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Investigation and long-term monitoring of Phragmites australis within Virginia's constructed wetland sites : final report

Kirk J. Havens
Virginia Institute of Marine Science

Walter I. Priest III
Virginia Institute of Marine Science

Harry Berquist
Virginia Institute of Marine Science

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Kirk J. Havens, Walter I. Priest, III, and Harry Berquist

College of William & Mary
Virginia Institute of Marine Science
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Final Report to the U.S. Environmental Protection Agency
(EPA Grant CD993024-01)

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Investigation and Long-term Monitoring of The Invasive Plant *Phragmites australis* within Virginia's Constructed Wetland Sites

P. australis invasion within constructed wetlands

[1]Kirk J. Havens, College of William and Mary, Virginia Institute of Marine Science, School of Marine Science, Department of Resource Management and Policy, P.O. Box 1346, Gloucester Point, Virginia 23062.

Walter I. Priest, III, College of William and Mary, Virginia Institute of Marine Science, School of Marine Science, Department of Resource Management and Policy, P.O. Box 1346, Gloucester Point, Virginia 23062.

Harry Berquist, College of William and Mary, Virginia Institute of Marine Science, School of Marine Science, Department of Resource Management and Policy, P.O. Box 1346, Gloucester Point, Virginia 23062.

Abstract

The use of constructed wetlands to replace natural wetlands is becoming pandemic. An investigation using Global Positioning System technology to map the vegetated communities of fifteen of the largest constructed wetlands in Virginia reveals that 80% are colonized by the invasive species, *Phragmites australis* Trin., and/or aggressive species, *Typha* spp. Tidally influenced wetlands that have subtidal perimeter ditches have significantly less ($p<0.05$) *P. australis* in the wetland interior than those without perimeter ditches. Fractured regression analyses show that 6 years after construction *P. australis* invasion can be extensive. Linear regression analysis suggests that, if conditions remain favorable for *P. australis* colonization, constructed wetlands could be overrun in 40 years.

Keywords:

Phragmites australis, mitigation, constructed wetlands, invasive species, Global Positioning System

[1]Corresponding author

INTRODUCTION

Human population growth in coastal regions has brought wetland systems under intensive pressure from developmental, agricultural, and industrial interests. The use of constructed wetlands to replace natural wetlands has become increasingly important to regulatory agencies and, consequently, to the developmental, agricultural, and industrial communities.

Wetlands construction, however, is a relatively young science, and the "successful" establishment of a constructed wetland is fraught with many difficulties, variables, and unknowns. Researchers and regulatory agencies have been plagued by the question of how long does it take for a constructed wetland to achieve the same level of maturity as the displaced natural wetland. Despite the obvious difficulties in assessing how well a constructed wetland resembles a natural wetland in a myriad of functions and values, a more subtle and disturbing question is whether the constructed wetland will maintain its planned integrity well into the future.

Due to the disturbance resulting from the excavation and construction of a wetland site, these areas are inherently more susceptible to invasion by unwanted opportunistic plant species than natural communities (Daiber 1986). A serious concern is that constructed wetland sites may be eventually overrun by these invasive plant species. Roman and others (1984) reported on the invasion of constructed wetlands in New Jersey by *Phragmites australis* Trin., and it has been noted by Odum (1988) that the invasion of unwanted plants into constructed wetlands is not an unusual occurrence.

Changes in vegetation patterns can also be a measure of the response of the wetland ecosystem to anthropogenic pressures such as population growth, development of the surrounding landscape, and fresh-water withdrawal from the watershed for industrial purposes. These activities can expedite or initiate colonization and propagation of invasive plant species within a constructed wetland by changes in site hydroperiod and excessive sedimentation. Establishment of the proper hydrologic regime within a constructed wetland is considered the most difficult and most important parameter in wetland construction. Overt or subtle disturbances in the hydrologic regime can compromise the functions and subsequent values of constructed wetlands by ultimately allowing the system to be partially or completely overrun by invasive plant species.

Due to the lack of information on constructed wetlands older than twenty years and the length of the maturation process, these systems may yet be subject to failure. A sobering projection of this scenario is one proposed by Barnard and Mason (1990). They suggest that by substituting natural wetlands with constructed wetlands, we may be, in effect, "mortgaging our wetland future".

We hypothesized that constructed wetlands in Virginia are susceptible to invasion by unwanted plant species. To test this hypothesis, a suite of Virginia's largest constructed wetland sites were selected for study. Vertical aerial photographs (both color and color infrared) were taken of each site and were overlaid with a detailed Global Positioning System (GPS) map of the vegetative communities including invasive species within the perimeter of the wetland.

Methods

All constructed wetlands (excluding Virginia Department of Highways sites) within the coastal plain of Virginia over an acre in area were selected for study (Figure 1). Virginia Department of Highway sites were excluded because of the unique permitting process involved in their construction and because a monitoring program to study them is presently being developed (Perry, pers. comm.). One Virginia Department of Transportation site (GC) was included because it is one of the oldest and most well-documented sites in Virginia. One site in Falmouth, Virginia was excluded to avoid duplication of effort since it is presently under investigation by a team of researchers (Spingarn, pers. comm.). Sites were identified from Barnard and Mason (1990) and through the Army Corps of Engineers, Norfolk District. A total of 15 sites (6 nontidal, 9 tidal) was surveyed with a combined wetland area of 68.3 acres. Sites range in age from one growing season to 12 years. The largest site is 13.2 acres. In situations where a natural wetland of similar type was adjacent to or nearby the constructed wetland, the natural wetland was also surveyed for invasive plant species and photographed resulting in aerial coverage of 9 natural wetlands.

Each site was visited and the vegetated community types identified and mapped. After each visit, equipment was washed to prevent accidental introduction of an invasive plant species into the next wetland site. Invasive plant species were identified according to the *List of Potentially Invasive Plants* (Virginia Heritage Program 1992). All invasive plant communities were kinematically surveyed using satellite based Trimble 4000ST Global Positioning System (GPS) receivers. Differential GPS survey methods were used to obtain accurate positioning to within two centimeters. Dominant community types (more than 50% one species) were delineated by walking the perimeter of specific vegetated community.

Use of the GPS for vegetated community surveying was unsuccessful at one site (FL) due to the presence of a heavily forested border which blocked the satellite transmission signal. The plant communities at this site were digitized from aerial photographs using Arc/Info software and were ground verified.

One site (KF) was visited in April 1994 when a perimeter of vegetation within a shallow water system was noted. However, when the site was overflown and photographed in September 1994 it was completely dry. On a return visit in November 1994 water was once again observed in the site.

Low altitude vertical imagery of each site was obtained using 70 mm Hasselblad cameras from the VIMS research aircraft. The aircraft is equipped with a floating floor mount to eliminate photographic distortion due to tilt and roll of the aircraft during flight. Each site was photographed with both color (Appendix I) and color infrared (Appendix II) film. Each image was digitalized by scanning, the color at 300 dpi and the color infrared at 800 dpi.

Each digital image was rectified using GPS ground control points and was then overlain with the Arc/Info polygon vector coverage created from the GPS survey data (Appendix III). Areas for each vegetated community type were calculated using ARC/INFO software (Appendix IV).

Study Sites in Virginia

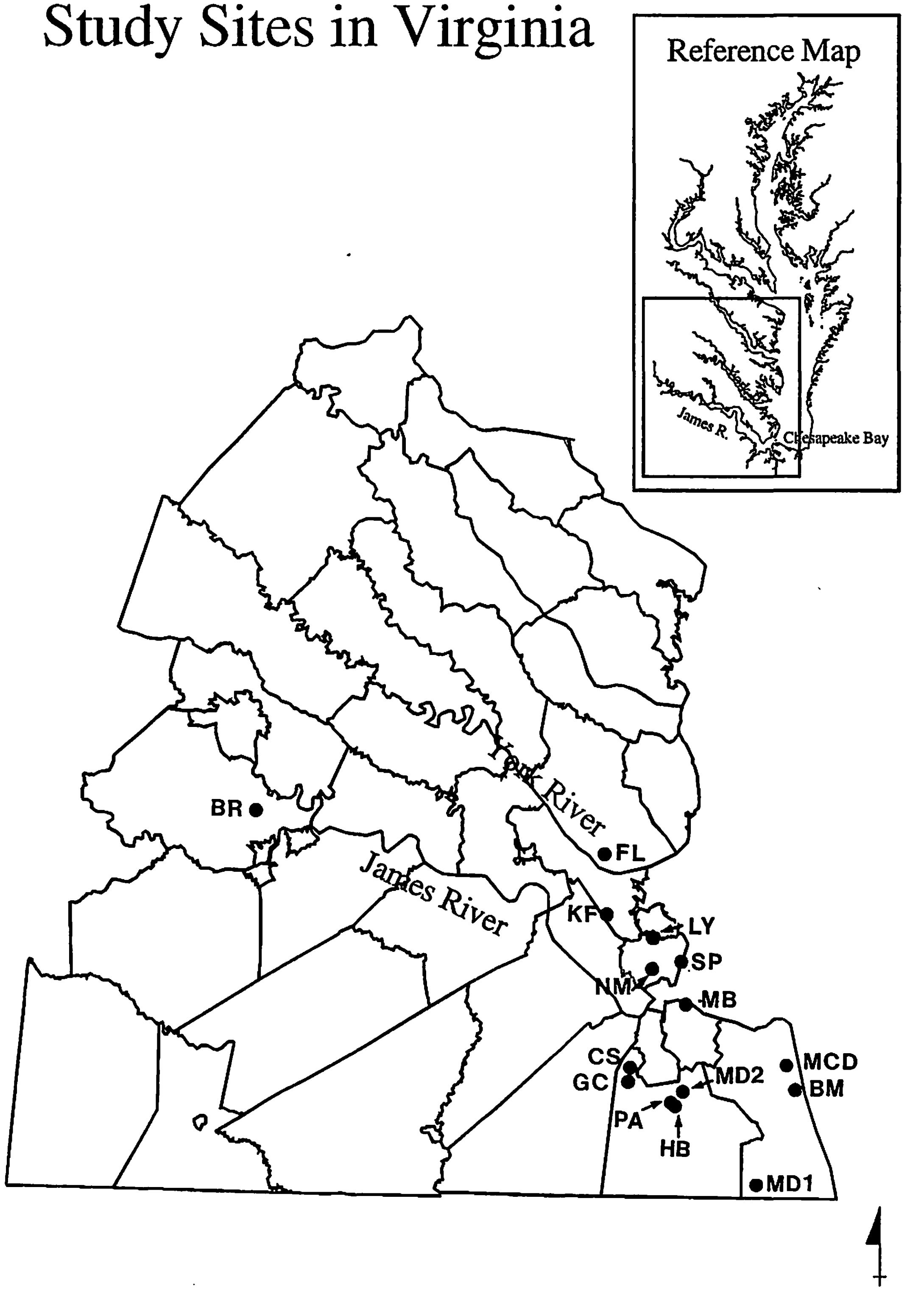

Figure 1. Fifteen Study Sites in Virginia

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Results

A total of 68.3 acres were surveyed (Table 1). Eleven of the fifteen (73%) constructed wetland sites were colonized by the invasive plant species, *Phragmites australis*. Five of the fifteen (33%) were colonized by *Typha* spp. In total, twelve sites (80%) have been colonized by *P. australis* and/or *Typha* spp. *Typha* spp. are not considered invasive, however some species are considered aggressive (Beare and Zedler 1987) and their presence within the study sites was noted (Table 2).

Nine of the constructed wetland sites had adjacent natural systems with similar vegetative community structure. Of these, two (FL and CS) had *P. australis* present as a result of sedimentation, with the subsequent rise in marsh surface elevation, from the construction of adjacent shopping center parking lots.

A correlation was observed between the average percent area of *P. australis* and the age of the constructed wetland ($r_{Pearson} = 0.746$, $p < 0.05$) (Figure 2). The regression equation Average Percent Area *P. australis* = -4.06 + 2.58(age in yrs) (r-sq (adj) = 48.7%, df=7, p=0.033) indicates that 48.7% of the average percent area of *P. australis* can be explained by the linear relationship to the age of the wetland (Figure 3).

Fractured regression analysis of the *P. australis*-invaded constructed wetlands (n=11) shows that the invasion reaches critical proportions at approximately 6 years of age (Figure 4). Long term monitoring of vegetative species is ongoing for one of the sample sites (GC) using established transects and percent cover estimates. At this site, a large increase in percent cover of *P. australis* can be observed between the 6th and 9th year, approximately 5% and 15% respectively (Figure 5) (Priest and Barnard 1993).

In a comparison of constructed tidal wetlands with and without perimeter ditches of ages 7-12 years, the perimeter ditched tidal wetlands (FL, MB, SP) had significantly less *P. australis* than the tidal wetlands without perimeter ditches (GC, HB, LY, MD1, NM) (p=0.046).

Discussion

The total amount of constructed wetland proposed to be created was 77.2 acres, however only 68.3 acres were measured in the surveys (Table 2). This may be attributed, in part, to our wetlands determination procedure. We only surveyed areas that had hydrophytic vegetation and evidence of hydrology. We, also, did not include the constructed wetland side slopes if such areas did not exhibit wetland characteristics. Some constructed wetland plans included the side slope area as part of the wetland acreage.

Phragmites australis is a cosmopolitan plant found throughout the world. In Europe its spread is controlled by both physical and biological factors, and it is considered a valuable plant (Haslam 1973). *P. australis* was first recorded in New England in colonial times and became a concern with resource managers in Virginia about 30-40 years ago (Silberhorn 1991). *P. australis* is an aggressive colonizer of disturbed sites and while a decline has been noted in Europe (Hartog and others 1989; Ostendorp 1989; Sukopp and Markstein 1989) it is rapidly gaining ground in North America displacing more desirable species such as *Spartina cynosuroides* Roth, *Zizania aquatica* L., and *Spartina patens* Muhl.

TABLE 1
Acres surveyed and species present for the constructed wetland study sites.

Site	Proposed Acres	Actual Acres	Species
NM	5.1	4.6	*Spartina alterniflora** *Spartina patens* *Spartina cynosuroides* *Phragmites australis* *Iva frutescens* *Baccharis halimifolia* *Panicum* sp.
SP	2.0	1.9	*Spartina alterniflora** *Spartina patens* *Phragmites australis*
LY	1.4	1.2	*Spartina alterniflora** *Phragmites australis*
FL	2.0	1.6	*Spartina alterniflora** *Spartina cynosuroides* *Spartina patens** *Distichlis spicata** *Iva frutescens*
MCD	3.0	2.0	*Phragmites australis* *Spartina cynosuroides* *Typha* sp. *Pontederia cordata** *Acorus calamus*
MD2	1.2	1.1	*Spartina alterniflora** *Phragmites australis* *Iva frutescens*
MB	7.5	6.9	*Spartina alterniflora** *Phragmites australis* *Iva frutescens*
HB	8.5	8.1	*Spartina alterniflora** *Phragmites australis* *Iva frutescens*
GC	8.4	7.8	*Spartina alterniflora** *Phragmites australis* *Spartina patens* *Distichlis spicata* *Iva frutescens* *Baccharis halimifolia* *Typha* sp.

TABLE 1 (concluded)

Site	Proposed Acres	Actual Acres	Species
PA	9.1	9.8	*Spartina alterniflora** *Spartina cynosuroides* *Phragmites australis*
BM	16.5	13.2	*Typha* sp. *Juncus* sp. *Scirpus triangulata* *Scirpus cyperinus** *Peltandra virginica**
MD1	1.5	1.4	*Typha latifolia* *Typha angustifolia* *Scirpus validus* *Juncus effusus* *Eleocharis obtusa* *Hydrocotyle* sp. *Carex* sp. *Nymphea odorata* *Phragmites australis*
KY	3.0	2.9	*Juncus effusus* *Scirpus cyperinus* *Andropogon virginicus* *Eleocharis obtusa* *Ludwigia* sp. *Typha* sp. *Ranunculus* sp. *Callitriche* sp.
BR	3.5	2.3	*Scirpus cyperinus* *Juncus effusus* *Eupatorium capillifolium* *Xanthium strumarium* *Panicum* sp. *Eleocharis* sp. *Typha* sp.
CS	4.5	3.5	*Juncus effusus* *Phragmites australis* *Typha* sp. *Ludwigia* sp. *Cyperus* sp. *Scirpus cyperinus* *Alnus serrulata* *Mikania scandens*
TOTAL	**77.2**	**68.3**	

*Planted

TABLE 2
List of constructed sites showing colonization by the invasive species Phragmites australis (Phraus) and the agressive species Typha spp. (Typspp.)

Site	Age	Total Area (m²)	Phraus Area (m²)	%	Typspp Area (m²)	%
PA	1	39688.5	259.8	0.7		
BM	1	53487.9			53	0.1
MD1	1	5568.6	1.2	0		
KF	2	11726.1				
BR	3	9346.3			2252	24.1
CS	4	14178.5	49.3	0.4	420.1	3
NM	7	18726	11538.4	61.6		
SP	7	7686.3	358	4.7		
LY	7	4908.8	143.9	2.9		
FL	7	6475				
MCD	9	8273.3	5191.6	62.8	77.1	0.9
MD2	9	4295.9	588.4	13.7		
MB	10	27919.3	2589.7	9.3		
HB	12	32589	2295	7		
GC	12	31731.9	11693.4	36.9	113.2	0.4

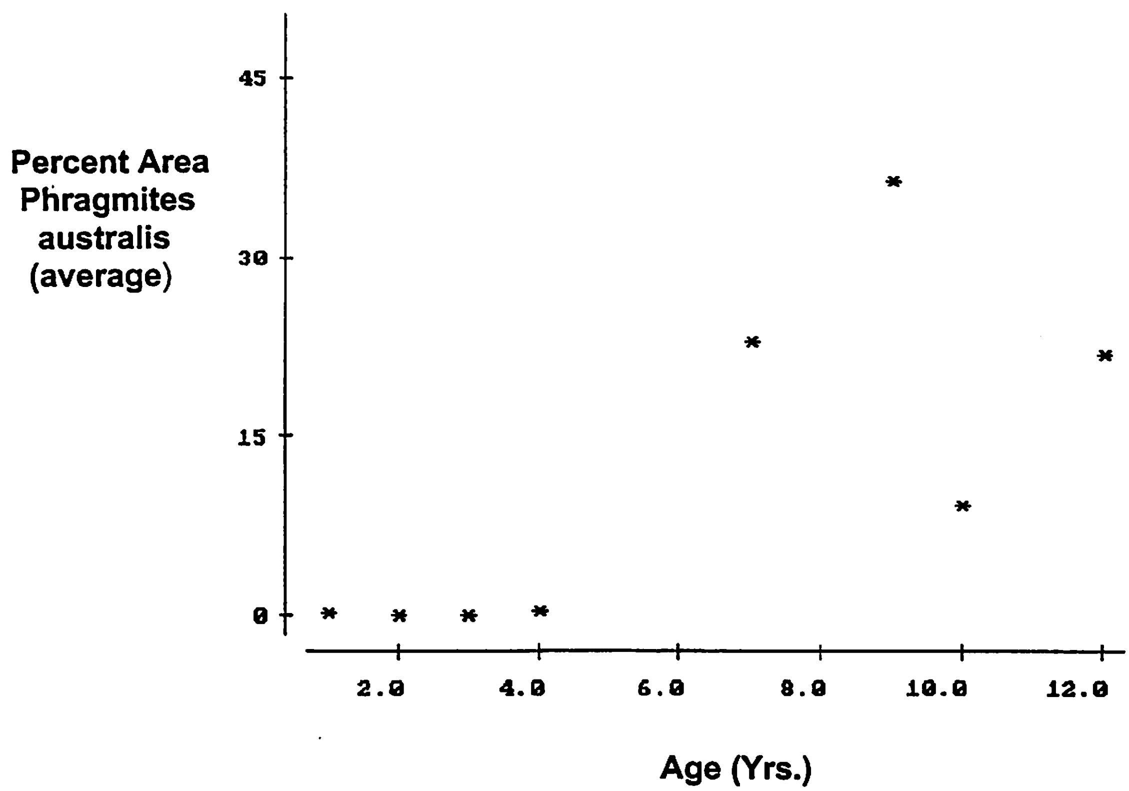

Figure 2. Correlation of age of wetland and % area of *P. Australis* ($r_{pearson}$=0.746, $p<0.05$).

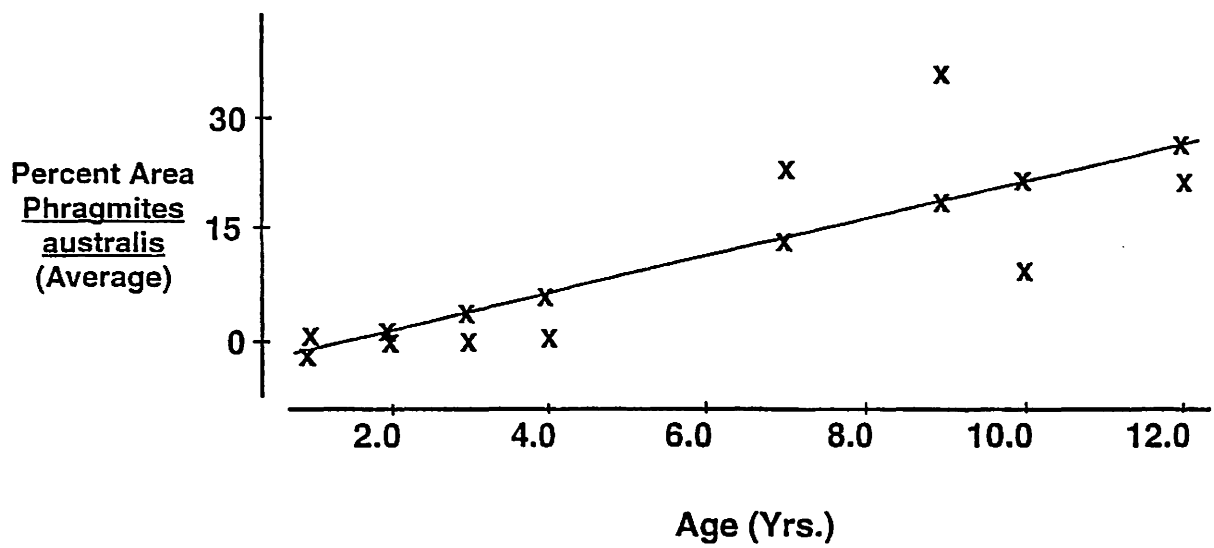

Figure 3. Linear regression of average percent area of *P. Australis* and the age of the constructed wetland. Average Percent Area *P. australis* = -4.06 + 2.58 (age in yrs) (r-sq (adj) = 48.7%, df=7, p=o.033).

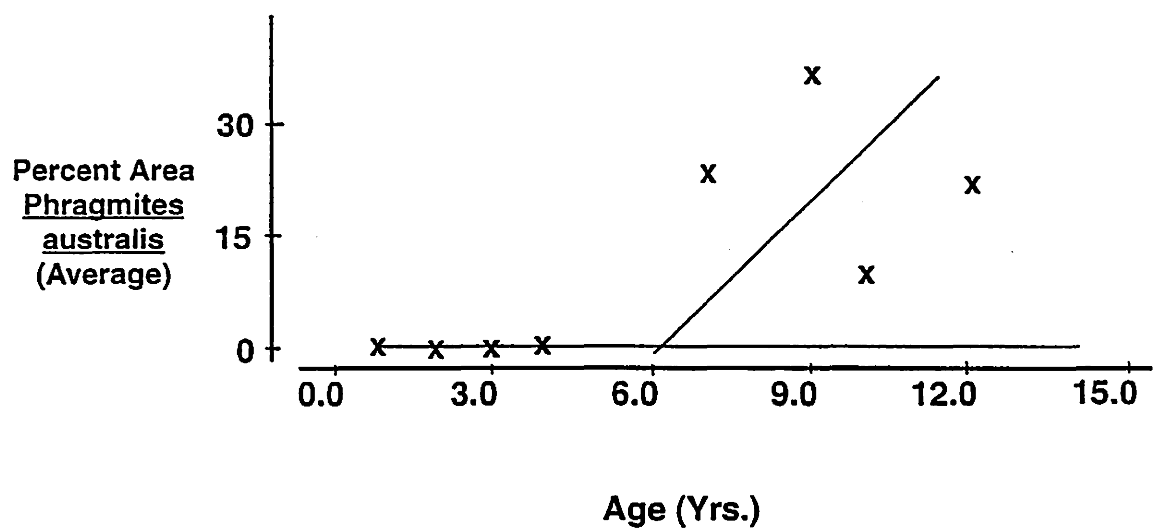

Figure 4. Fractured regression analysis of *P. Australis*-invaded constructed wetlands showing measurable invasion occurring at approximately 6 years of age (n=11).

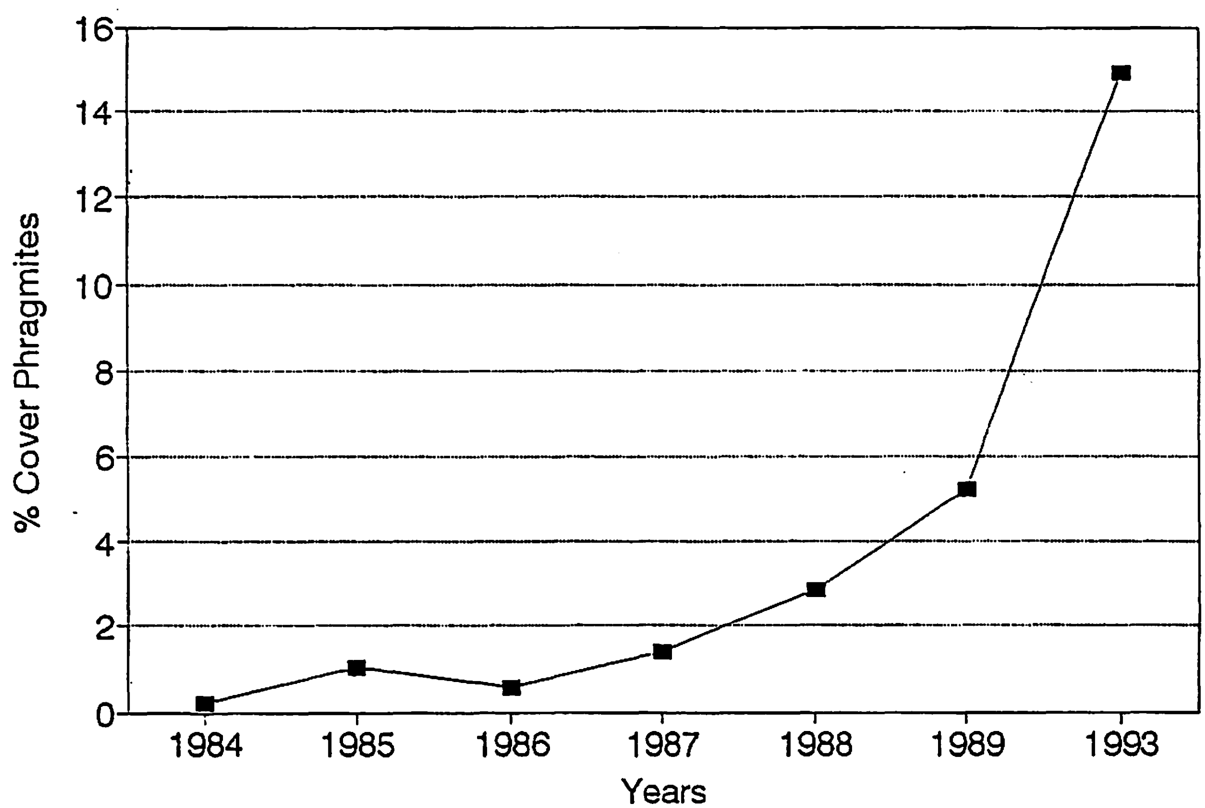

Figure 5. Percent cover of *P. Australis* in GC from 1984-1993.

P. australis can survive in most wet habitats, except areas of extreme nutrient deficiency or high salinity (Haslam 1973) and can germinate under 1 cm of water (Spence 1964). Colonization, though, by seedlings on submerged bottoms and within closed vegetation is severely restricted (Weisner and Eskstam 1993). Its rapid vegetative propagation of approximately 1-2 meters per year and its ability to suppress competitors by shading and litter mat formation (Haslam 1973) gives *P. australis* a distinct advantage over other species. Once established it is extremely difficult to eradicate. Attempts to remove *P. australis* with herbicides and multiple burnings have met with some success (Jones and Lehman 1987; Cross and Fleming 1989) while just burning has been less successful (Van der Toorn and Mook, 1982; Thompson and Shay 1989). In a previous study of one of the sample sites (MB), *P. australis* appeared to be inhibited by tidal flooding and mesohaline conditions (Priest 1989). More recently, salinity ($15gl^{-1}$, $30gl^{-1}$) and flooding (10cm and 20cm depths) have been shown to decrease height, biomass, recoverable underground reserves and non-structural carbohydrate concentration in *P. australis* (Hellings and Gallagher 1992) though Yamasaki and Tange (1981) observed *P. australis* survival even at 60 cm water depths.

These non-rigid horizontal rhizomes are the principal means of *P. australis* colony expansion. They terminate in vertical rhizomes which, if near the surface, develop aerial shoots. As *P. australis* encroaches into a wetland, a pattern of circular patches is established through horizontal rhizome, vertical rhizome, and aerial shoot growth patterns (Haslam 1969; Hara and others 1993) (Figure 6). *Typha* can spread more quickly under slow flow conditions and seed colonization is more frequent in *Typha* than *P. australis* (Haslam 1971).

Horizontal rhizomes are the juvenile stem type and are responsible for renewing and maintaining the population. They normally live 3-6 years and provide a supply of new vertical rhizomes which bear the aerial shoots (Haslam 1973). If the horizontal rhizomes meet unfavorable conditions, such as salinity and inundation, growth and encroachment can be inhibited. The significantly less ($p<0.05$) amount of *P. australis* in perimeter ditched tidal wetlands in this study suggests that the establishment of a subtidal perimeter ditch can slow the vegetative invasion of *P. australis* into the center of constructed wetlands by creating conditions unfavorable to horizontal rhizome encroachment.

Conclusions and Recommendations

Since *P. australis* can be extremely difficult to eradicate once established and out data indicate that populations of *P. australis* appear to reach critical levels after approximately 6 years of age; it is suggested that constructed wetland sites should be monitored for at least 10 years to help prevent *P. australis* colonization. If it becomes necessary, mechanical removal should be done with care since *P. australis* can spread by rhizome fragments which need only to become lodged on wet soil with a portion exposed to air or dry soil for establishment to occur (Haslam 1973).

The regression equation, Average Percent Area *P. australis* = -4.06 + 2.58 (age in yrs), suggests that if conditions within a constructed wetland remain favorable for *P. australis* colonization, such as sedimentation or restricted tidal inundation, then constructed wetlands could be overrun in approximately 40 years.

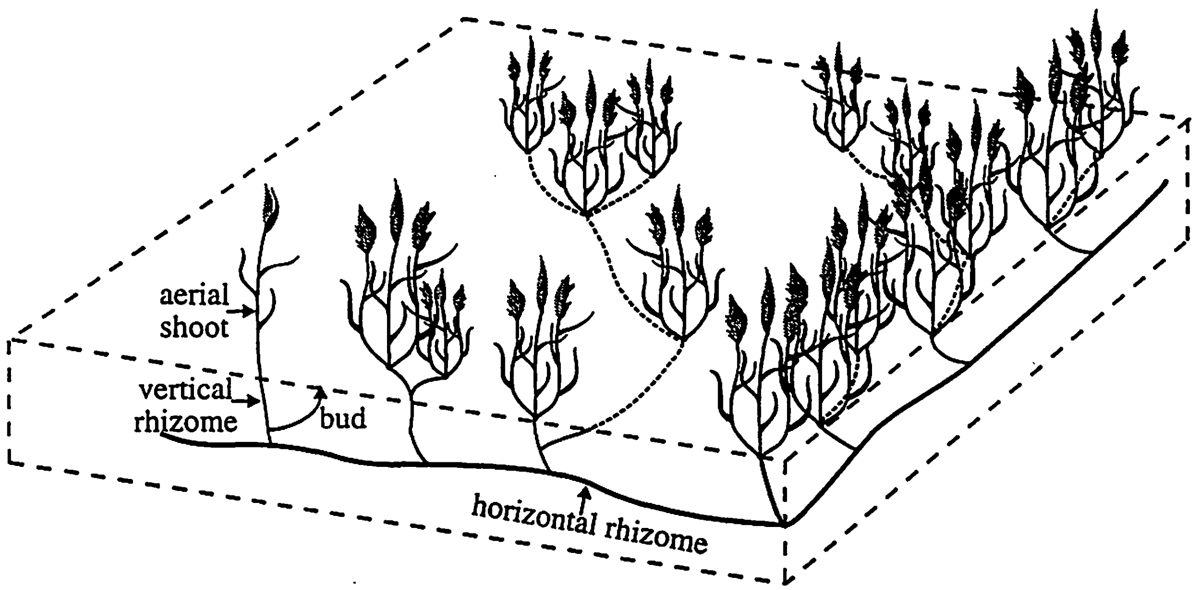

Figure 6. Vegetative propagation of *P. australis* (modified from Haslam, 1969).

A number of management options can be undertaken to minimize the invasion potential of *P. australis* into constructed wetlands. The establishment of subtidal perimeter ditches can inhibit rhizomal propagation into the constructed wetland interior. Properly constructed side slopes that minimize sedimentation into the constructed wetland will help prevent a rise in wetland surface elevation which would favor *P. australis* colonization. In estuarine wetlands, planting herbaceous species at high stem densities (i.e. on 30 cm centers) would accelerate the formation of a closed cover in vegetated areas adjacent to the creek channel and rivulets and help prevent colonization by unwanted species such as *P. australis*. Much of the potential for *P. australis* invasion in polyhaline areas can be eliminated by concentrating restoration efforts to wetlands at and below mean high water. In addition, a maintenance program to remove *P. australis* (including rhizome fragments) for 10 years would aid the planted wetland species establish a closed cover and inhibit invasion during the critical six year post-construction period.

The implication that constructed wetland sites could be dominated over time by less desirable, invasive plant species should be of considerable concern to resource managers. This is particularly true in situations where regulating agencies require the construction of wetlands to replace natural wetlands that are lost due to permitting actions (compensatory mitigation). If constructed wetlands are ultimately invaded by undesirable species. the function and value of these systems could be severely compromised and the overall natural resource value greatly diminished. The resistance of *P. australis* to physical and biological breakdown as compared to endemic species such as *Spartina alterniflora* (Graneli 1989; Hellings and Gallagher 1992) may decrease a wetland's foraging value to fish (Havens and others 1995). The concept and practice of constructing one large wetland to compensate for numerous small wetland impacts (mitigation banking) rather than individually replacing the small wetland losses could be potentially dangerous from an invasive species perspective. If the mitigation bank is invaded and overrun with a less desirable species, the loss of the one site would have a cumulative impact on the area watershed.

Wetland construction is a developing science and presently the question remains as to how well constructed wetlands replace the function and value of the natural welands that are lost. Constructed wetlands should be designed with limiting colonization by undesirable, invasive species as a foremost criterion and with an intense 10 year monitoring program.

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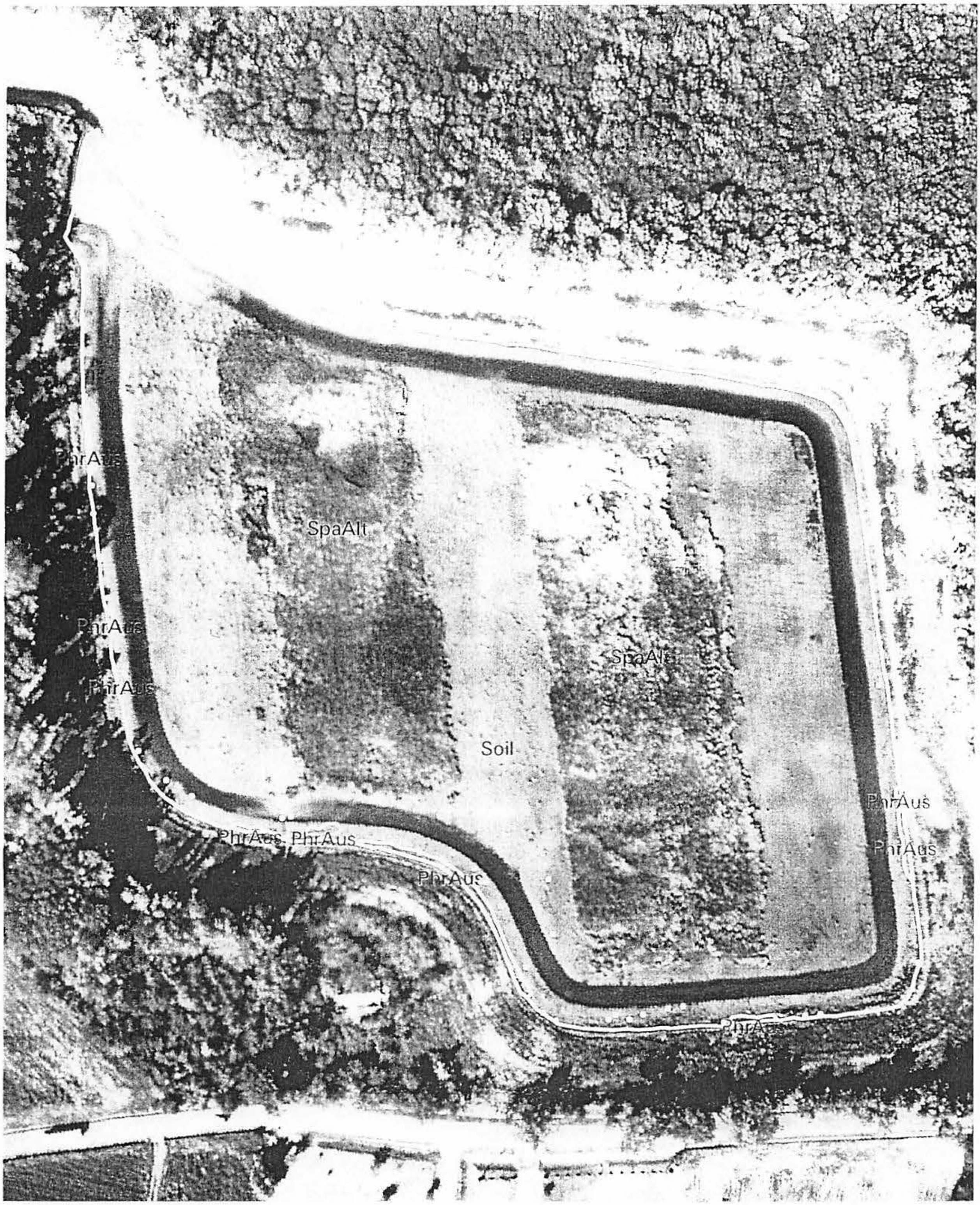
APPENDIX I

APPENDIX II

APPENDIX III



= GPS Survey
=15 cm dia. circle

Age: 1 year
Date of Photo: 9/94

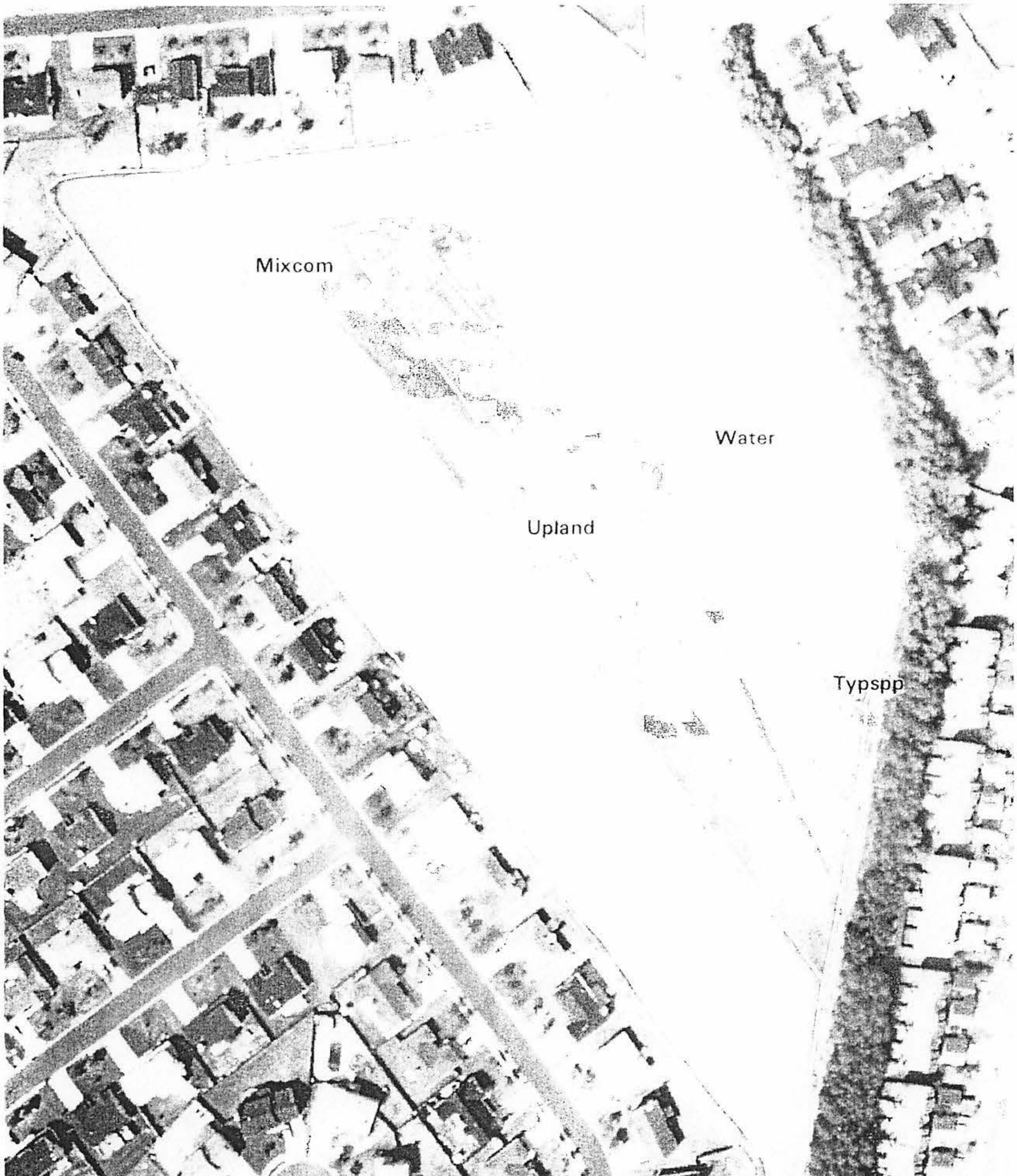
Scale

50 0 Meters

Constructed Wetland (PA)

CHESAPEAKE

Dept. of Resource Management & Policy, VIMS



= GPS Survey

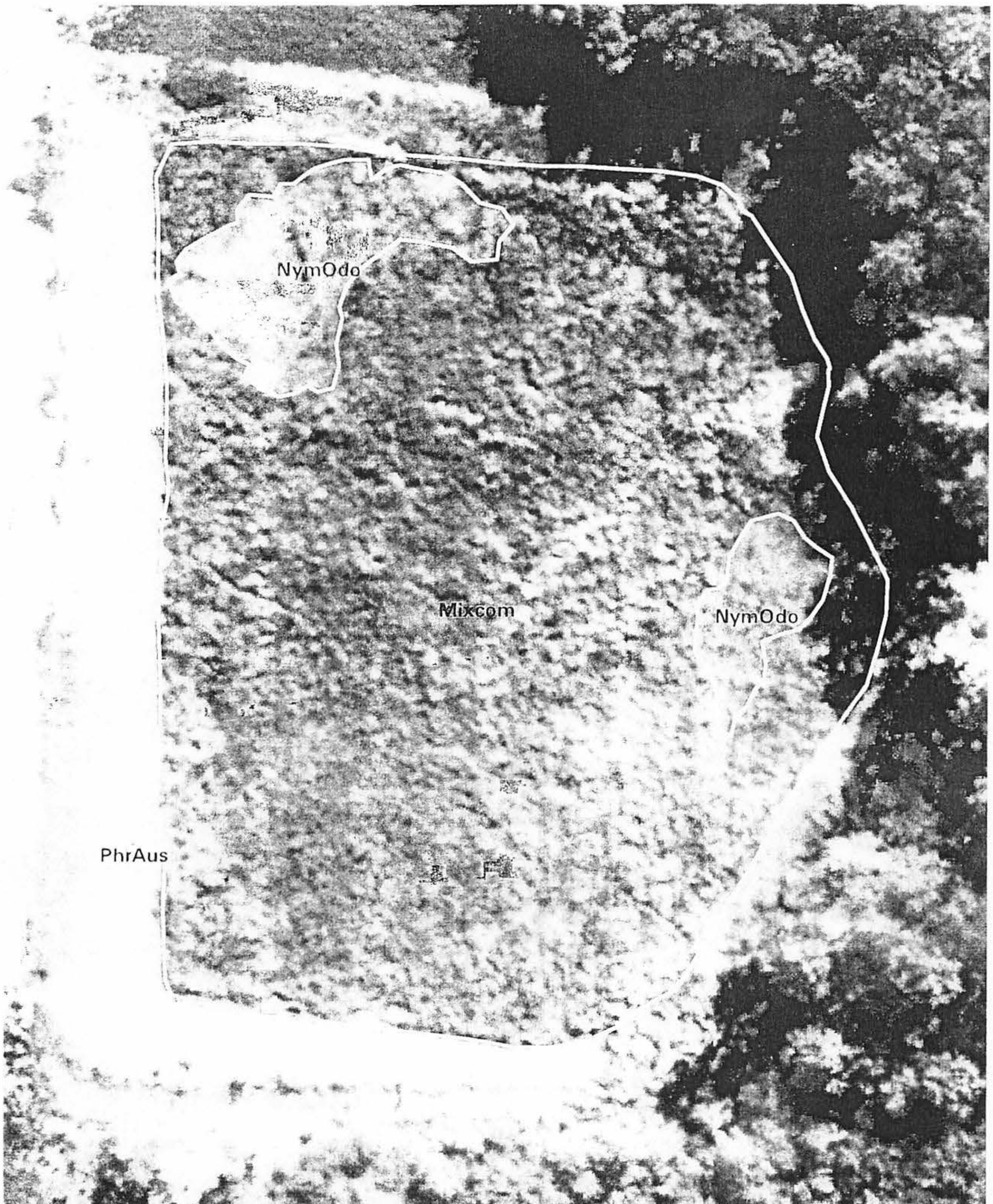
Age: 1 year
Date of Photo: 9/94

Scale

Constructed Wetland (BM)

VA BEACH

Dept. of Resource Management & Policy, VIMS



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Date of Photo: 9/94

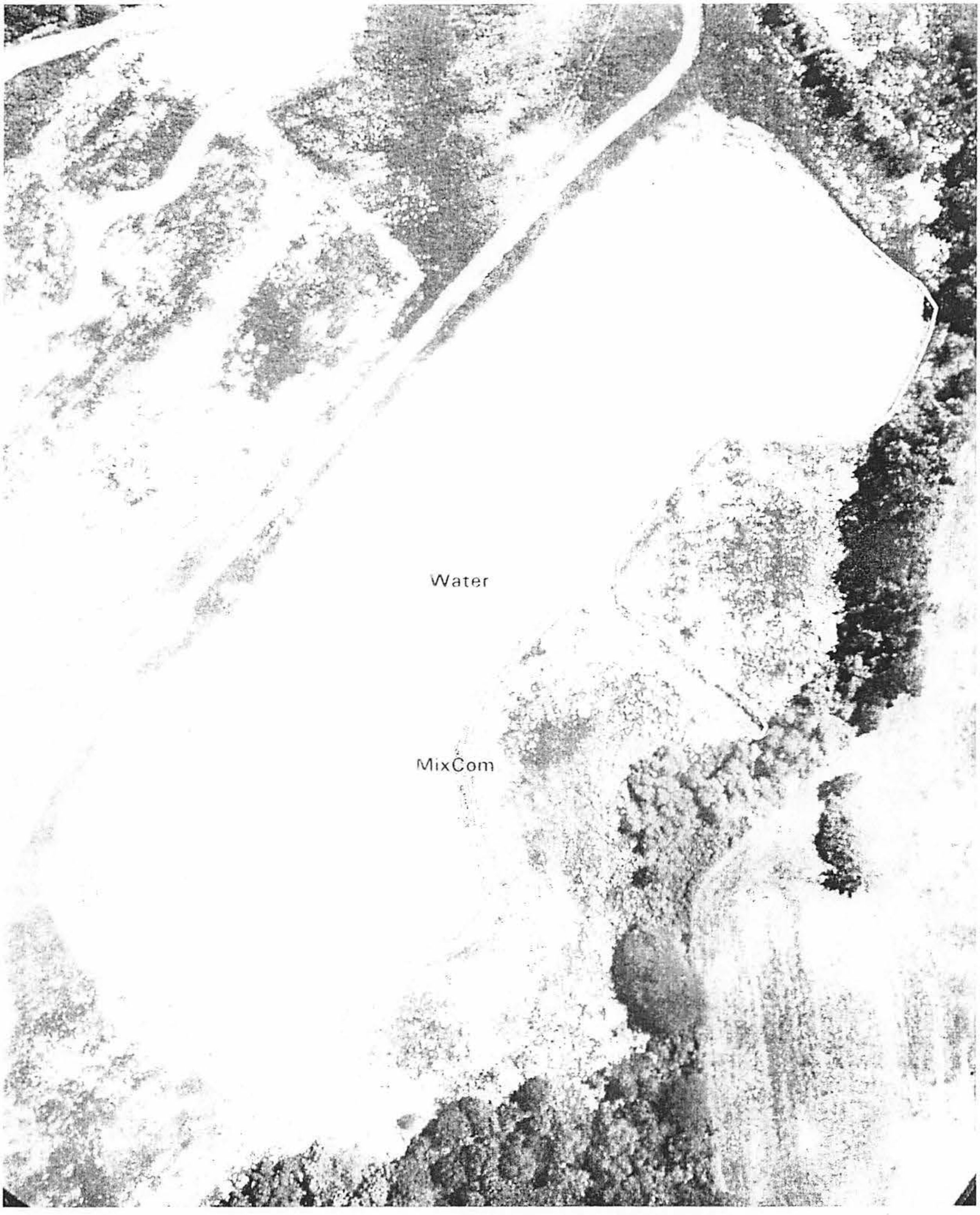
Scale

20 0 Meters

Constructed Wetland (MDI)

VA BEACH

Dept. of Resource Management & Policy, VIMS



= GPS Survey

Age: 2 year
Date of Photo: 9/94

Scale

50 0 Meters

Constructed Wetland (KF)

NEWPORT NEWS

Dept. of Resource Management & Policy, VIMS

= GPS Survey

Age: 3 year
Date of Photo: 9/94

Scale

Constructed Wetland (BR)

CHESTERFIELD

Dept. of Resource Management & Policy, VIMS

= GPS Survey

Age: 4 years
Date of Photo: 9/94

Scale

50 0 Meters

Constructed Wetland (CS)

CHESAPEAKE

Dept. of Resource Management & Policy, VIMS

= GPS Survey

Age: 7 years
Date of Photo: 9/94

Scale

20 0 20 Meters

Constructed Wetland (SP)

HAMPTON

Dept. of Resource Management & Policy, VIMS

= GPS Survey

Age: 7 years
Date of Photo: 9/94

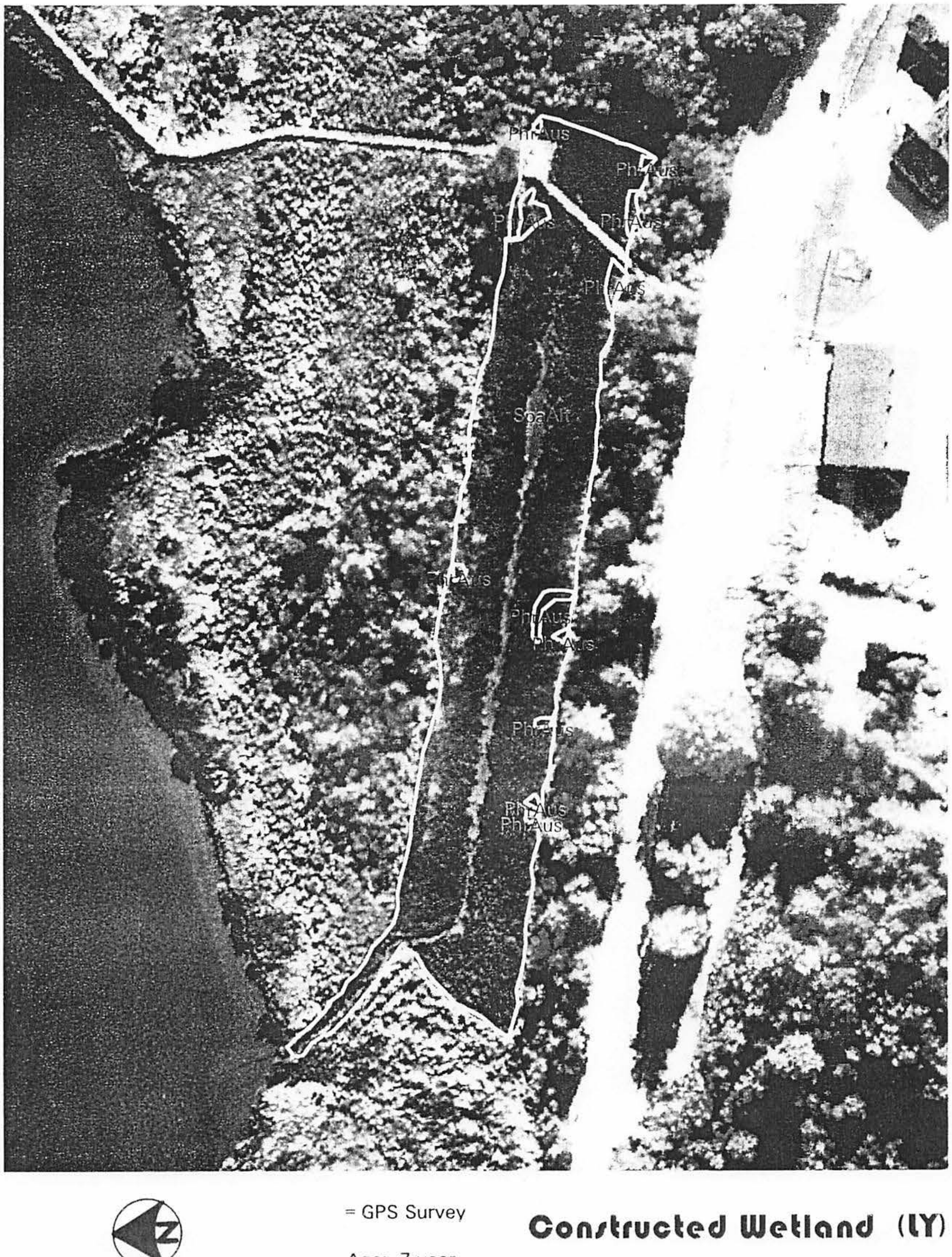
Scale

50 0 Meters

Constructed Wetland (NM)

HAMPTON

Dept. of Resource Management & Policy, VIMS



= GPS Survey

Age: 7 year
Date of Photo: 9/94

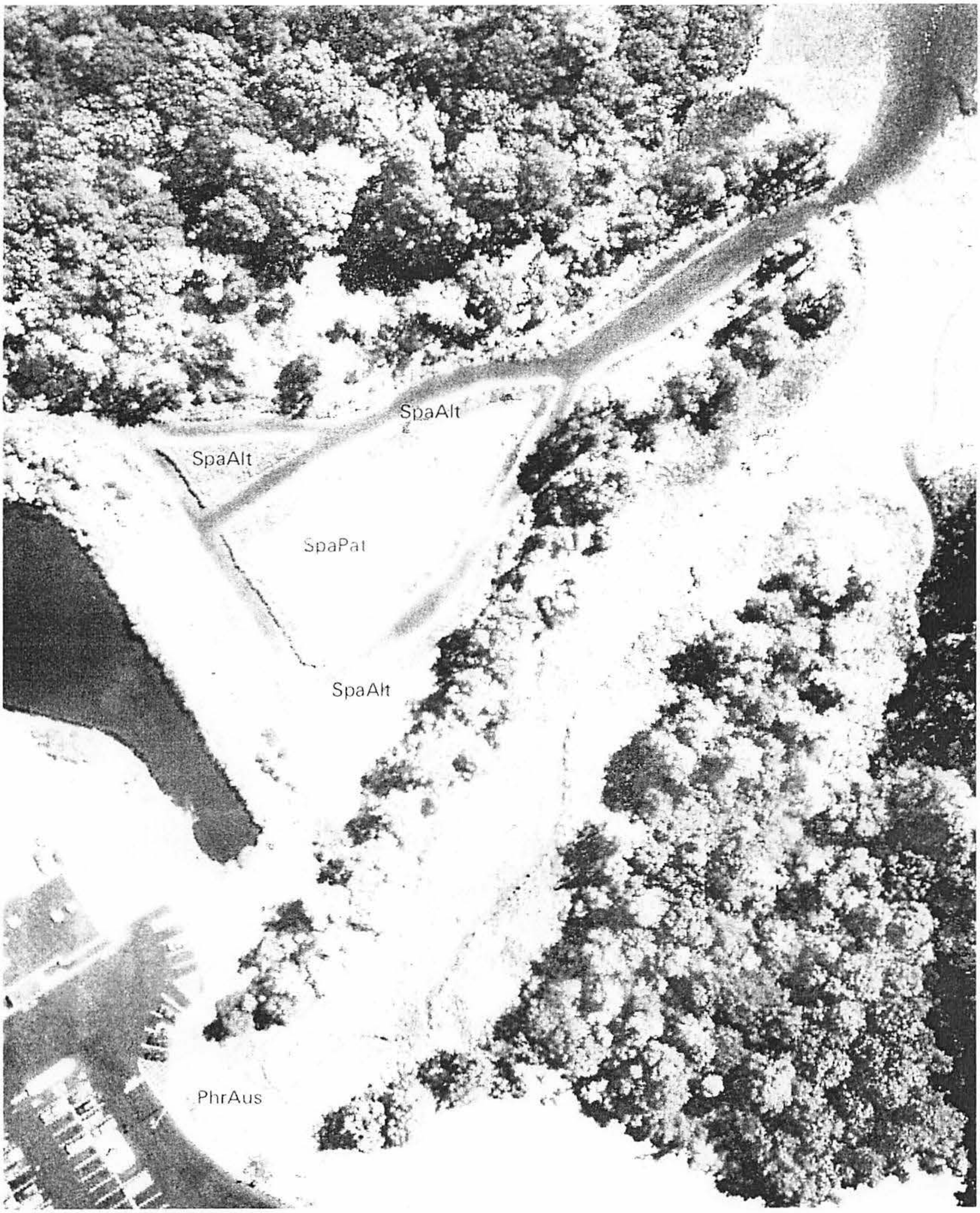
Scale

50 0 Meters

Constructed Wetland (LY)

HAMPTON

Dept. of Resource Management & Policy, VIMS



Age: 8 years
Date of Photo: 9/94

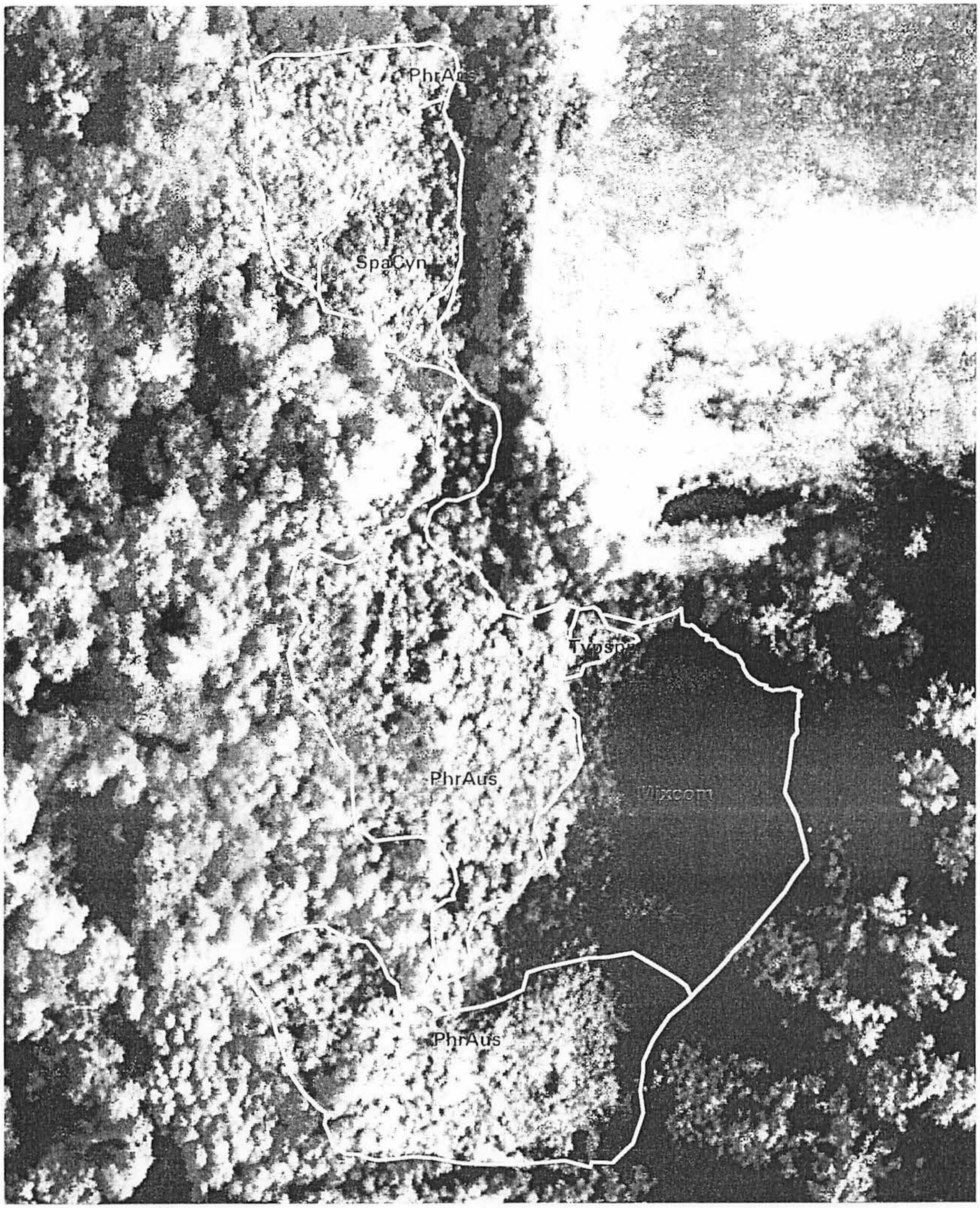
Scale

Meters
50 0

Constructed Wetland (FL)

GLOUCESTER

Dept. of Resource Management & Policy, VIMS



N

= GPS Survey

Age: 9 year
Date of Photo: 9/94

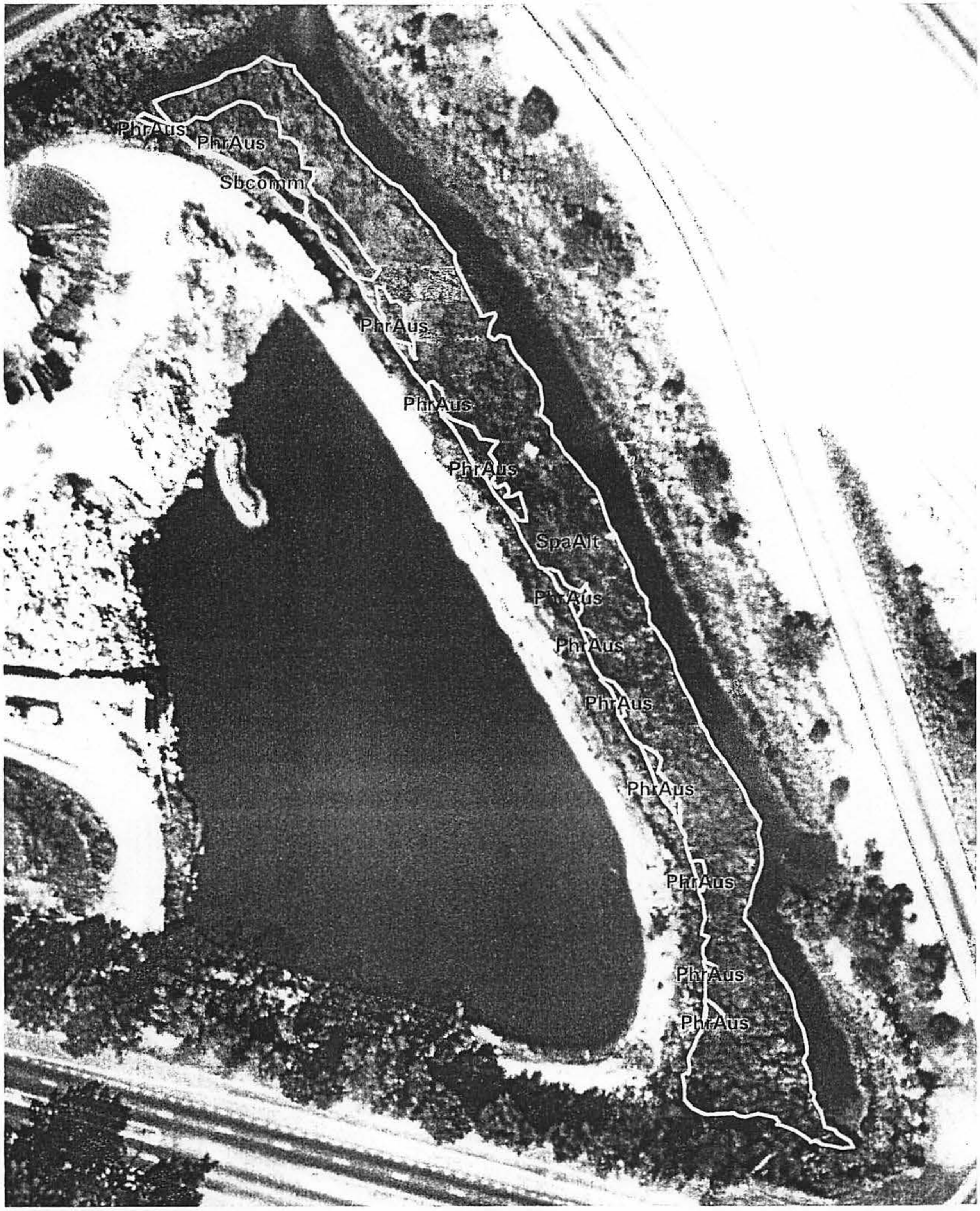
Scale

20 0 20 Meters

Constructed Wetland (MCD)

VA BEACH

Dept. of Resource Management & Policy, VIMS



N

= GPS Survey

Age: 9 year
Date of Photo: 9/94

Scale

Meters

50 0

Constructed Wetland (MD2)

CHESAPEAKE

Dept. of Resource Management & Policy, VIMS

= GPS Survey

Age: 10 years
Date of Photo: 9/94

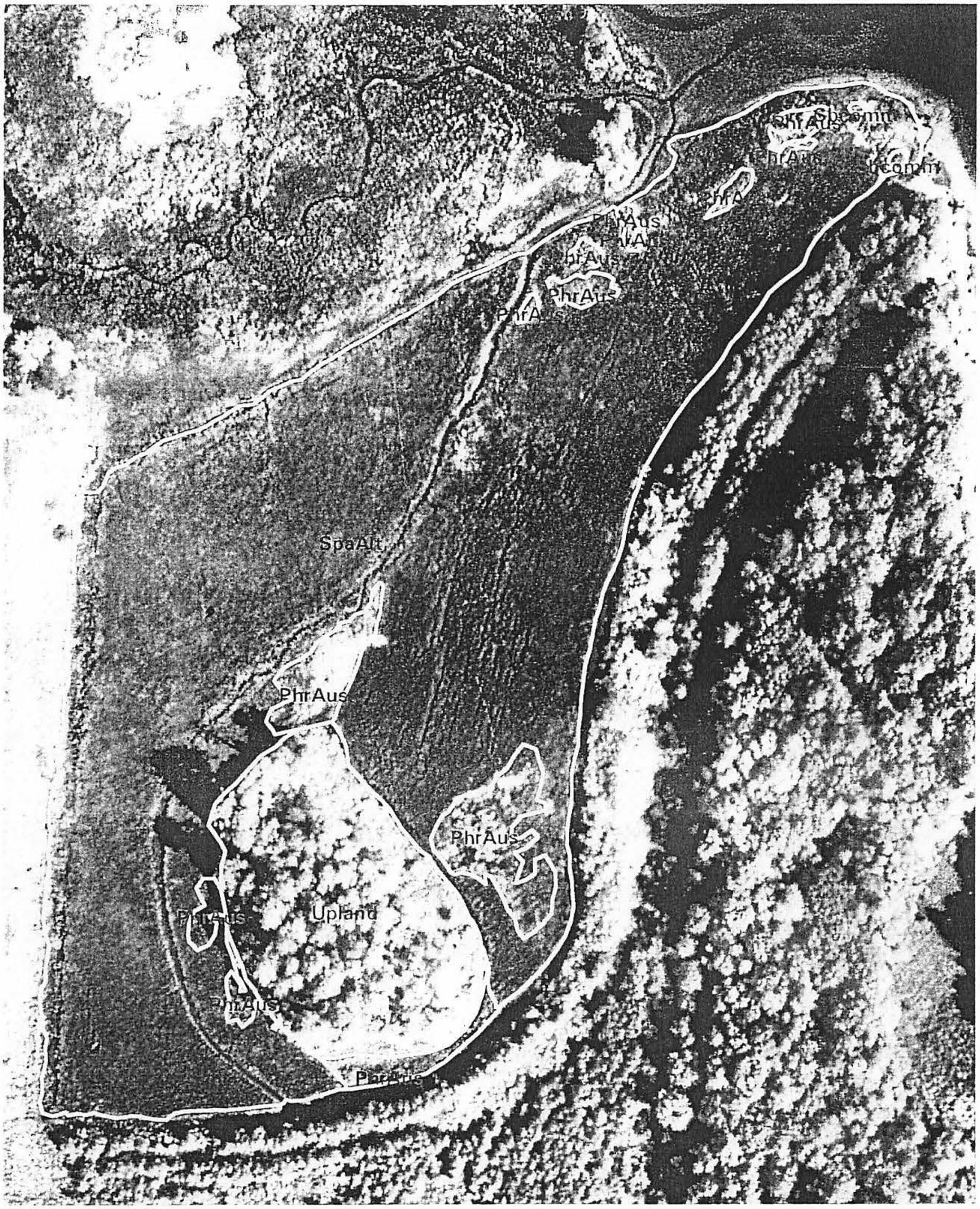
Scale

50 0 Meters

Constructed Wetland (MB)

NORFOLK

Dept. of Resource Management & Policy, VIMS



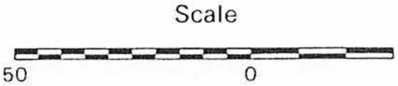
= GPS Survey

Age: 12 years
Date of Photo: 9/94

Constructed Wetland (HB)

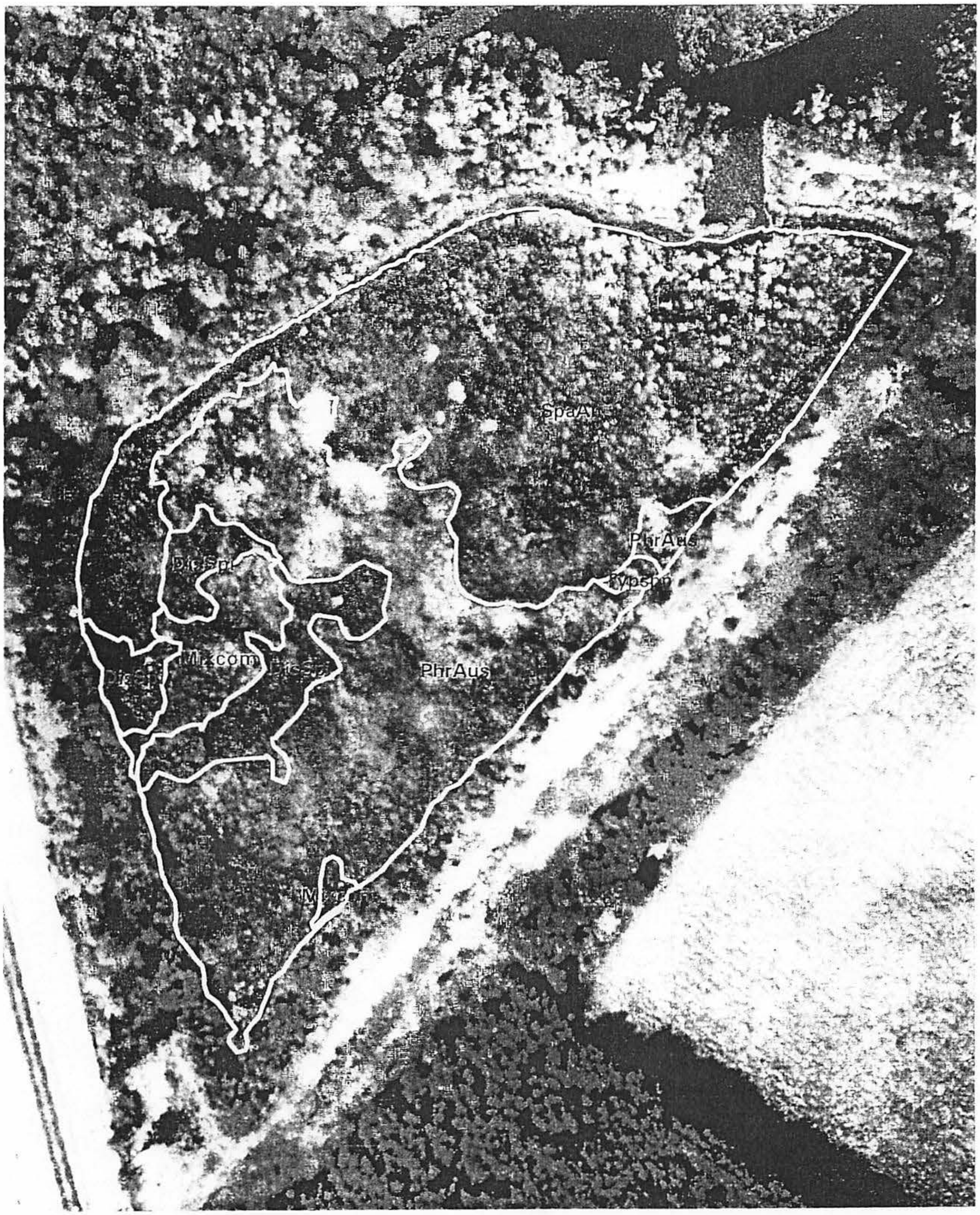
CHESAPEAKE

Scale



Meters

Dept. of Resource Management & Policy, VIMS



= GPS Survey

Age: 12 years
Date of Photo: 9/94

Scale

50 0 Meters

Constructed Wetland (GC)

CHESAPEAKE

Dept. of Resource Management & Policy, VIMS

Appendix IV

Appendix IV. Area (m²) of each community type within the constructed wetland sites (n=15). Perim = community type perimenter in meters.

		Total		Phraus			Spaalt			Mixcom			Typspp			Spapat			Nymodo		
Site	Age	Area	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim
PA	1.0	39688.5	859.6	259.8	0.7	334.3															
BM	1.0	53487.9	1605.0							9806.9	18.3	1175.0	53.0	0.1	85.3						
MD1	1.0	5568.6	291.7	1.2	0.0	4.7				5016.0	90.1	446.5							551.5	9.9	159.5
KF	2.0	11726.1	647.4							1835.4	15.7	1194.4									
BR	3.0	9346.3	434.0							5484.2	58.7	466.2	2252.0	24.1	383.2						
CS	4.0	14178.5	499.6	49.3	0.4	34.6				13709.2	96.7	708.7	420.1	3.0	177.6						
NM	7.0	18726.0	813.1	11538.4	61.6	1451.9	5274.5	28.2	986.2							1913.1	10.2	380.1			
SP	7.0	7686.3	424.4	358.0	4.7	190.1	6703.0	87.2	400.4							625.3	8.1	215.9			
LY	7.0	4908.8	493.4	143.9	2.9	184.9	4764.9	97.1	650.0												
FL	7.0	6475.0	468.3				2473.4	38.2	976.5							1810.1	28.0	189.4			
MCD	9.0	8273.3	651.2	5191.6	62.8	693.4				2323.7	28.1	254.9	77.1	0.9	41.2						
MD2	9.0	4295.9	600.1	588.4	13.7	409.3	3661.4	85.2	744.6												
MB	10.0	27919.3	915.1	2589.7	9.3	2070.2	25329.6	90.7	1187.5												
HB	12.0	32589.0	861.2	2295.0	7.0	842.9	25754.1	79.0	1677.7												
GC	12.0	31731.9	805.4	11693.4	36.9	971.0	15688.1	49.4	847.4	1458.8	4.6	310.7	113.2	0.4	47.3						

		Total		Sbcom			Spacyn			Disspi			Upland			Soil			Water		
Site	Age	Area	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim	Area	%	Perim
PA	1.0	39688.5	859.6													39428.7	99.4	910.3			
BM	1.0	53487.9	1605.0										5521.3	10.3	569.4				38106.8	71.2	2089.1
MD1	1.0	5568.6	291.7																		
KF	2.0	11726.1	647.4																9890.6	84.4	547.0
BR	3.0	9346.3	434.0										898.9	9.6	178.9	585.7	6.3	182.8	125.5	1.3	45.6
CS	4.0	14178.5	499.6																		
NM	7.0	18726.0	813.1																		
SP	7.0	7686.3	424.4																		
LY	7.0	4908.8	493.4																		
FL	7.0																		2185.5	33.8	695.1
MCD	9.0	8273.3	651.2				680.9	8.2	112.3												
MD2	9.0	4295.9	600.1	46.0	1.1	74.7															
MB	10.0	27919.3	915.1																		
HB	12.0	32589.0	861.2	30.1	0.1	29.0							4509.7	13.8	260.6						
GC	12.0	31731.9	805.4							2778.4	8.8	570.4									

Phraus = *Phragmites australis* Spaalt = *Spartina alterniflora* Spapat = *Spartina patens* Nymodo= *Nymphea odorata*
Mixcom = mixed community Typspp = *Typha species* Sbcom = Saltbush community Spacyn = *Spartina cynosuroides*
Disspi = *Distichlis spicata*