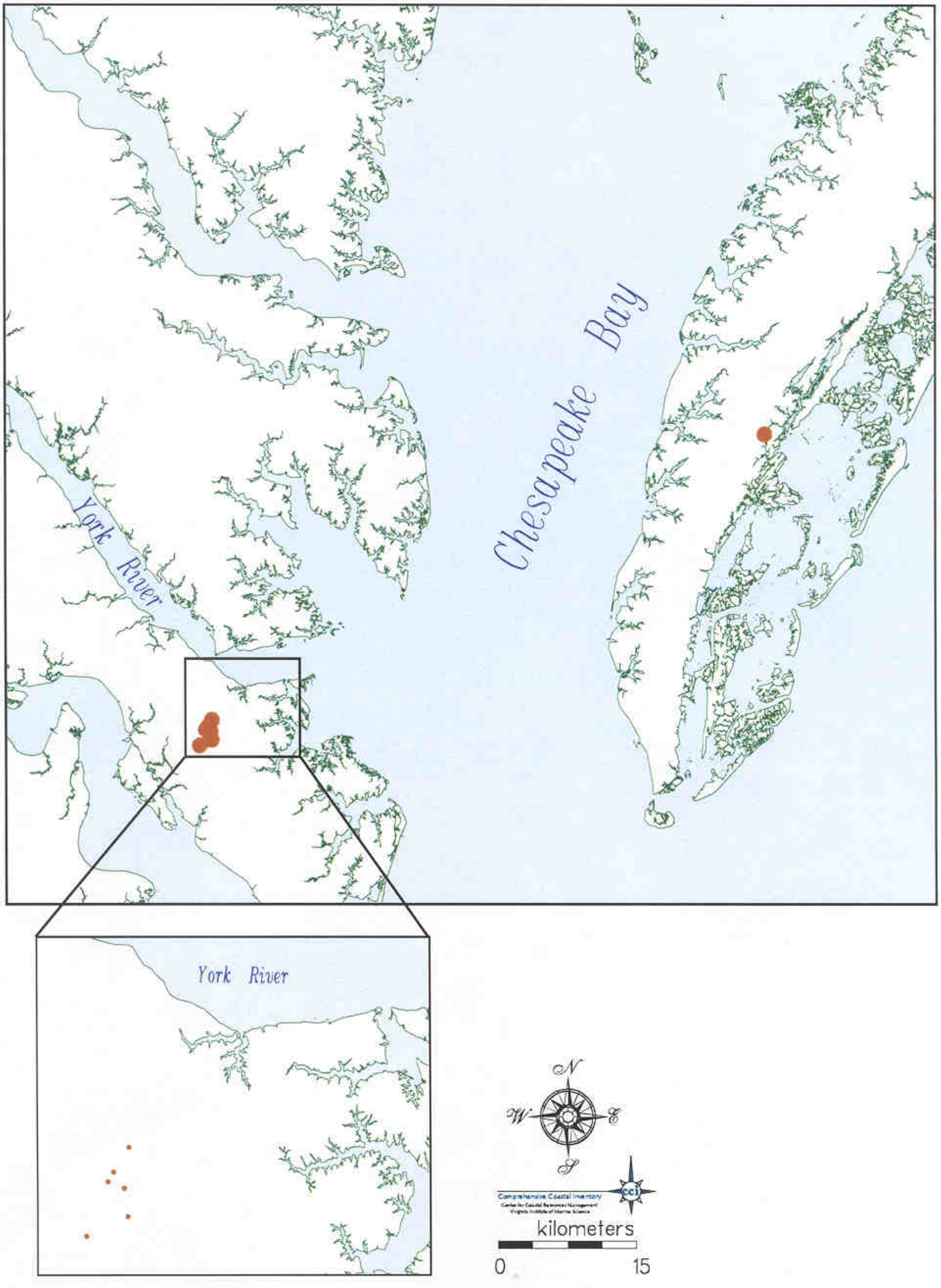
Sampling Protocol

A review of other protocols, existing literature, and insight gained from the development of a Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils in the Coastal Plain of Virginia (EPA CD#993723-01-0), led to the development of a modified protocol to sample vegetation (canopy trees, mid-story trees, saplings, shrubs, herbs, vines, and exotic species), habitat characteristics (tree cavities, dead standing trees, fallen debris, and hummocks), soils (consistence of the A and B horizons and depth of O and A horizons), and hydrology (topography, ponding depth, and ponding duration). Both the wetland and the adjacent buffer area were sampled within a 1/10 acre plot (11.35m radius).

After preliminary data collection and workshop discussions with other researchers involved in depression wetland model development, a consensus was reached to sample a basic suite of variables across the various regions (Delaware, Maryland, and Virginia). Sample variables and sampling protocol are depicted in Appendix I. Included in the protocol is a stressor checklist (Appendix III) and a data collection verification checklist (Appendix IV).

Calibration and some validation was conducted on the seven Grafton Ponds sites by comparing the data obtained from the sampling protocol with data obtained from an earlier, independent, more intensive research effort at these sites. In addition, an amphibian

Figure 1. Site locations.



and habitat/landscape variables study was conducted at the seven sites to determine variable compatibility and to identify the need for protocol adjustments.

Results

Vegetation

Vegetation was divided into six (6) strata: herbaceous, vines, shrubs, saplings (>1 m high < 7.5 cm dbh), mid-story trees (≥ 7.5 < 15 cm dbh), and canopy trees (≥ 15 cm dbh).

A complete plant species list is detailed in Appendix II. NC8, R2, F5, and R4 had the highest basal area per acre for trees within the buffer area, though, D6 and F5 had the highest hardwood/softwood ratio (Table 1). Stem density of trees per hectare was highest in sites R1, NC8, and R3, however, over 50% of the density of NC8 and R3 was in saplings (Tables 2-7).

Table 1. Basal area of trees within buffer zone including hardwood to softwood ratios.

Site	BA ft2/acre (BAF 10)	BA ft2/acre (BAF 5)	Hardwood/Softwood Ratio
NC8	180	150	0.16
R2	170	210	0.30
F5	130	110	0.96
R4	100	155	0.08
R1	70	165	0.59
D6	70	80	0.98
D7	60	60	0.33
R3	0	0	0

Table 2. Total stem count (#) for canopy trees > 15 cm dbh within the depression zone.

	F5	NC8	R1	R2	R3	R4	D6	D7
Species	#	#	#	#	#	#	#	#
A. rubrum		23		1	1	1		
C. glabra								
D. virginiana			2	1				1
I. opaca								
L. styraciflua			3	2	1			1
N. sylvatica		17	20	2	1	13		
P. taeda			1					
Q. alba			1					
Q. lyrata	2							
Q. nigra								
Q. phellos					2			
Total	**2**	**40**	**27**	**6**	**5**	**14**	**0**	**2**
Density stems/hectare	**50**	**1000**	**675**	**150**	**125**	**350**	**0**	**50**

Table 3. Total stem count (#) for canopy trees > 15 cm dbh within the transition zone.

	F5	NC8	R1	R2	R3	R4	D6	D7
Species	#	#	#	#	#	#	#	#
A. rubrum	3							
C. glabra								
D. virginiana								1
I. opaca				1				
L. styraciflua	2			1				
N. sylvatica	3							3
P. taeda	1			2				
Q. alba								
Q. lyrata	2							
Q. nigra				1				
Q. phellos								1
Total	**11**	**NA**	**NA**	**5**	**0**	**NA**	**0**	**5**
Density stems/hectare	**275**	**NA**	**NA**	**125**	**0**	**NA**	**0**	**125**

Table 4. Total stem count (#) for midstory trees 7.5<15 cm dbh within the depression zone.

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	F5	NC8	R1	R2	R3	R4	D6	D7
Species	#	#	#	#	#	#	#	#
A. rubrum		12						
C. glabra								
D. virginiana			2	2		1		8
I. opaca								
L. styraciflua		2						
N. sylvatica		15	7	3	26	4		
P. taeda								
Q. alba			1					
Q. lyrata	1							
Q. nigra								
Q. phellos		1			6	1		
Total	**1**	**30**	**10**	**5**	**32**	**6**	**0**	**8**
Density stems/hectare	**25**	**750**	**250**	**125**	**800**	**150**	**0**	**200**

Table 5. Total stem count (#) midstory trees 7.5<15 cm dbh within the transition zone.

	F5	NC8	R1	R2	R3	R4	D6	D7
Species	#	#	#	#	#	#	#	#
A. rubrum	3			2	1			
C. glabra								
D. virginiana								
I. opaca								
L. styraciflua	1			2	4			
N. sylvatica								4
P. taeda								
Q. alba								
Q. lyrata								
Q. nigra	1			3				
Q. phellos								1
Total	**5**	**NA**	**NA**	**7**	**5**	**NA**	**0**	**5**
Density stems/hectare	**125**	**NA**	**NA**	**175**	**125**	**NA**	**0**	**125**

Table 6. Total stem counts (#) for saplings <7.5 cm dbh within the depression zone.

	F5	NC8	R1	R2	R3	R4	D6	D7
Species	#	#	#	#	#	#	#	#
A. rubrum		13			15			
C. glabra								
D. virginiana			5					35
F. pennsylvanica		1						
I. opaca		1		1				
L. styraciflua		17	1		8			
M. virginiana		1						
N. sylvatica		38			15			
P. taeda								
Q. alba								
Q. lyrata	2							
Q. nigra			1					
Q. phellos		1			2			
Total	**2**	**72**	**7**	**1**	**40**	**0**	**0**	**35**
Density stems/hectare	**50**	**1800**	**175**	**25**	**1000**	**0**	**0**	**875**

Table 7. Total stem counts (#) for saplings <7.5 cm dbh within the transition zone.

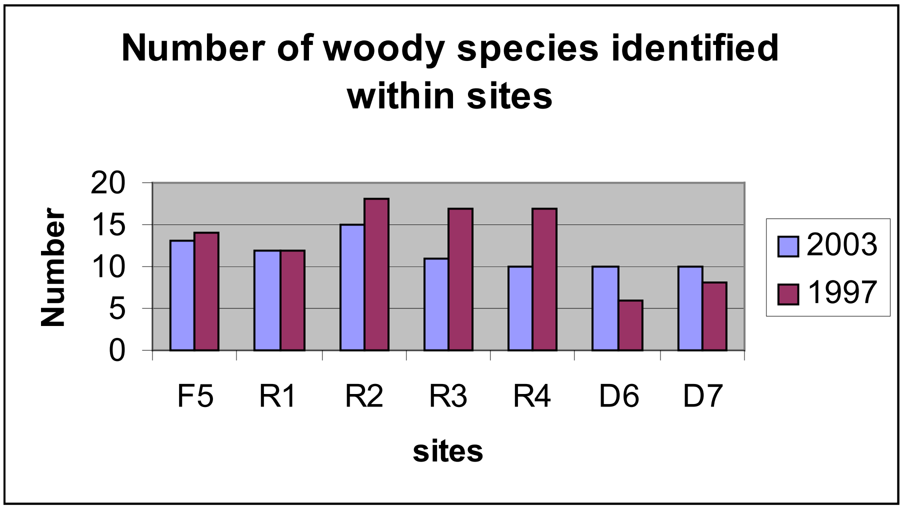
	F5	NC8	R1	R2	R3	R4	D6	D7
Species	#	#	#	#	#	#	#	#
A. rubrum	1			1	12			
C. glabra								
D. virginiana								1
F. pennsylvanica								
I. opaca								
L. styraciflua	1				8			
M. virginiana								
N. sylvatica				1	1			
P. taeda								
Q. alba								
Q. lyrata	1							
Q. nigra								
Q. phellos					1			1
Total	**3**	**NA**	**NA**	**2**	**22**	**NA**	**0**	**2**
Density stems/hectare	**75**	**NA**	**NA**	**50**	**550**	**NA**	**0**	**50**

R4, R1, and F5 had the highest percent of canopy trees while D7, R3, and NC8 had the highest percent of saplings (Table 8). The sites with highest percentage of saplings were also sites that have been impacted within the last few decades by timbering or utility easement maintenance. R2, F5, R3, and R4 had the highest number of woody species while D6 and D7 had the lowest number of woody species (Figure 2).

Table 8. Percent of canopy trees, mid-story trees, and saplings per site.

	F5	NC8	R1	R2	R3	R4	D6	D7
Percent Canopy Trees	54	28	61	42	5	70	0	12
Percent Mid-story Trees	25	21	23	46	35	30	0	23
Percent Saplings	21	51	16	12	60	0	0	65

Figure 2. Number of woody species per site identified in this study (2003) and an earlier study (Rawinski 1997).



F5, NC8, and R2 were the only sites with standing dead greater than 15 cm dbh and greater than 2 m high (Table 9). Coarse woody debris is considered important for amphibian and invertebrate populations (deMaynadier and Hunter 1995, Braccia and Batzer 2001) and standing dead is important for nesting and foraging sites for birds (Watts, per. Com.).

Table 9. Total count of standing dead greater than 15cm dbh and greater than 2m high.

	F5	NC8	R1	R2	R3	R4	D6	D7
Total count	2	5	0	2	0	0	0	0
Density stems/hectare	**50**	**125**	**0**	**50**	**0**	**0**	**0**	**0**

R1, R2, and R3 had the highest shrub and vine density (Tables 10-12).

Table 10. Total stem count of shrubs within the depression zone.

	F5	NC8	R1	R2	R3	R4	D6	D7
Acer rubrum			1				12	
Cephalantus occidentalis	2							
Clethra alnifolia			29		5	3		
Diospyros virgininiana			24					
Itea virginica								
Leucothe racemosa				67		2		
Liquidambar styraciflua			1			1		
Myrica cerifera		41			1			
Nyssa sylvatica			1					
Quercus phellos			1					
Rhododendron viscosum		1	3	15				
Rosa palustris		1						
Rubus cuneifolias		1						
Symplocos tinctoria								
Vaccinum corymbosum		1	229	20	3			
Total	**2**	**45**	**289**	**102**	**9**	**6**	**12**	**0**
Density stems/hectare	**50**	**1125**	**7225**	**2550**	**225**	**150**	**300**	**0**

Table 11. Total stem count of shrubs within the transition zone.

	F5	NC8	R1	R2	R3	R4	D6	D7
Acer rubrum								
Cephalantus occidentalis								
Clethra alnifolia					9			
Diospyros virgininiana							11	
Itea virginica							16	
Leucothe racemosa							9	
Liquidambar styraciflua					6		13	
Myrica cerifera								
Nyssa sylvatica								
Quercus phellos								
Rhododendron viscosum								
Rosa palustris								
Rubus cuneifolias								
Symplocos tinctoria				31				
Vaccinum corymbosum	26			8	103			
Total	**26**	**NA**	**NA**	**39**	**112**	**NA**	**49**	**0**
Density stems/hectare	**650**	**NA**	**NA**	**975**	**2800**	**NA**	**1225**	**0**

Table 12. Total stem counts for vines within the depression and transition zones of sites.

	F5	NC8	R1	R2	R3	R4	D6	D7
Smilax rotundifolia (within depression)	0	11	144	0	105	9	30	3
Smilax rotundifolia (within transition)	29	NA	NA	33	0	NA	0	245
Total	**29**	**11**	**144**	**33**	**105**	**9**	**30**	**248**
Density stems/hectare	**363**	**275**	**3600**	**413**	**1313**	**225**	**375**	**3100**

The volume of coarse woody debris was highest in D6, NC8, R2, and R1 and lowest in R3 (Figure 3). Both R1 and D7 had newly fallen debris as part of their total percentage (Figure 4).

Figure 3. Volume (m^3) of coarse woody debris per site.

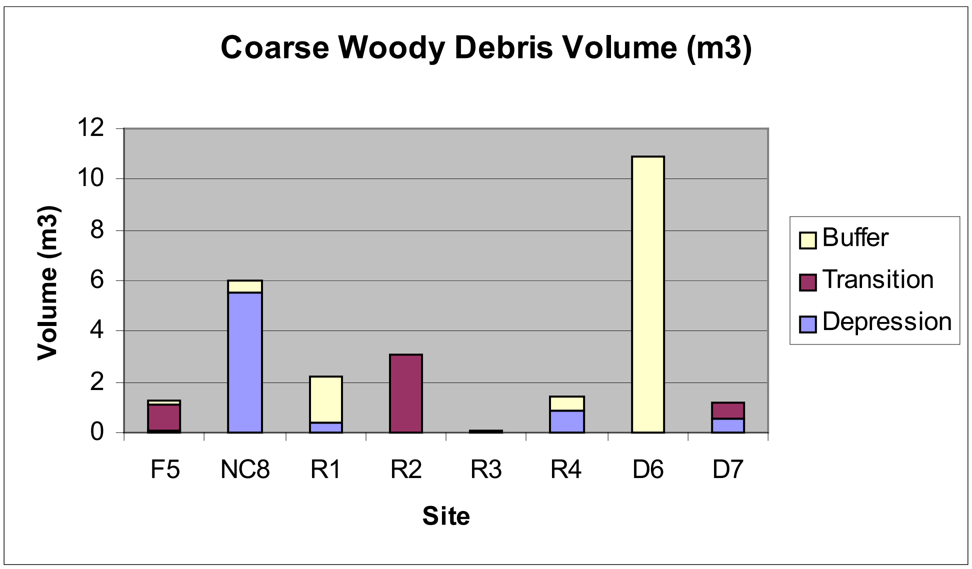
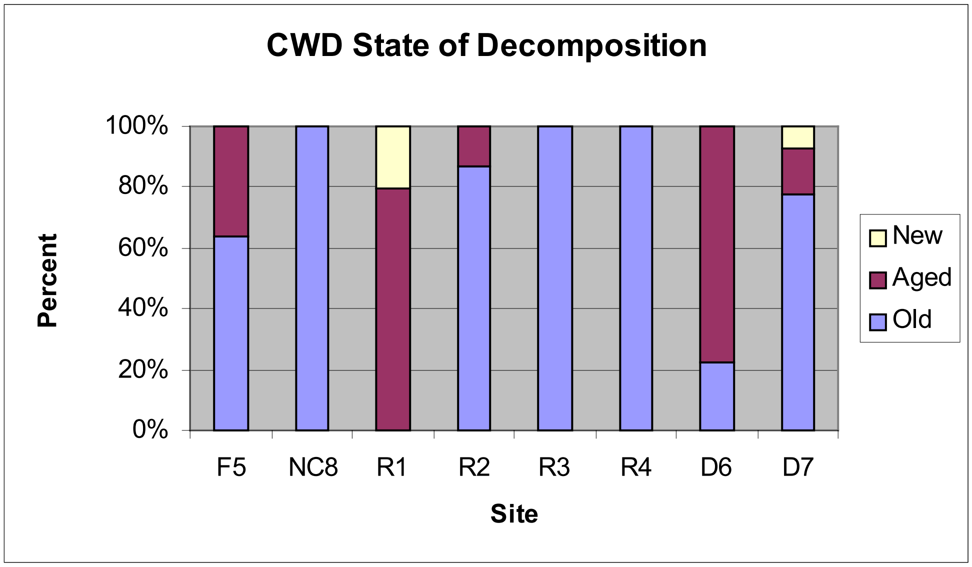


Figure 4. State of decomposition of coarse woody debris per site.



Macrotopography

Distance to the nearest hummock varied from 0 m to 17 m (Figure 5). Depths within the depressions varied from 0.12 m to 0.66 m (Figure 6). All ponds went dry by the early summer. It should be noted that Virginia was under drought conditions during the study period. Ponded depth was determined by noting the highest flooded level within the pond. This was calculated from water marks on trees in the depression as outlined in Appendix II. The percentage height of the water level above the depth of the depression may be a good indicator of the connectivity with other depressions and flats within a region (Table 13).

Figure 5. Distance to the closest hummock from the center of the depression and the average distance of hummocks in the sample area.

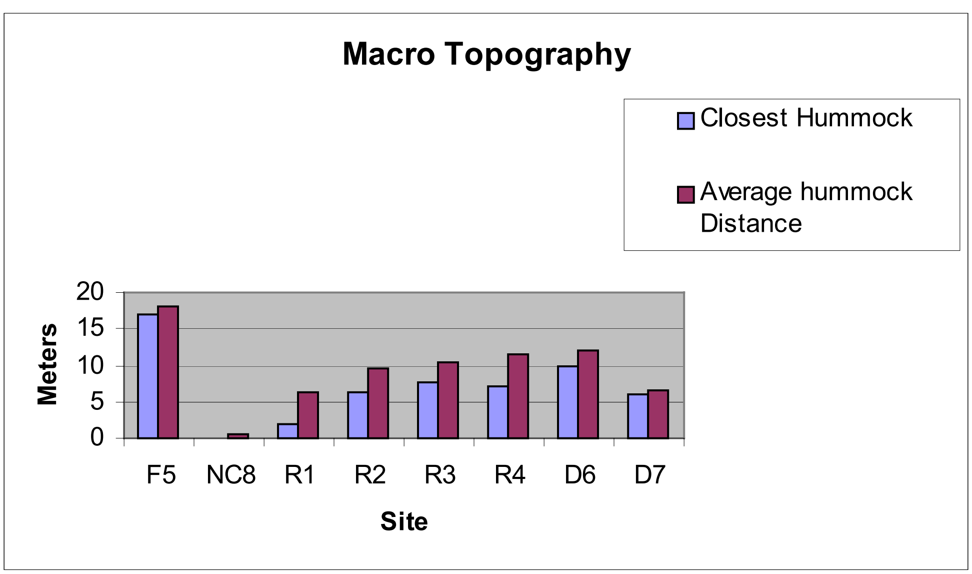


Figure 6. Depth of the depression relative to the depression rim (Pond Depth) and depth of evidence of flooded height (Ponded Depth) as recorded from water marks on trees.

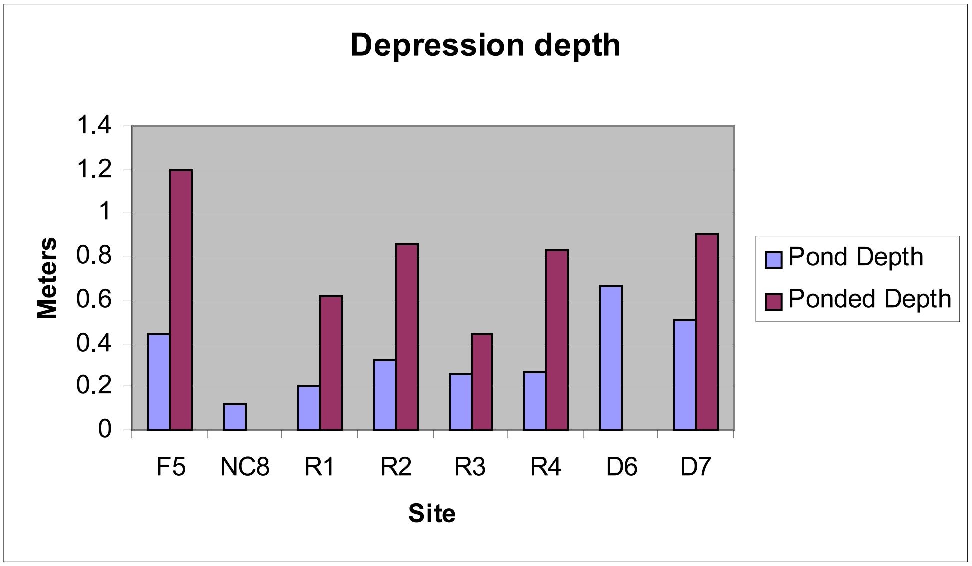


Table 13. Flooding height above pond depth as a percentage of pond depth.

	F5	NC8	R1	R2	R3	R4	D6	D7
Flooded height above pond depth (percent)	173	0	210	169	69	207	0	76

Soils

Soils within the depression, transition (where present), and buffer zones were examined at each of the eight sites to determine differences in soil horizonation among sites and whether anthropogenically disturbed sites could be distinguished from relatively undisturbed areas based upon soil properties such as texture.

To evaluate the soil within each zone of the eight sample sites, profiles to a depth of 18 inches where taken using a 4 inch bucket hand auger. The depth of the O horizon, when present, and A horizon were measured (inches) along with the consistence of the A and B horizons. Consistence, a function of soil texture and moisture content, is a simple field-measured property of soil. Representative peds from the A and B horizons were sampled under conditions of moist consistence, or where the soil moisture content is between dryness and field moisture capacity (Buol et al. 1980). Consistence of the horizons were determined according to the soils resistance to finger pressure. The values for moist consistence are provided below:

0. Loose	Soil material is noncoherent.
1. Very Friable	Aggregates easily crushed between thumb and index finger.
2. Friable	Gentle thumb and finger pressure required to crush aggregates.
3. Firm	Moderate thumb and finger pressure required to crush aggregates.
4. Very Firm	Strong thumb and finger pressure required to crush aggregates.
5. Extremely Firm	Aggregates cannot be broken by thumb and finger pressure.

*Identification, nomenclature, and description of soil horizons consistent with: Schoeneberger et al. (2002).

Six of the eight sites had at least one zone where the O horizon was absent (Figure 7). Of these six sites, 5 did not exhibit an O horizon in the depression zone, suggesting that decomposition of organic material keeps pace with deposition. Also, two sites, D6 and R1, exhibited no development of an O horizon in their herbaceous buffer zones.

Six of eight sites exhibited at least one zone with a thick A horizon (≥6 inches). Of the six, only two sites exhibited thick A horizons in the depression zone (D6, R2). The depression zone of Site R2 had the thickest A horizon at 12 inches. Sites D6, D7, F5, R1 and R2 had thick A horizons in the transition zone. Thin A horizons (≤3inches) were reported at five zones within four sites (Figure 8).

The cut-over utility easement buffer zonesite (D6) exhibited the firmest A horizon soil (Figure 9). The majority of sites and zones exhibited firm to very firm soils in the B horizon (Figure 10).

Figure 7. Thickness of the O horizon in the depression, transition, and buffer zones per site.

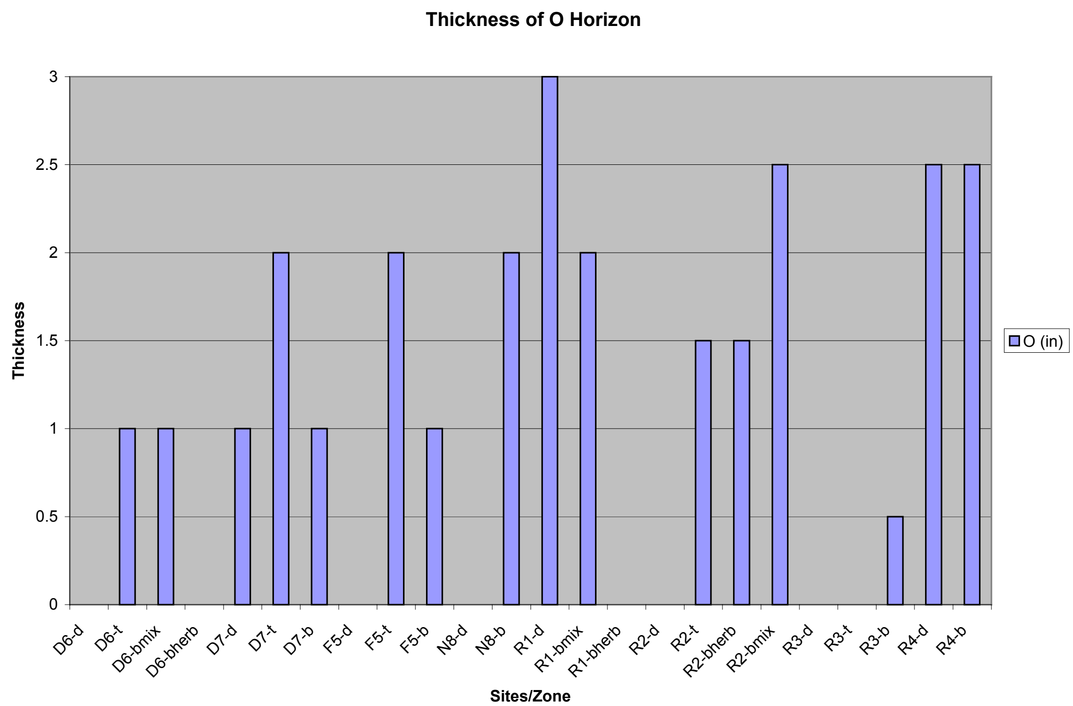


Figure 8. Thickness of the A horizon in the depression, transition, and buffer zones per site.

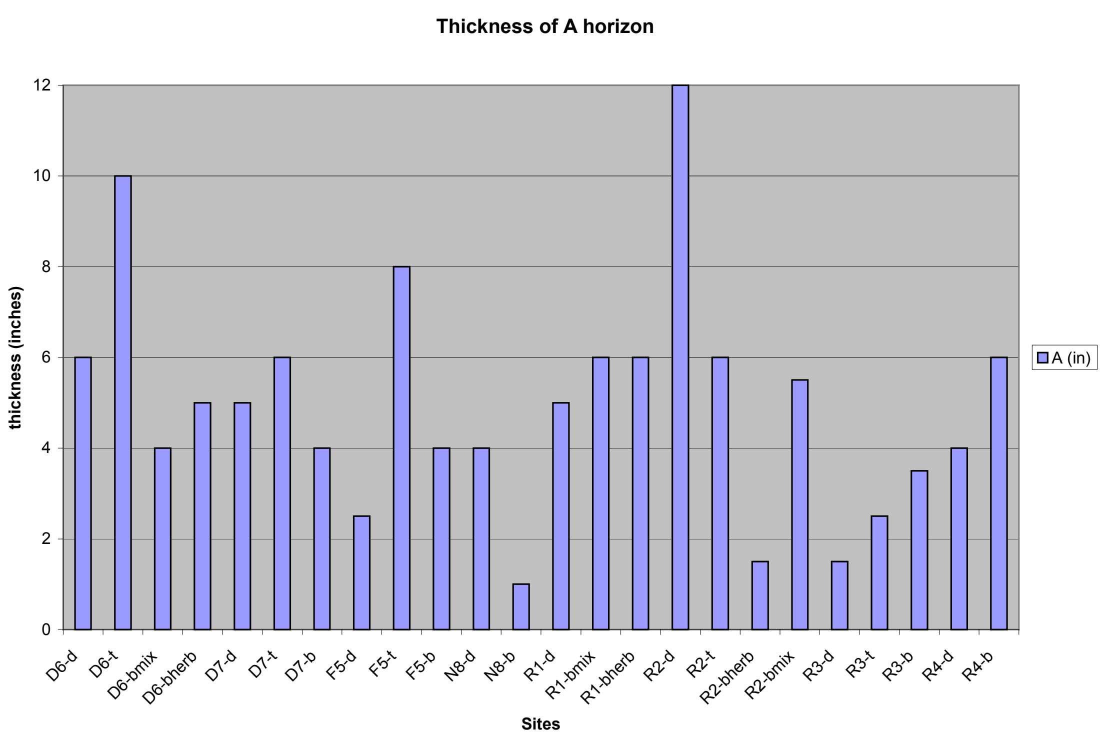


Figure 9. Consistence of the A horizon. 0= loose, 1= very friable, 2= friable, 3= firm, 4= very firm, and 5= extremely firm.

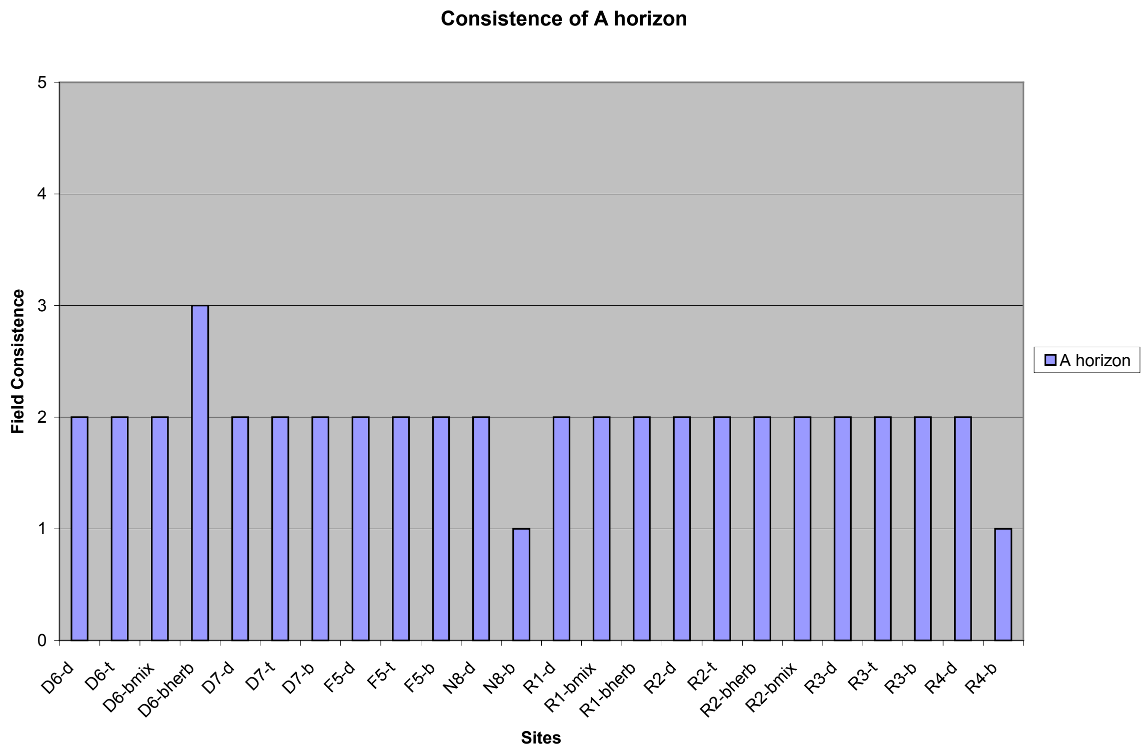
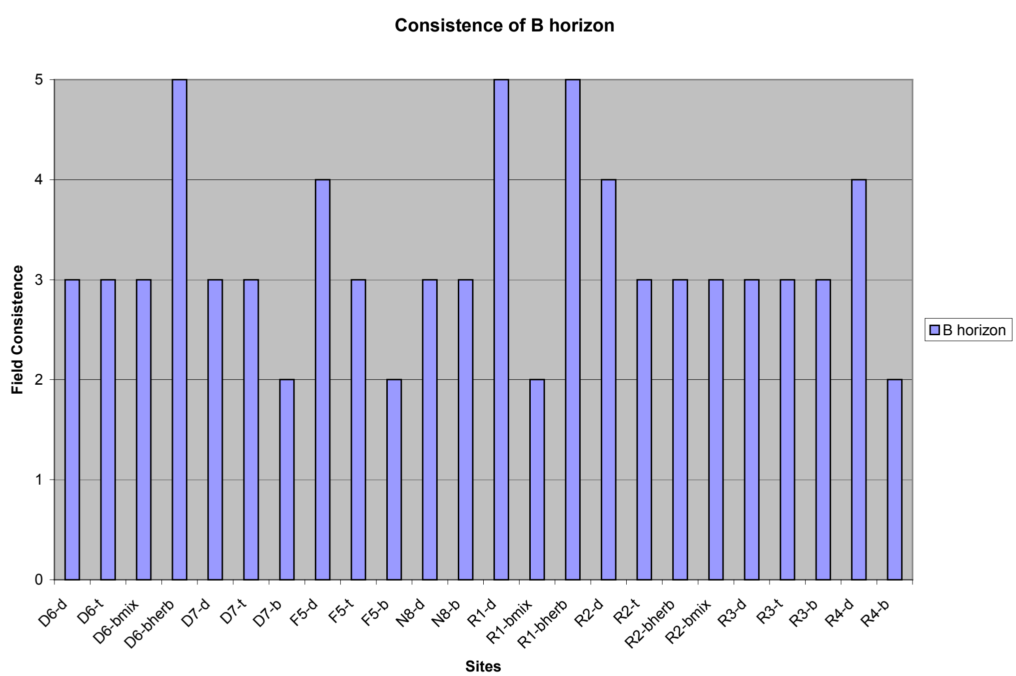


Figure 10. Consistence of the B horizon. 0= loose, 1= very friable, 2= friable, 3= firm, 4= very firm, and 5= extremely firm.

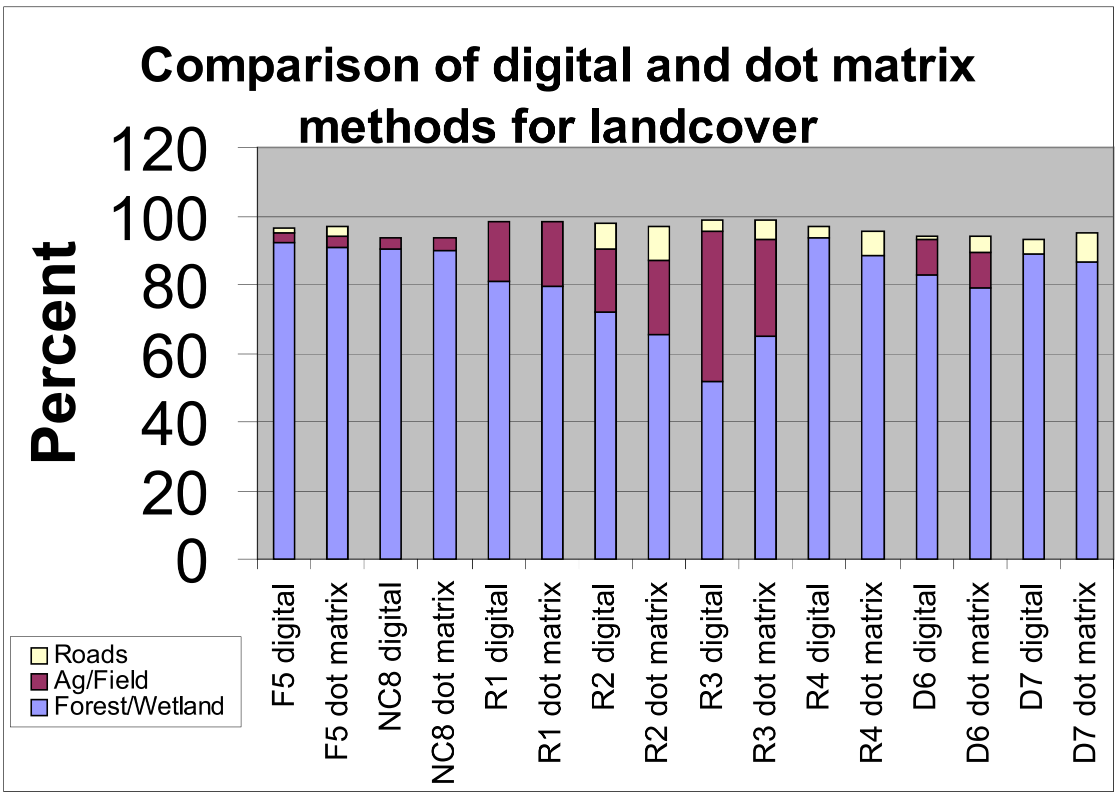


Buffer

The degree to which the surrounding land is fragmented by various land use types and the subsequent exposure of the interior wetland can impact a wetlands wildlife value (i.e. interior forest bird species) (Temple and Cary 1988). Forested and additional wetlands (scrub/shrub communities) are considered having high wildlife habitat value (Paton 1994; Keyser et al. 1998).

Analysis of landuse types within the 200m buffer using the either the Dot Matrix Method and GIS methods indicated no significant difference (P=0.687) (Figure 11).

Figure 11. A comparison of digital (GIS) and dot matrix methods for determining percent landcover within sample sites.



A percentage of the 200 m buffer at sites R4, NC8, F5 and D6 is forested (Figure 12). NC8, F5, and R1 had high values in presence of tree cavities and species of plants important to wildlife (Table 15). Tree cavities are an important habitat component in forested systems providing both cover and nesting sites (Carey 1983; Davis 1983).

Roadways and maintained fields can impact wildlife, especially amphibians (Lehtinen et al. 1999; Yahner et al. 2001). F5, NC8, and R4 had no evidence of maintained field within the 200 m buffer. R3, R2, R1, and D7 had more than 16% of the buffer as maintained field (Figure 7). R2, D7, and R3 had the highest percentage of roadway within the buffer area (Figure 13).

The number and proximity of additional depressional wetlands in the vicinity of the site can influence amphibian populations and the dynamics of metapopulations of other wetlands fauna (Gibbs 1993; Semlitsch and Bodie 1998; Lehtinen et al. 1999). F5 had the highest area percentage of wetlands within the buffer area while D7 had the highest number of additional wetlands within the buffer area (Figure 14). D6, D7, and F5 had additional wetlands within 20 m of the sample site (Figure 15). Sites D7, D6, and R4 (Figure 16) were closest to roads.

Figure 12. Percent forested and wetland area within 200 m buffer.

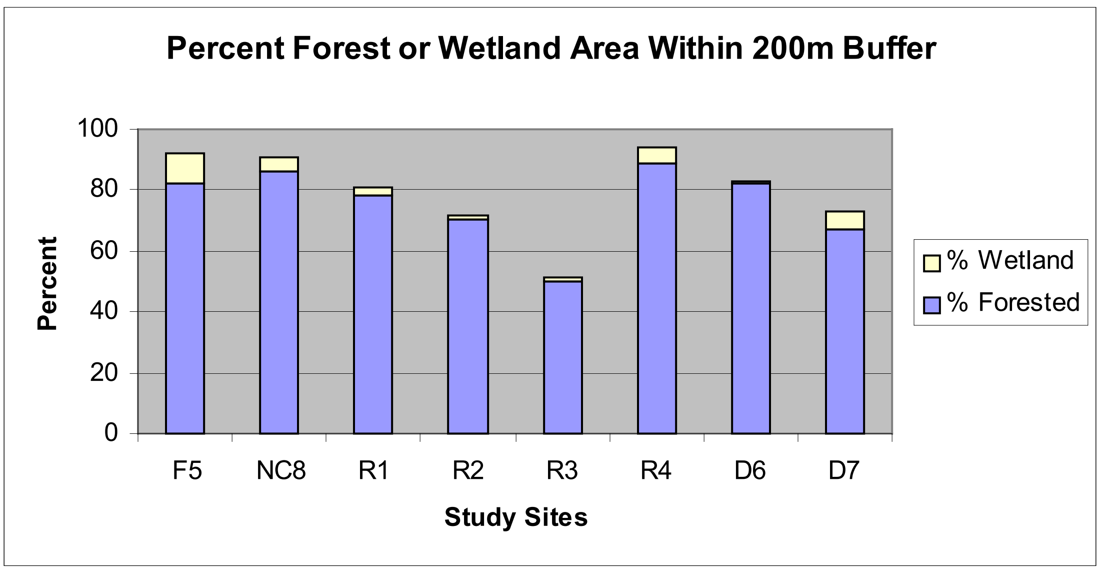


Figure 13. Percent paved road, unpaved road and railroad within 200 m buffer.

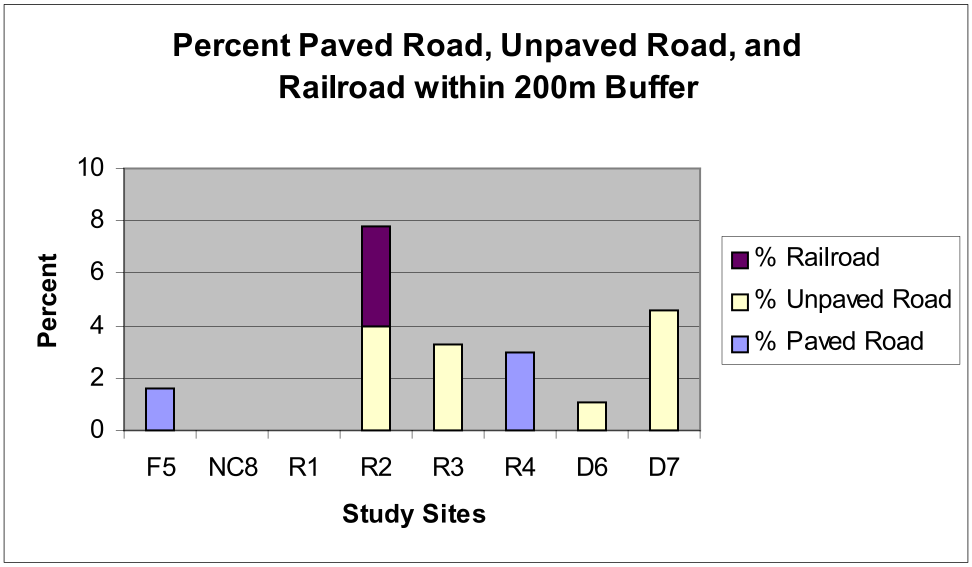


Figure 14. Total number and percent area of other depressional wetlands within 200 m buffer.

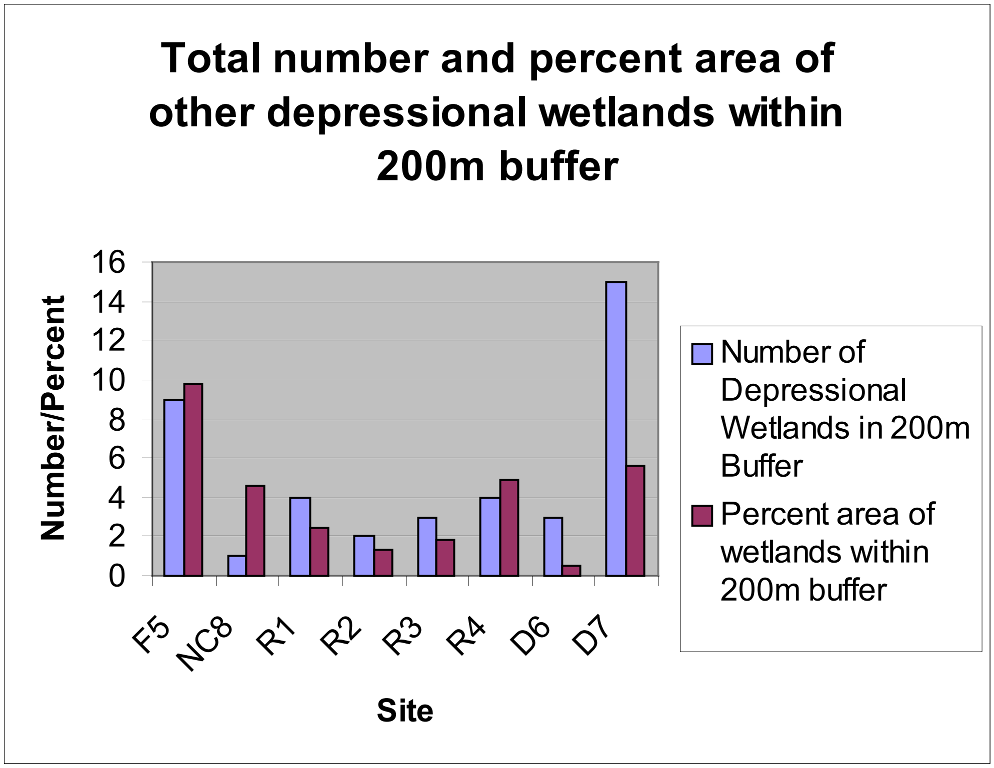


Figure 15. Distance from depressional wetland to nearest depressional wetland.

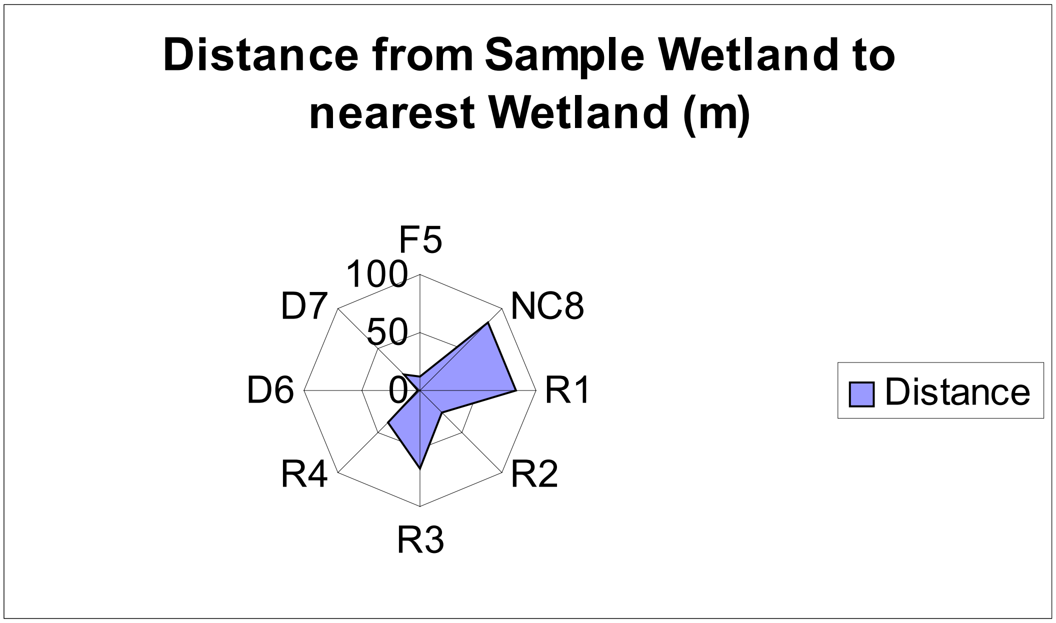
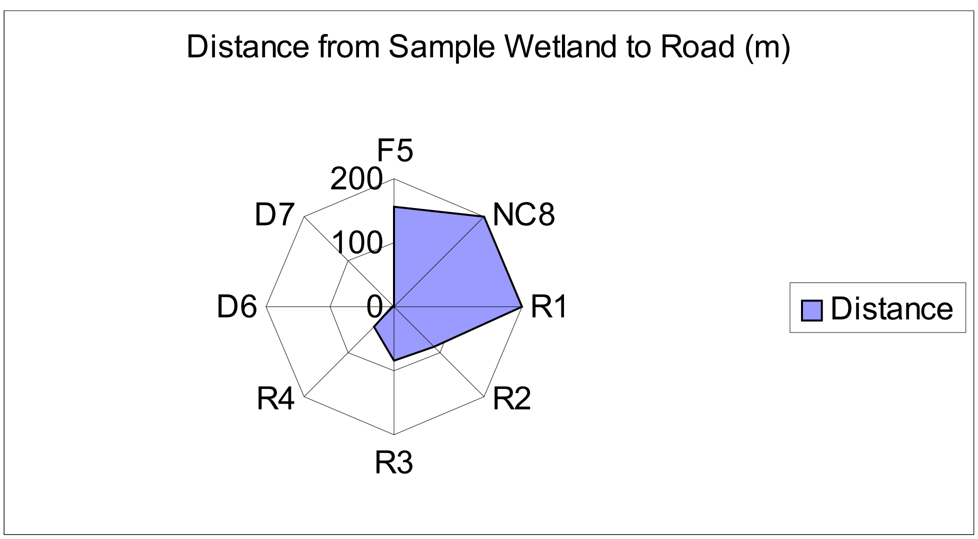
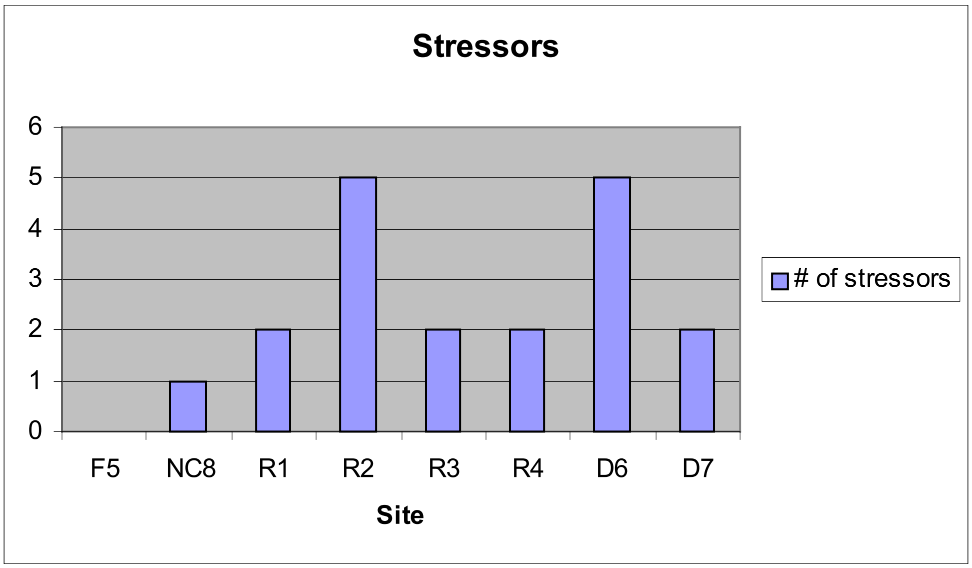


Figure 16. Distance from depressional wetland to road.



Stressors (Appendix III) were identified at each site. Stressors were chosen based on their potential to affect a site's habitat or water quality function. F5 had no identified stressors while R2 and D6 had the highest number of stressors.

Figure 17. Total number of stressors identified per site.



Validation

Wetlands found in depressional geomorphic settings are widely considered of high value to amphibians which exhibit complex life cycles depending on both aquatic and terrestrial habitats (Semlitsch 1998). To validate selected habitat variables to actual habitat value we surveyed seven of the eight sites for amphibian species. Sites were surveyed on 15 March, 2-3 April, 7-8 May, and 13 June 2002. Most surveys were conducted at night, although some of the reconnaissance in March revealed several species during daytime surveys. Call, netting, and coarse woody debris sampling were conducted. This data was combined with previous survey data (Roble 1998) to obtain a comprehensive listing of species (Table 14) utilizing these sites.

Vegetation within seven of the sites was sampled intensively in 1997 using permanent, circular, contiguous, 100 m2 plots established along straight transects which crossed the depression from one side to the other (Rawinski 1997). The more rapid assessment used in this field study did not capture the same level of species richness as previous, more intensive sampling, but trends in richness were similar; particularly regarding woody species (Table 14).

Table 14 .Species richness of amphibians in seven depressional wetland sites.

Species	F5	R1	R2	R3	R4	D6	D7
Rana sphenocephala	X	X	X	X	X	X	
Rana catesbeiana	X		X				
Rana clamitans	X			X			
Pseudacris brimleyi	X	X	X	X	X	X	
Pseudacris feriarum	X						
Pseudacris crucifer	X	X	X	X	X	X	X
Acris crepitans	X	X	X	X		X	
Hyla chrysoscelis	X	X	X			X	X
Bufo fowleri	X	X	X				X
Gastrophryne carolinensis	X					X	
Ambystoma mabeei (listed State-threatened)	X	X		X			
Ambystoma opacum	X						
Amphiuma means		X					
TOTALS	12	8	7	6	3	6	3

Summary

This report encompasses the initial development of an HGM WDW depressional model up to the preliminary development stage and serves as an initial framework for a WDW depressional model for the coastal plain of Virginia. These results can serve as a foundation for subsequent studies to complete the process.

A number of variables have high potential for discerning levels of disturbance within forested depressional sites in Virginia (Table 15). Data from additional sites will help contribute to a more accurate index for determining the amount of deviation from a pristine, undisturbed system.

Table 15. Summary of some variables per site.

Variable/Site	F5	NC8	R1*	R2	R3*	R4	D6*	D7*
Size of sampled wetland (ha)	0.73	1.68	0.28	0.40	0.23	0.77	1.42	0.71
Total Number of stressors	0	1	2	5	2	2	5	2
Total Amphibian Species	12	NA	8	7	6	3	6	3
Density of Standing Dead (stems/hectare)	50	125	0	50	0	0	0	0
Volume Coarse Woody Debris (m^3)	1.28	5.98	2.22	3.04	0.07	1.43	10.88	1.20
Number of Woody Species	13	12	11	15	11	10	10	10
Hardwood/softwood ratio	0.96	0.16	0.59	0.30	0	0.08	0.98	0.33
Density of Canopy Trees (stems/ha)	163	1000	675	138	63	350	0	88
Density of Mid-story Trees (stems/ha)	75	750	250	150	463	150	0	163
Density of Saplings (stems/ha)	63	1800	175	38	275	0	0	463
Density of Shrubs (stems/ha)	350	1125	7225	1763	1513	150	763	0
Density of Vines (stems/ha)	363	275	3600	413	1313	225	375	3100
Number of Plant Species	23	34	26	24	28	13	27	21
Number of Strata Present	6	6	6	6		5	3	5
Significant Presence of Invasives				X	X			X
Valuable Wildlife Plant Species	16	17	16	16	16	12	13	14
Number of tree cavities (cavities/ hectare)	213	200	75	25	0	50	0	0
Soil Consistence in buffer A Horizon	2	1	2	2	2	1	3	2
Percent Forest Within 200m Buffer	82.3	85.9	78.4	70.7	49.8	88.9	82.2	67.1
Percent Additional Wetlands Within Buffer	9.8	4.6	2.4	1.3	1.8	4.9	0.5	5.6
Percent Maintained Field Within Buffer	0	0	17.6	18.2	43.7	0	10.3	16.1
Percent Roadway Within 200m Buffer	1.6	0	0	7.8	3.3	3.0	1.1	4.6
Distance to Nearest Road (m)	157	>200	>200	87	84	43	3	0

* Considered disturbed by Rawinski (1997) due to past clear-cutting or mowing and containing a *Saccharum giganteum-Panicum rigidulum-Eleocharis tuberculosa* subassociation at its deepest point.

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Appendix I. List of plant species per site with those especially important for wildlife.

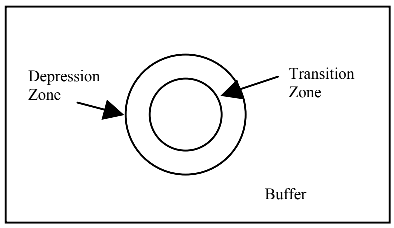
	F5	NC8	R1	R2	R3	R4	D6	D7
Acer rubrum	X	X	X	X	X	X	X	X
Andropogon glomeratus					X			
Andropogon virginicus			X		X		X	
Asclepias incarnata				X				
Asimina triloba	X							
Bidens coronata		X						
Boehmeria cylindrica		X						
Carex albolutescens	X							
Carex comosa		X	X		X	X		
Carex crinita								X
carex joori	X							X
Carex lupilina			X					
Carex lurida			X					
Carya glabra	X							
Cephalanthus occidentalis	X							
Chasmantium laxum		X		X			X	
Clethra alnifolia			X		X	X		X
Decodon verticillatus		X						
<u>**Diospyros virginiana**</u>			X				X	X
Dulichium arundinaceum			X		X		X	
Eleocharis tortilis		X	X					
Eleocharis tuberculosa					X		X	
Elymus virginicam								X
Eupatorium capillifolium								X
Eupatorium rugosum								
Gelsemium sempervirens				X				
Heteranthera dubia			X					
Hieracium gronovii	X							
Hottonia inflata	X							
Houstonia caerutea					X			
Hydrocotyl umbellata		X						
Hypericum virginicum							X	
Hypericum walteri		X						
Ilex opaca		X	X	X			X	
Itea virginica							X	
Juncus acuminatus			X				X	
Juncus canadensis							X	
Juncus effusus		X			X		X	
Juncus repens							X	
Juncus scirpoides			X					
Juncus tenuis								X
Leersia orzoides		X						
Lespedeza cuneata					X			
Leucothoe racemosa				X		X	X	X
Liquidambar styraciflua	X	X	X	X	X	X	X	X
Liriodendron tulipfera		X						
Listera australis	X							
Lycopus rubellus		X						
Microstegium vimineum	X			X				X
Mitchella repens	X			X		X		
	F5	NC8	R1	R2	R3	R4	D6	D7
Myrica cerifera		X			X			

Nyssa sylvatica	X	X	X	X	X	X		X
Onoclea sensibilis		X						
Osmunda regalis		X						
Oxydendrum arboreum	X					X		
Panicum dichotomiflorum							X	
Panicum dichotomum		X						
Panicum rigidulum					X			X
Panicum verrucasum					X			X
Panicum virgation			X					
Peltandra virginica								
Phytolacca americana				X				
Pilea pumlia		X						
Pinus taeda	X	X	X	X	X	X	X	X
Pinus virginica					X	X		
Polygonum hydropiperoides		X		X				
Proserpinaca palustris		X	X				X	
Pteridium aquilinum					X			
Ptilimnium capillaceum				X				
Quercus alba	X		X	X			X	
Quercus falcata	X			X				
Quercus lyrata	X							
Quercus michauxii		X		X			X	
Quercus nigra				X	X			
Quercus phellos	X	X	X	X	X		X	X
Quercus velutina	X			X	X	X		
Ranunculus parviflorus					X			
Rhexia virginica			X		X		X	X
Rhododendron canescens		X	X	X				X
Rhus toxicondendron		X						
Rosa palustris		X						
Rubus cuneifolias		X			X			
Ruppia maritima	X							
Saccharum giganteum							X	
Sassafras albidum						X		
Saururus cernuus		X						
Scirpus cyperinus							X	X
Senecio tomentosus					X			
Smilax rotundifolia	X	X	X	X	X	X	X	X
Solidago microcephala			X				X	
Solidago rugosa					X			
Spagnum sp.								
Symplocos tinctoria				X				
Utricularia radiata			X					
Vaccinium corymbosum	X	X	X	X	X			X
Vitus labrusca		X						
Woodwardia virginica							X	
Totals	23	34	26	24	28	13	27	21
Bolded=mod/high wildlife value	**16**	**17**	**16**	**16**	**16**	**12**	**13**	**14**
Bolded & Underlined = mod/high winter wildlife value	**2**	**3**	**3**	**2**	**3**	**3**	**4**	**3**

Appendix II. Woody Depressional wetland sampling protocol.

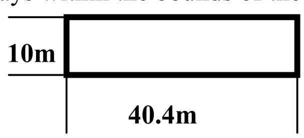
Woody Depressional wetland sampling protocol.

Main sampling method of an 11.35m radius plot = 1/10 acre = 404 m^2.
Depression zone – Area of dominant vegetation typically either forested or scrub-shrub located below the ordinary high water mark.
Depression Transition zone – Area sometimes present within the depression zone. Identified by a change in the dominant vegetation or strata beginning within the depression zone and extending to the ordinary high water mark.
Buffer zone – Area surrounding the depressional wetland (may be either upland or wetland), above the ordinary high water mark (or transition zone if present) of the depression.



Location and placement of Primary Sampling Unit (11.35 radius circular plots)

1. Locate a minimum of 1 plot in each of the depressional zone, transition zone, and buffer zone.
2. Plots should be placed within a homogenous community type.
3. If there is more than one community in a single zone then separate plots should be sampled in each community type.
4. Plots should be located in an area that is representative of the community within the zone
5. Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35m point to define the 11.35 m radius plot
6. If a zone is narrower than the plot diameter of 22.7m, construct a plot with the same area (0.1acre=404 m^2) that stays within the bounds of the vegetative community (give examples)



$V_{treedensity}$ (for sampling within the depression and transition zones)
Definition: $V_{treedensity}$ - density and relative density of trees ≥ 15cm dbh;
Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: $V_{treebasal}$ is measured by recording dbh and species of all trees ≥ 15cm dbh in an 11.35m radius plot.
dbh is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the dbh should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the dbh measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

Measurement Units: Number of trees (counts), dbh in cm to the nearest millimeter
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), dbh tape.
Data Management: Enter into database: site name, plot number, species, direct count, dbh,

$V_{midstory}$
Definition: density and basal area of mid-story trees ≥ 7.5 cm & < 15 cm dbh .

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species and dbh of all mid-story trees [≥ 7.5 cm & < 15 cm dbh] within the 11.35m radius plot. DBH is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the dbh should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the dbh measurement, attempt to pull the vine away so that you only measure the tree trunk. For saplings with multiple stems, stems are counted individually if they split lower than 1.3 m from the ground. If a sapling has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main stem at 1.3 m.

Measurement Units: number of mid-story trees (count) by species, dbh in cm to the nearest millimeter
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), dbh tape.
Data Management: Enter into database: site name, plot number, species, count, dbh, basal area.

$V_{sapling}$
Definition: count of saplings > 1m high, dbh of 1 cm to 7.5 cm.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species of all saplings > 1m high with a dbh of 1 cm to 7.5 cm in 11.35m radius plot. DBH is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the dbh should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the dbh measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

Measurement Units: number of sapling trees (count) by species.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), dbh tape, meter stick.
Data Management: Enter into database: site name, plot number, species, count.

$V_{cavities}$
Definition: presence of tree cavities.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Count all tree cavities with openings ≥ 2.5 cm diameter within 2 m of the ground in each 11.35m radius plot

Measurement Units: Count.
Sampling Frequency Each zone present (one plot / zone).
Equipment: Meter tapes (2), meter stick.
Data Management: Enter into database: site name, plot number, count.

$V_{Standingdead}$

Definition: presence of dead standing woody debris.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol:. Record dbh and species (if possible) of all dead standing trees ≥ 15cm dbh and > 2m high in an 11.35m radius plot. Diameter at breast height (dbh) is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the dbh should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the dbh measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

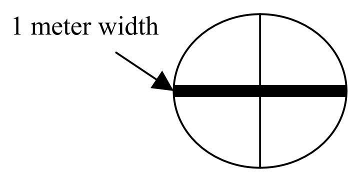
Measurement Units: Count, dbh in cm
Sampling Frequency:
Equipment: Meter tapes (2), dbh tape
Data Management: Enter into database: site name, plot number, count, species, dbh.

V_{shrubs}

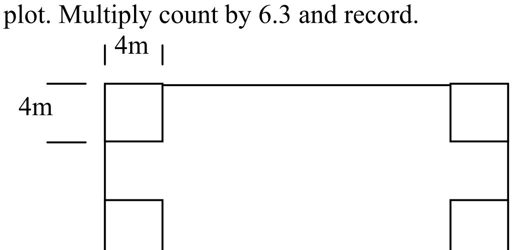
Definition: density of shrubs > 1m high. A shrub is defined as a single-stemmed woody plant between 1 meter and 3 m high or a multi-stemmed woody plant greater than 1 m high.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species and number of all shrubs within the 11.35m radius plot. **Special note: if site has an abundant coverage of shrubs the following alternative sampling methods can be used**.
For circle plots: Randomly select one of the two 22.7m transect lines and count all shrub clumps and stems within a 1m strip along the transect (total sample area = $22.7m^2$). Multiply count by 17.8 and record.



For rectangular plots: In each corner of the rectangular plot establish a 4m x 4m plot. Count all shrub clumps and stems with each $16m^2$ plot. Multiply count by 6.3 and record.



Measurement Units: Count by species.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), meter stick, pin flags.
Data Management: Entered in database as site name, plot number, species, count.

V_{vine}

Definition: density of woody vines > 1m in height.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Count and record the species of all woody vines > 1 m in height in the 11.35m radius plot. **Special note**: **if site has abundant vine coverage the alternative sampling methods described above for shrubs can be used.**

Measurement Units: count.
Sampling Frequency: Once during the growing season.
Equipment: Meter stick, meter tapes (2).
Data Management: Enter into database: site name, plot number, species, count.

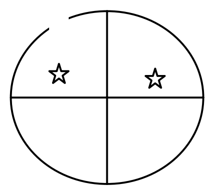
V_{herb}

Definition: Presence of herbaceous species, occurrence level.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species of all observed herbs in the 11.35m radius plot. Observe the four quarter sections of the 11.35 radius plot and record the number of subplots in which each species occurs: 1,2,3,or 4.

For Example, if a species occurs in two quarters record 2 for that species.



Measurement Units: Occurrence level.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), plant press or collecting bags for unknown specimens.
Data Management: Enter into database: site name, plot number, species, occurrence level.

V_{exotic}

Definition: presence of exotic (non-native) plant species.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point. This defines the 11.35 meter radius plot.

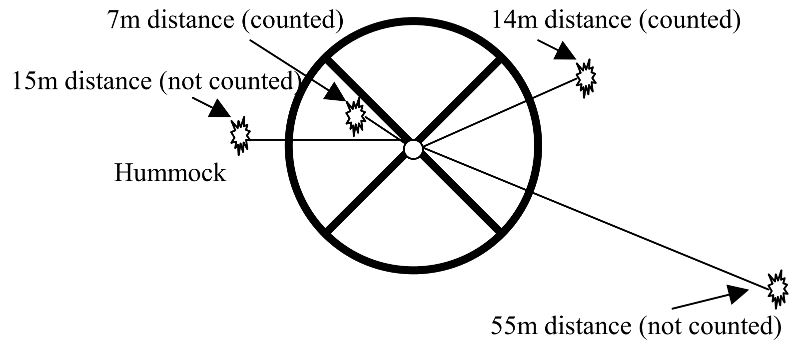
Protocol: Record the presence of all exotic plant species found in each strata (tree, sapling, shrub, herb) within the 11.35m radius plots.

Measurement Units: presence/ absence by strata
Sampling Frequency: Once during the growing season; 3 plots/ site (minimum)
Equipment: Meter tapes (2).
Data Management: Enter into database: site name, plot number, species, strata.

Vhummock
Definition: presence of macrotopography.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point. This defines the 11.35 meter radius plot. Measure out from plot center in each quarter slice to the nearest hummock.

Protocol: $V_{hummock}$ is measured using a modified point quarter method. From the center of the 11.35 m radius plot measure the distance in meters from the plot center to the nearest hummock (topographic feature > 15 cm high) within each quarter (up to 50 m distant).



Measurement Units: Meters.
Sampling Frequency: Four measurements / 11.35m radius plot.
Equipment: Meter tapes (2), meter stick.
Data Management: Enter into database: site name, plot number, compass bearing, distance in meters.

$V_{topography}$

Definition: Ponding depth of site.

Set-up: Two people: one with stadia rod, one with hand level.

Protocol: $V_{topography}$ is measured from the lowest elevation of the depression's rim. Record compass bearing from the lowest elevation within the depression to sampling point on rim. Use a hand level to measure the maximum depth of the depression with a stadia rod placed within the depression at the lowest elevation. Record the level. Align the bottom of the stadia rod with the bottom of the OHW mark, if present, on nearby trees. Record the level. Move the stadia rod to the hand level observation point and record the level.
Measurement Units: Meters.
Sampling Frequency: Once per site to determine maximum depth. Five trees / site if watermarks present.
Equipment: Hand level and stadia rod.
Data Management: Enter into database: site name, plot number, level of depression rim, level of depression bottom, level of water marks.

V_o

Definition: presence and depth of O soil horizon.

Set-up: At plot center of each 11.35m radius plot or rectangular plot, dig a soil pit approximately 46 cm deep

Protocol: V_o is measured at the center of each 11.35m radius plot or rectangular plot. Record the depth of the O horizon if present.

Measurement Units: Depth in cm.
Sampling Frequency: Within each sample area.
Equipment: Meter tapes (2), meter stick, sharp shooter shovel.
Data Management: Enter into database: site name, plot number, depth of O horizon (cm).

V_a

Definition: presence and depth of A soil horizon.

Set-up: At plot center of each 11.35m radius plot or rectangular plot, dig a soil pit approximately 46 cm deep

Protocol: V_a is measured at the center of a 11.35m radius plot or rectangular plot. Record the depth of the A horizon.

Measurement Units: Depth in cm.
Sampling Frequency: Once within each sample area.
Equipment: Meter tapes (2), meter stick, sharp shooter shovel.
Data Management: Enter into database: site name, plot number, depth of A horizon (cm).

$V_{consistence}$

Definition: Consistence of A and B soil horizons, when present.

Set-up: At plot center of each 11.35m radius plot or rectangular plot, dig a soil pit approximately 46 cm deep

Protocol: $V_{consistence}$ is measured at the center of an 11.35m radius plot or rectangular plot. Sample peds from both the A and B horizons, if present. Consistence is determined using moist soil peds where: loose =0, very friable =1, friable =2, firm =3, very firm =4, and extremely firm =5. Record number for each horizon.

Measurement Units: Numeric (0,1,…5).
Sampling Frequency: Within each sample area.
Equipment: Meter tapes (2), sharp shooter shovel.
Data Management: Enter into database: site name, plot number, and consistence (0,1,...5) of A and B horizons.

V_{pan}

Definition: the depth to and thickness of a confining layer (i.e. plow pan, fragipan, argillic horizon, etc.) when present, that restricts the movement of water through the soil.

Set-up: At center of each 11.35m radius plot or rectangular plot, dig a soil pit approximately 46 cm deep

Protocol: V_{pan} is measured at the center of an 11.35m radius plot or rectangular plot. Record the depth to and thickness of the confining layer, if present.
Measurement Units: Depth and thickness in cm. Consistence 0,1,2,3,4,or 5.
Sampling Frequency: Within each sample area.
Equipment: Meter tapes (2), meter stick, sharp shooter shovel.
Data Management: Enter into database: site name, plot number, depth (cm), thickness (cm)

V_{cwd}

Definition: presence of downed coarse woody debris

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot or establish 1/10 acre rectangular plot if necessary.

Protocol: Count and measure the length and dbh of all downed coarse woody debris that has a mean dbh of $\geq$ 15cm. Measure the length of each piece and determine the mean dbh by measuring the dbh at each end of the log and averaging the two. All coarse woody debris that is at least part in the plot should be counted. Additionally, determine the extent of decay: newly fallen, aged, or highly decomposed.

Measurement Units: Count, length in meters and centimeters, mean dbh in cm and decay level
Sampling Frequency: Within each sample area.
Equipment: Meter tapes (2), dbh tape
Data Management: Enter into database: site name, plot number, count, length, dbh, volume, decay level.

Sampling the Buffer Area within 200m of Depression

V_{BAF}

Definition: Basal area of trees ≥ 15cm dbh.

Set-up: From a randomly selected area within the representative 200 m buffer zone, sample each tree ≥15cm dbh using an angle gauge or prism with a basal area factor (BAF) of 5 and 10.

Protocol: If the buffer zone is comprised of more than one vegetative community or different land use types, sample each of the different communities until they cumulatively exceed 90 percent of the total buffer area. Record the total number of each species that are considered "in" for BAF 5 and BAF 10.

Measurement Units: Species and count.
Sampling Frequency: Once during the growing season within each sample area.
Equipment: angle gauge or prism.
Data Management: Enter into database: site name, plot number, species, direct count for BAF 5 and BAF 10.

$V_{landscape}$

To measure $V_{landscape}$ overlay a dot matrix grid on a topographic map or recent aerial photograph. Delineate a 200 m buffer around the WAA. Geographic Information System (GIS) programs can be substituted if available. Determine the percentage of land use types that encroach into the 200 m buffer and count the number of separate encroachments by land use type. Landuse types should be sorted by Industrial, Urban – high developed, rural – low developed, Agricultural, and Forested/Wetland/scrub-shrub/open water categories.

$V_{metapop}$

To measure $V_{metapop}$ overlay a dot matrix grid on a topographic map or recent aerial photograph. Delineate a 200 m buffer around the WAA. Geographic Information System (GIS) programs can be substituted if available. Count the number of other depressional wetland areas, if present, within the 200 m buffer zone.

Other measurements:
Rapid assessment sheet to record stressors

Water quality (measure DO, temperature, pH).

Appendix III. Stressor checklist.

HGM - Depressional Wetlands
Stressors and Water Quality Data Sheet

Site Name ______

Zone
- Depressional
- Transition
- Buffer

Plot Number ______

Evaluation Date ______

Community Type
- Natural Pine Forest
- Planted Pine Forest
- Hardwood Forest
- Mixed Hardwood/Pine Forest
- Mixed Pine/Hardwood Forest
- Shrub-Scrub
- Herbaceous
- Unvegetated
- Agriculture/Pasture
- Agriculture/Cropland
- Woody Depression

Hydrologic Modification
- ☐ No Hydrologic Modification
- ☐ Ditch
- ☐ Point Source Inputs
- ☐ Tile Drain
- ☐ Filling,grading,dredging
- ☐ Dike
- ☐ Road bed/Railroad
- ☐ Weir/Dam
- Road Type: State Highway / Residential / Gravel Road
- ☐ Dead/Dying Trees
- ☐ Stormwater inputs/culvert

Sedimentation
- ☐ No Sedimentation
- ☐ Sediment Deposits/Plumes
- ☐ Active Plowing
- ☐ Eroding Banks/Slope
- ☐ Active Grazing
- ☐ Active Construction
- ☐ Active Forest Harvesting
- ☐ Siltlines on ground or vegetation
- Suspended Solids: High / Medium / Low

Dissolved Oxygen
- ☐ Excessive Aquatic Plants or Algal Mat
- ☐ Excessive Organic Debris in Water
- DO: ______

Vegetation Alteration
- ☐ No Vegetation Alteration
- ☐ Mowing
- ☐ Brush Cuttin
- ☐ Aquatic Weed Control
- ☐ Adjacent Power Lines
- ☐ Excessive Herbivory

Toxicity and Acidification
- ☐ No Toxic Activity
- ☐ Toxic Spills
- ☐ Adjacent Industrial Site
- ☐ Adjacent Mines

Miscellaneous
- ☐ Mosquito Control/Spraying
- ☐ Absence of Expected Biota
- Temperature: ______
- pH: ______

Staff Guage
- Staff Guage Level (ft) ______
- Staff Guage Reading Time ______

Comments ______

Appendix IV. Final data collection checklist.

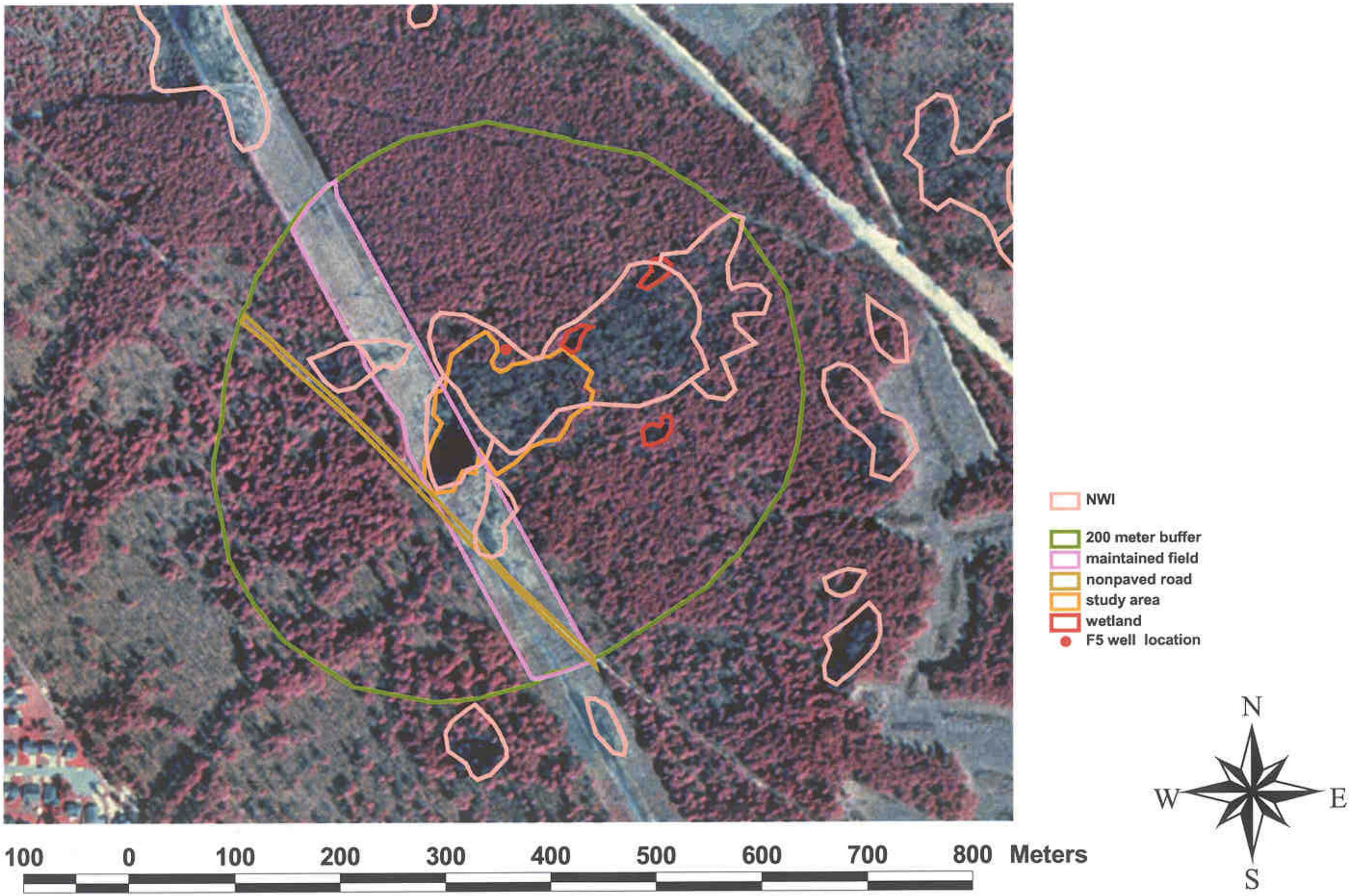
HGM - Depressional Wetlands
Site Check List

Site Name		Community Type	Natural Pine Forest Planted Pine Forest Hardwood Forest Mixed Hardwood/Pine Forest Mixed Pine/Hardwood Forest Shrub-Scrub Herbaceous Unvegetated Agriculture/Pasture Agriculture/Cropland Woody Depression
Zone	Depressional Transition Buffer		
Plot Number			
Evaluation Dat			
BAF Counts Complete?	Yes No		
Standing Dead Checked?	Yes No	Soil Root Data Collected?	Yes No
All Cavities Counted?	Yes No	Soil Pore Data Collected?	Yes No
Shrubs and Vines Counted?	Yes No	Soil Description Completed?	Yes No
Herb Occurance Counted?	Yes No	Staff Guage Read?	Yes No
Woody Debris Measured?	Yes No	Stressors Evaluated?	Yes No
Woody Debris Decomposition Evaluated?	Yes No	DO, Temp, and pH Recorded?	Yes No
Topography Data Collected?	Yes No	THIS FORM IS COMPLETE?	Yes No

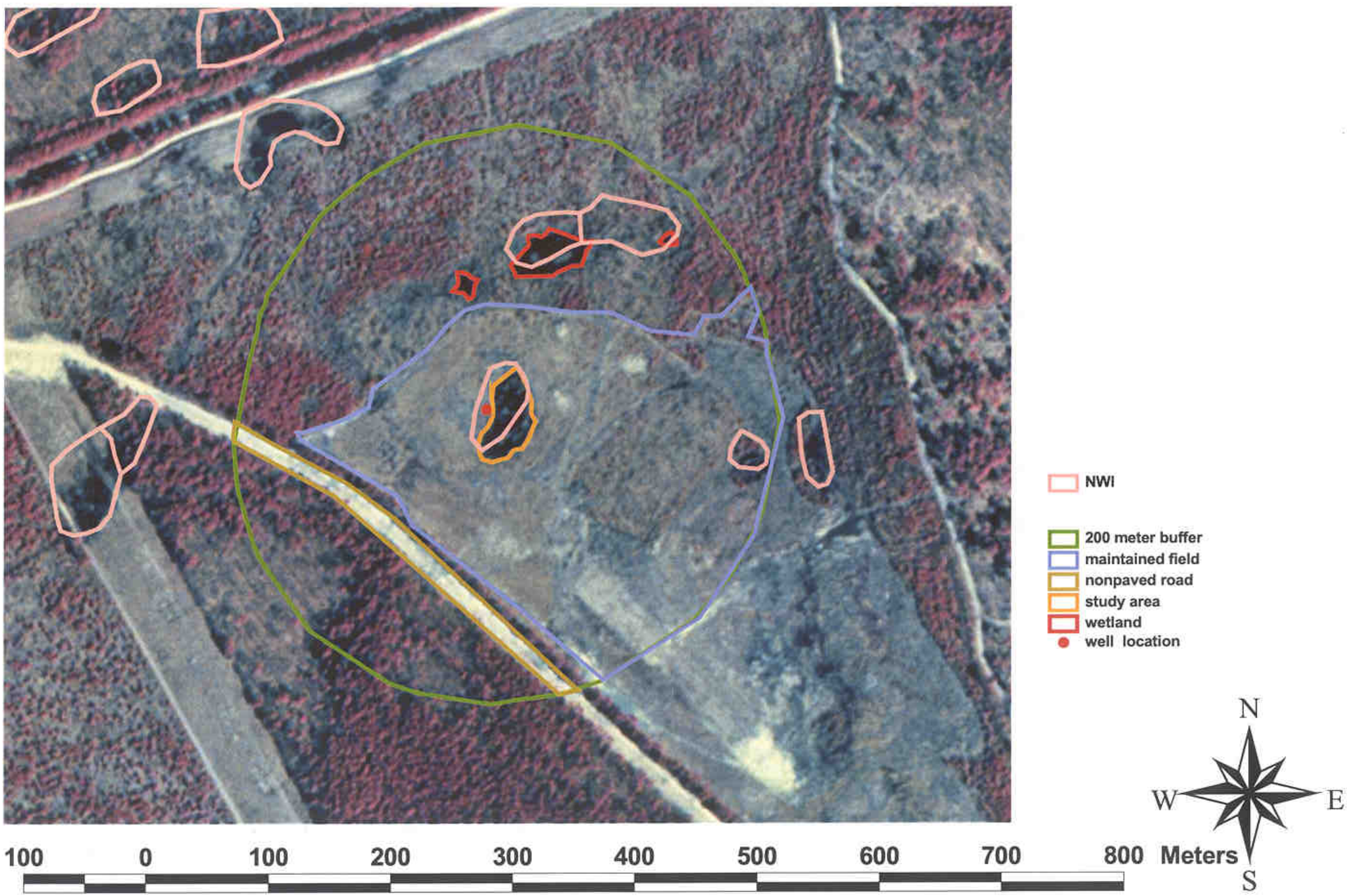
Comments:

Appendix V. Digital Ortho Quarter Quads (DOQQ's) for each sample site. Sample site is delineated as well as NWI mapped wetlands and a 200 m buffer.

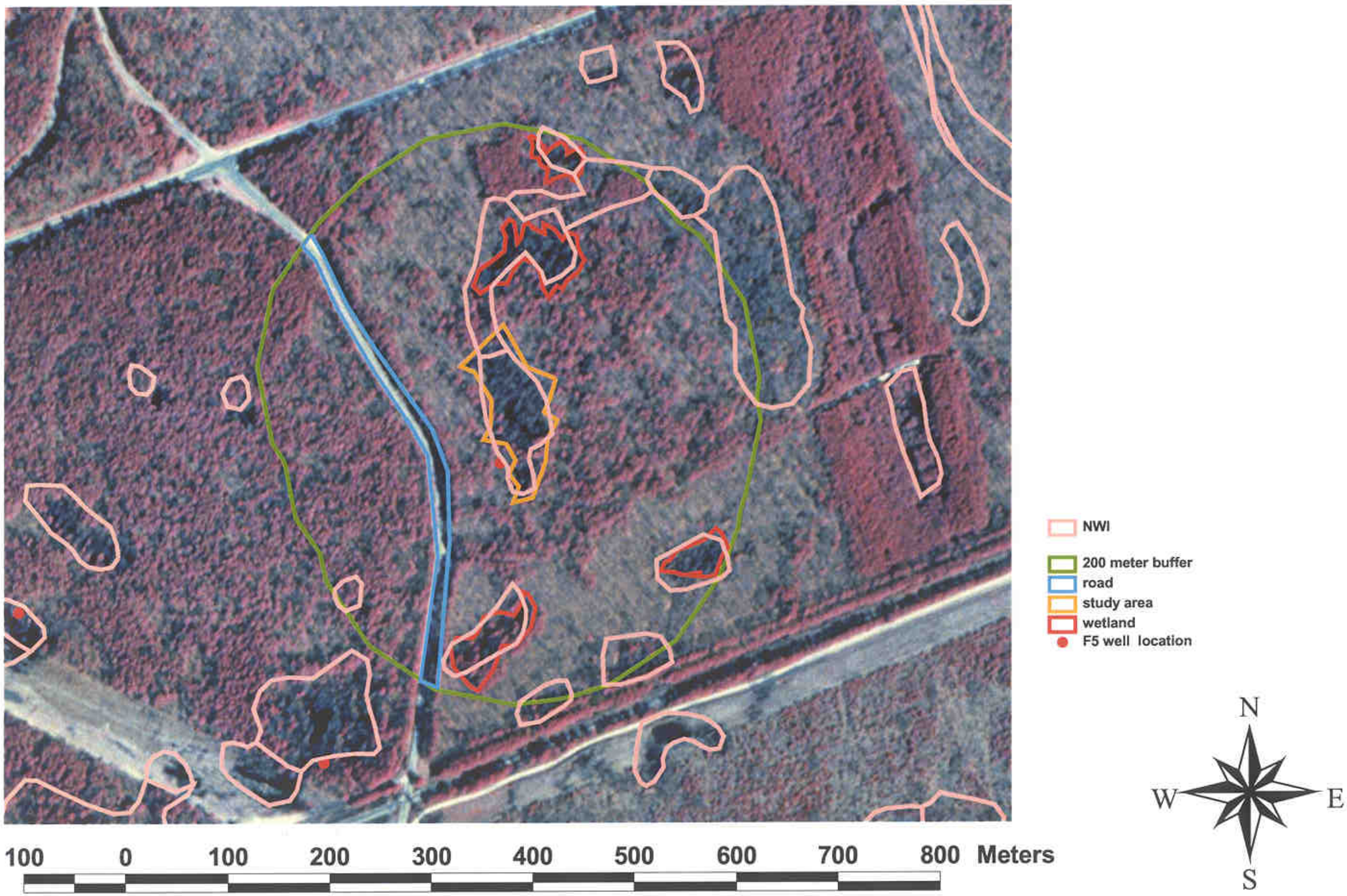
D - 6


NWI
200 meter buffer
maintained field
nonpaved road
study area
wetland
F5 well location
100 0 100 200 300 400 500 600 700 800 Meters
N
W
E
S

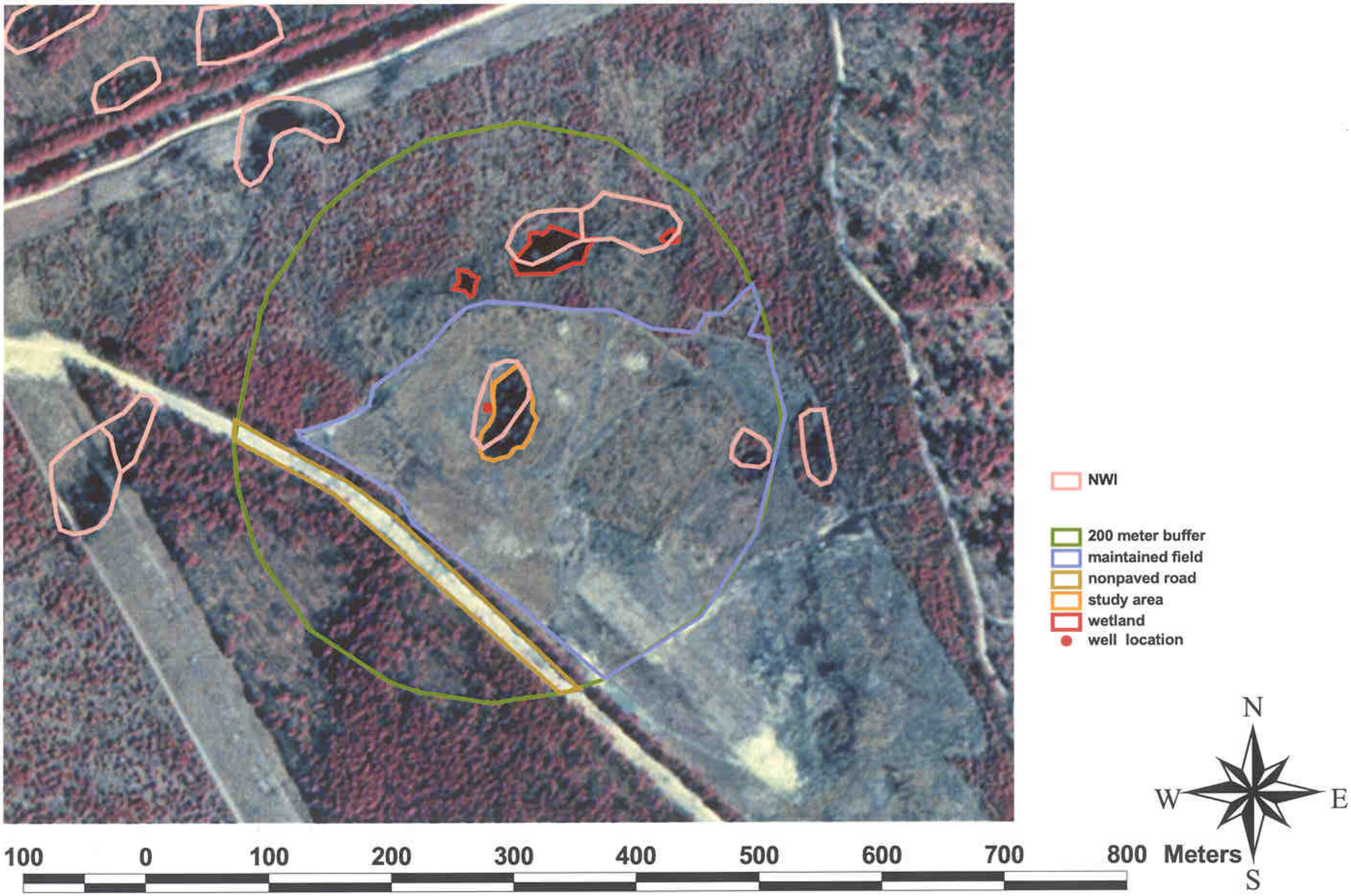
R - 3


NWI
200 meter buffer
maintained field
nonpaved road
study area
wetland
well location
100 0 100 200 300 400 500 600 700 800 Meters
N
W
E
S

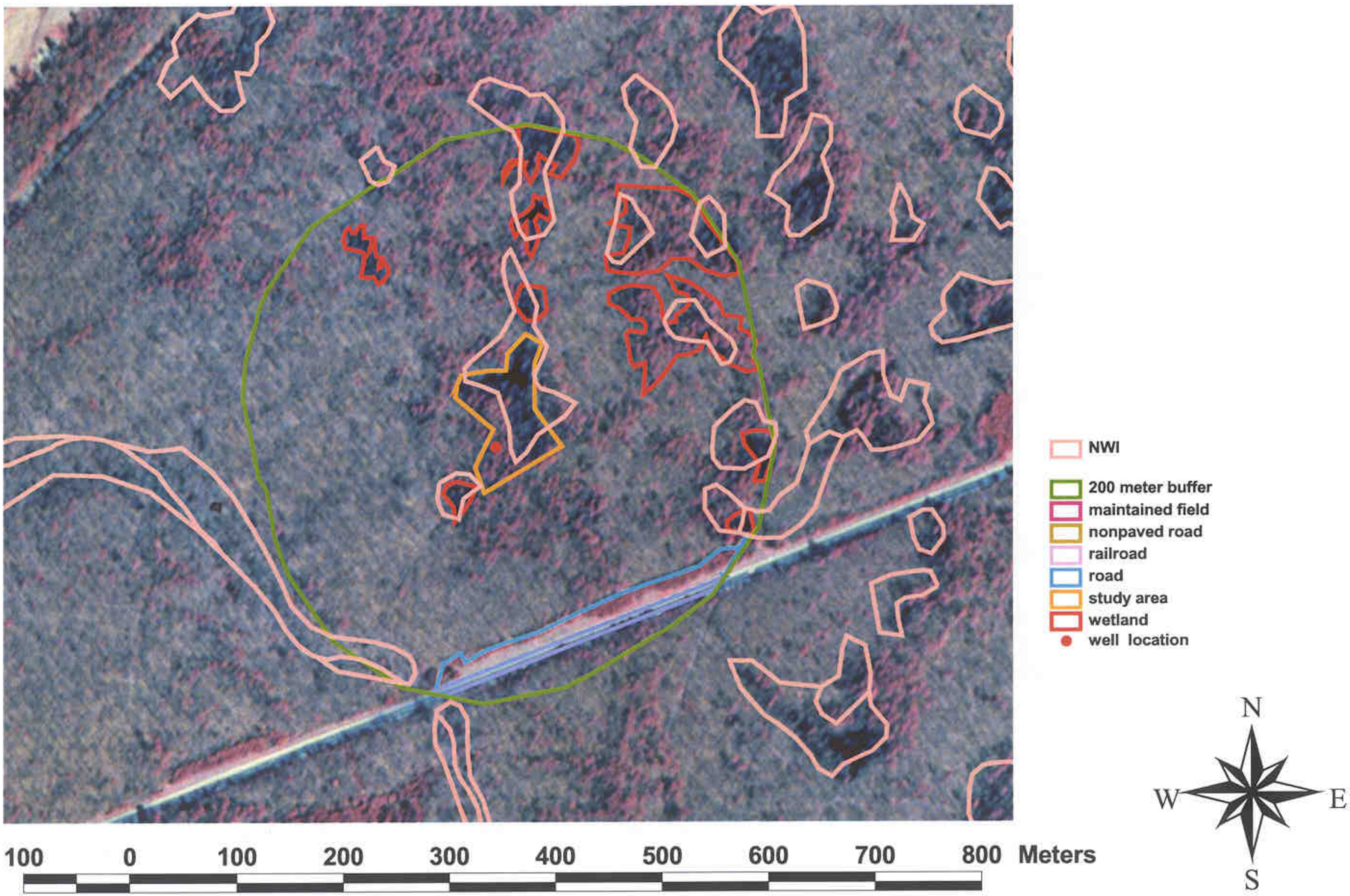
R - 4


NWI
200 meter buffer
road
study area
wetland
F5 well location
100 0 100 200 300 400 500 600 700 800 Meters
N
W
E
S

R - 3

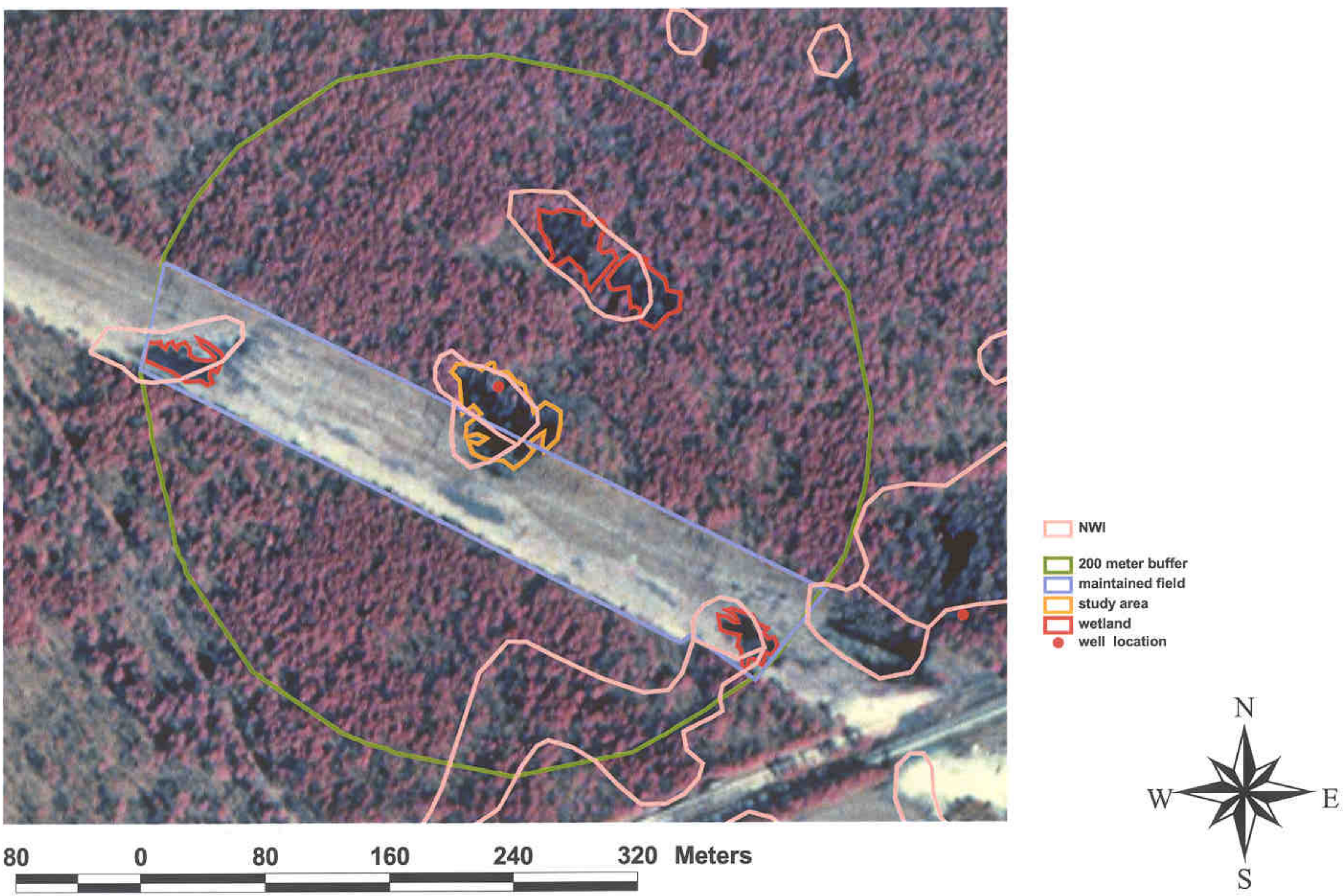

NWI
200 meter buffer
maintained field
nonpaved road
study area
wetland
well location
N
W
E
S
100 0 100 200 300 400 500 600 700 800 Meters

R - 2

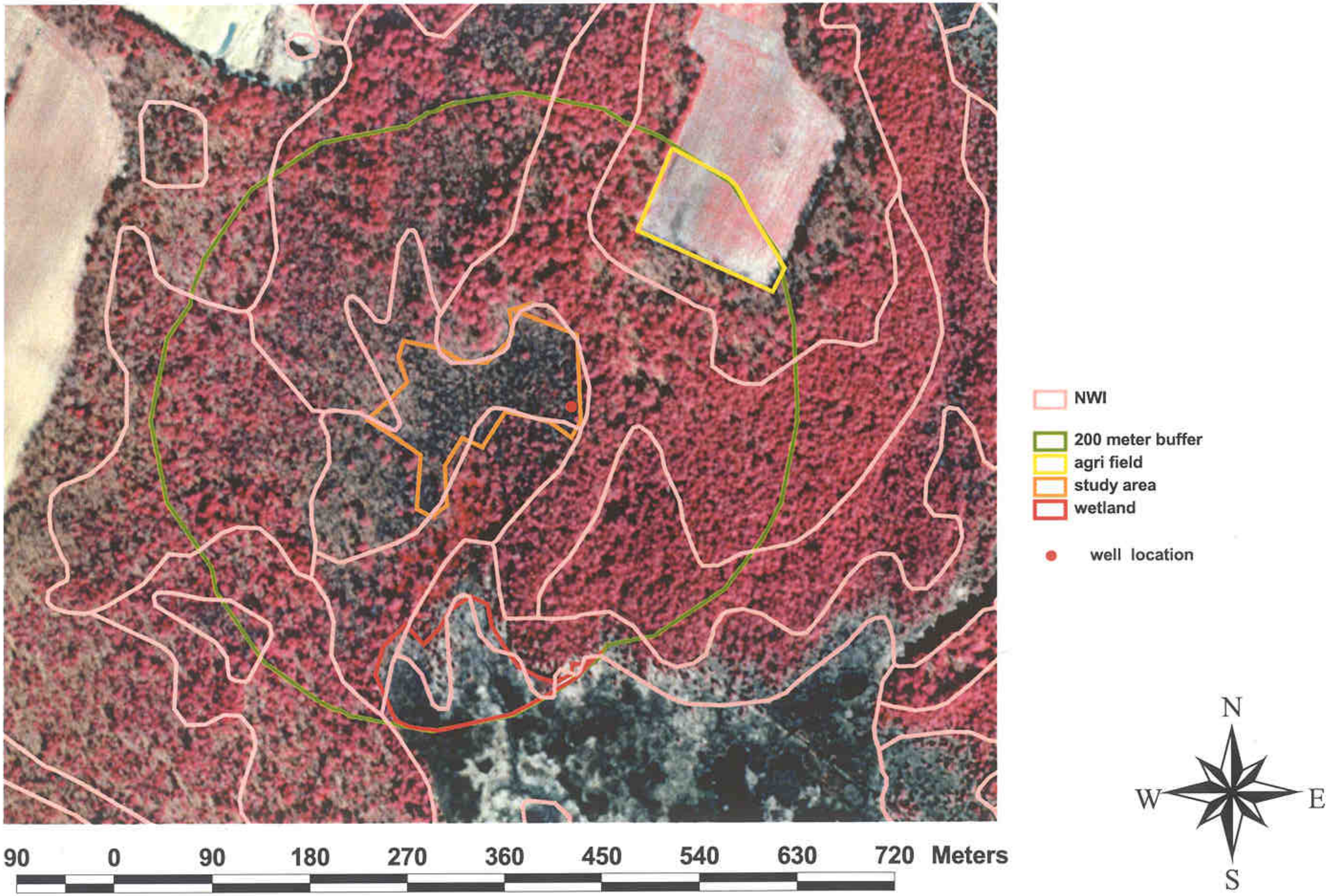


NWI
200 meter buffer
maintained field
nonpaved road
railroad
road
study area
wetland
well location
N
W
E
S
100
0
100
200
300
400
500
600
700
800
Meters

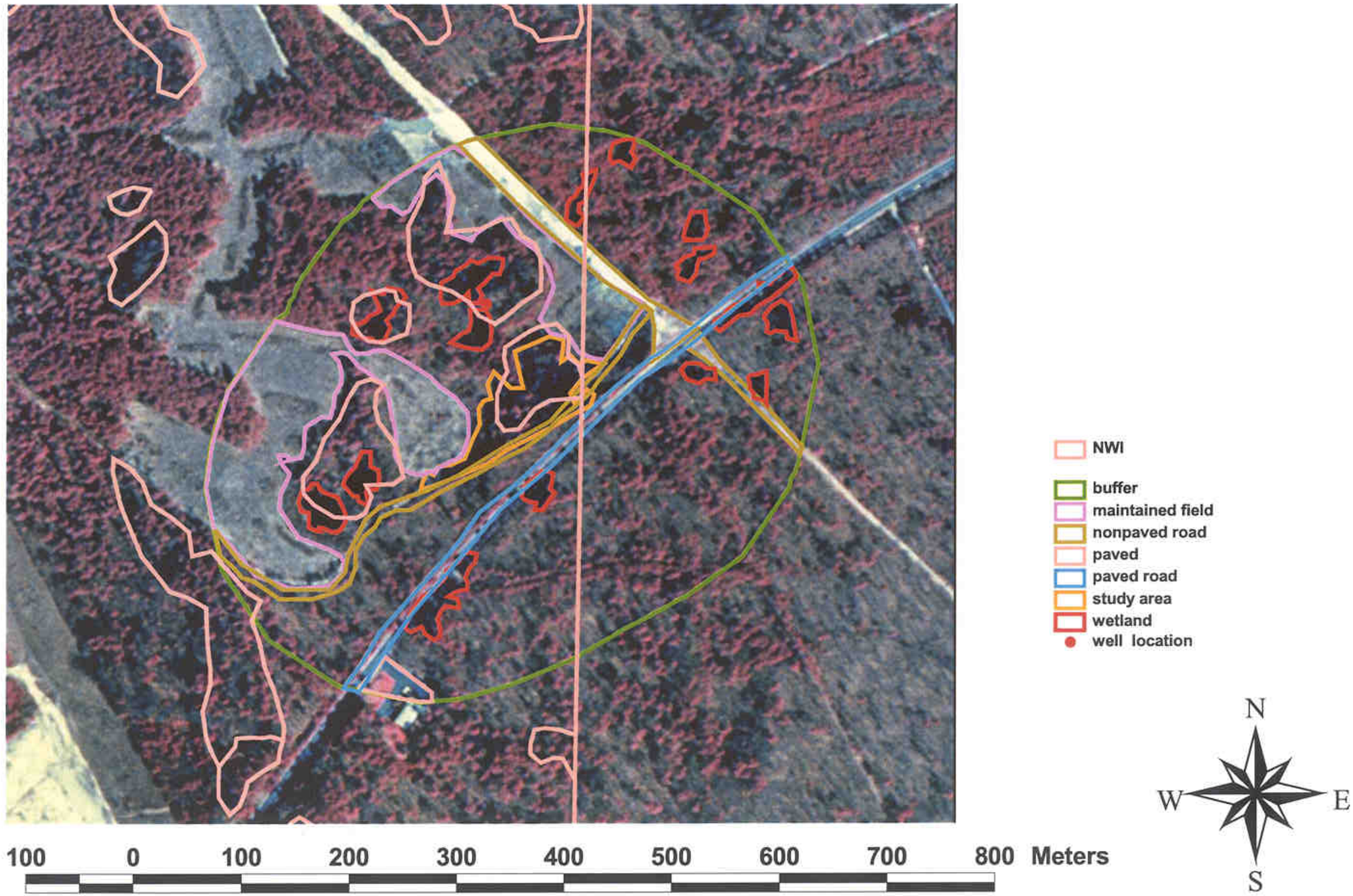
R - 1


NWI
200 meter buffer
maintained field
study area
wetland
well location
N
S
W
E
80
0
80
160
240
320
Meters

NC - 8


NWI
200 meter buffer
agri field
study area
wetland
well location
90 0 90 180 270 360 450 540 630 720 Meters
N
W
E
S

D - 7


NWI
buffer
maintained field
nonpaved road
paved
paved road
study area
wetland
well location
100
0
100
200
300
400
500
600
700
800
Meters
N
W
E
S