UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

AQUATIC HABITAT CHANGE WITHIN SELECTED POOLS OF THE UPPER MISSISSIPPI RIVER FROM 1975 TO 2000

A Chapter Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

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Biology

August 2007

AQUATIC HABITAT CHANGE WITHIN SELECTED POOLS OF THE UPPER MISSISSIPPI RIVER FROM 1975 TO 2000

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We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Biology

The candidate has completed the oral defense of the thesis.

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ABSTRACT

Asche, D. Aquatic habitat change within selected pools of the Upper Mississippi River from 1975 to 2000. Master of Science in Biology, May 2007, 61pp. (R.W. Tyser)

Impoundment of the Upper Mississippi River (UMR) in the 1930s created large areas of biologically diverse and productive backwater habitat. These areas may be threatened by rapid sediment accumulations that promote increased rates of allogenic succession. Aquatic habitat change in selected backwater areas from Pool 4 to Pool 19 of the UMR was analyzed for a 25-year period (1975 to 2000) using color infrared aerial photography and geographic information system (GIS) software. The objective was to describe aquatic habitat changes and determine the extent to which these changes were consistent with allogenic succession. Four cover classes were recognized, representing a transition from open water to terrestrial vegetation. Several changes were observed that were consistent with allogenic succession including a transition of emergent vegetation to grasses, forbs and/or woody vegetation. Other changes did not follow this trend including persistence of open water/submersed vegetation and conversion of emergent vegetation to open water. The results suggest that allogenic succession does not adequately account for all aquatic habitat changes observed in this study. Other factors, including fetch and wave action, may account for persistence of open water conditions and loss of emergent vegetation.

ACKNOWLEDGEMENTS

Facilities for this research were provided by the Upper Midwest Environmental Sciences Center (UMESC) in La Crosse, Wisconsin and the University of Wisconsin – La Crosse. I thank my major advisor, Dr. Rob Tyser, for his guidance, support, and encouragement throughout the duration of the project. I also thank my committee members Dr. Timothy Gerber, Dr. Mark Sandheinrich, and Dr. Cynthia Berlin for advice and assistance. Staff at the Upper Midwest Environmental Sciences Center, including J.C. Nelson, Jennifer Dieck, and Larry Robinson also provided much support and technical assistance. Also, I am grateful for the support from my family and friends for several years of encouragement on the project.

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INTRODUCTION

As part of the larger Mississippi River basin, the Upper Mississippi River (UMR) extends from Lake Itasca, Minnesota to its confluence with the Ohio River and is widely recognized as an exceptional natural and commercial resource. It is managed as a system of federal and state wildlife refuges and as a federal navigation waterway (Peck & Smart, 1986). For the past 200 years, it has been intensively managed for flood control and cargo transport, culminating in the construction of 29 locks and dams that were completed in the 1930s (Fremling & Claflin, 1984).

Construction of locks and dams along the UMR altered the river from a free-flowing system to a series of shallow, impounded pools. Characteristics of these pools include reduction in current velocities, expansion of water surface area, and elevated water levels under low-flow conditions, resulting in increased year-round stabilization of water levels (Chen & Simmons, 1986; Peck & Smart, 1986). Lock and dam construction expanded backwater areas and marsh vegetation throughout the original floodplain and decreased woody vegetation by raising water levels in impounded areas (Peck & Smart, 1986). Lock and dam construction also changed important physical parameters of the river. For example, Fischer and Claflin (1995) noted the loss of numerous small islands from Pool 8 of the UMR and a loss of depth within the pool resulting from sedimentation.

Backwater areas of the UMR are lotic systems that are influenced by their connectivity with the main stem thereby resulting in exchange of water, nutrients, and sediments. Impoundment by dams and levees normally results in reduced connectivity and possible loss of biodiversity, patterns that have been observed in backwater areas of the UMR (Fischer & Claflin, 1995; Ward & Stanford, 1995). In addition to a loss of species diversity, reduction in connectivity can also lower current velocities and thus promote sediment accumulation in backwater areas (Bhowmik & Adams, 1989; Fremling & Claflin, 1984). For example, Tyser et al. (2001) observed that diversity of plant communities in UMR backwaters increased after a major flood event, presumably because of increased connectivity, flushing of accumulated sediment, and re-establishment of subdominant plant species.

Estimations of sedimentation rates in the UMR are variable, ranging from 1.0-5.0 cm/yr (Eckblad et al., 1977; McHenry et al., 1984), and some backwater areas are estimated to have lost more than 50% of their volume (Bhowmik & Adams, 1989; Bhowmik & Demissie, 1989; Eckblad et al., 1977). Conversely, other studies have observed relatively low rates of sedimentation (Korschgen et al., 1987; Rogala & Boma, 1996).

Sedimentation in a lotic system caused by impoundment and reduction of connectivity can result in aquatic habitat change in backwater areas (Junk et al., 1989; Tazik et al., 1993; Ward & Stanford, 1995), a process called allogenic succession. Allogenic succession resulting from sedimentation promotes changes in plant community structure, including expansion of rooted floating species (e.g., *Nelumbo lutea* and *Sagittaria*) into open water areas (Eckblad et al., 1977; Tazik et al., 1993) or a general trend toward more terrestrial conditions (Bhowmik & Adams, 1989). Based on observed sedimentation patterns, the predicted lifespan of some backwater areas has been estimated to be about 50 to 100 years (Eckblad et al., 1977; McHenry et al., 1984).

Though factors such as impoundment, connectivity, reduced current velocities, and sedimentation are known to promote allogenic succession, this process has not been well studied. In this study, aquatic habitat changes in selected backwater areas of the UMR were described over a 25-year period through the use of color infrared aerial photography and geographic information system (GIS) procedures. The objective of this research was to describe aquatic habitat changes in selected UMR backwater communities and to determine the extent to which these changes were consistent with allogenic succession.

MATERIALS AND METHODS

Study Site Selection

Based on the availability of aerial photography taken in 1975 (1977 for Pool 7 only) and 2000, 10 pools in the UMR (Pools 4, 5, 5a, 7, 8, 11, 12, 13, 16, and 19) were selected for potential study (Figure 1). Using spatial databases prepared by the Upper Midwest Environmental Sciences Center (UMESC), areas classified with significant amounts of "backwater contiguous floodplain shallow aquatic areas" were considered as possible study sites. These were areas consisting of a mosaic of open water and islands that included small water channels and floodplain water bodies having surface flow connections with the main channel (Wilcox, 1993). Coverage of this habitat type represented 37% to 70% (mean = 52%) of the total backwater habitat in these pools (Appendix A). Vegetation in these areas included a diverse mix of open water, submersed, rooted floating, emergent, grass, and woody vegetation.

Sizes and locations of potential study sites (Table 1) were determined with ArcView v. 3.1 software (Environmental Systems Research Institute (ESRI) Inc., Redlands, CA, USA). Areas that included habitat management projects (e.g., dredging, flow alteration, island reconstruction) by government agencies and main channel and main channel border areas were excluded from consideration. Based on previous research (Tyser et al., 2001), a study site area of 400 ha to 1400 ha was judged sufficient

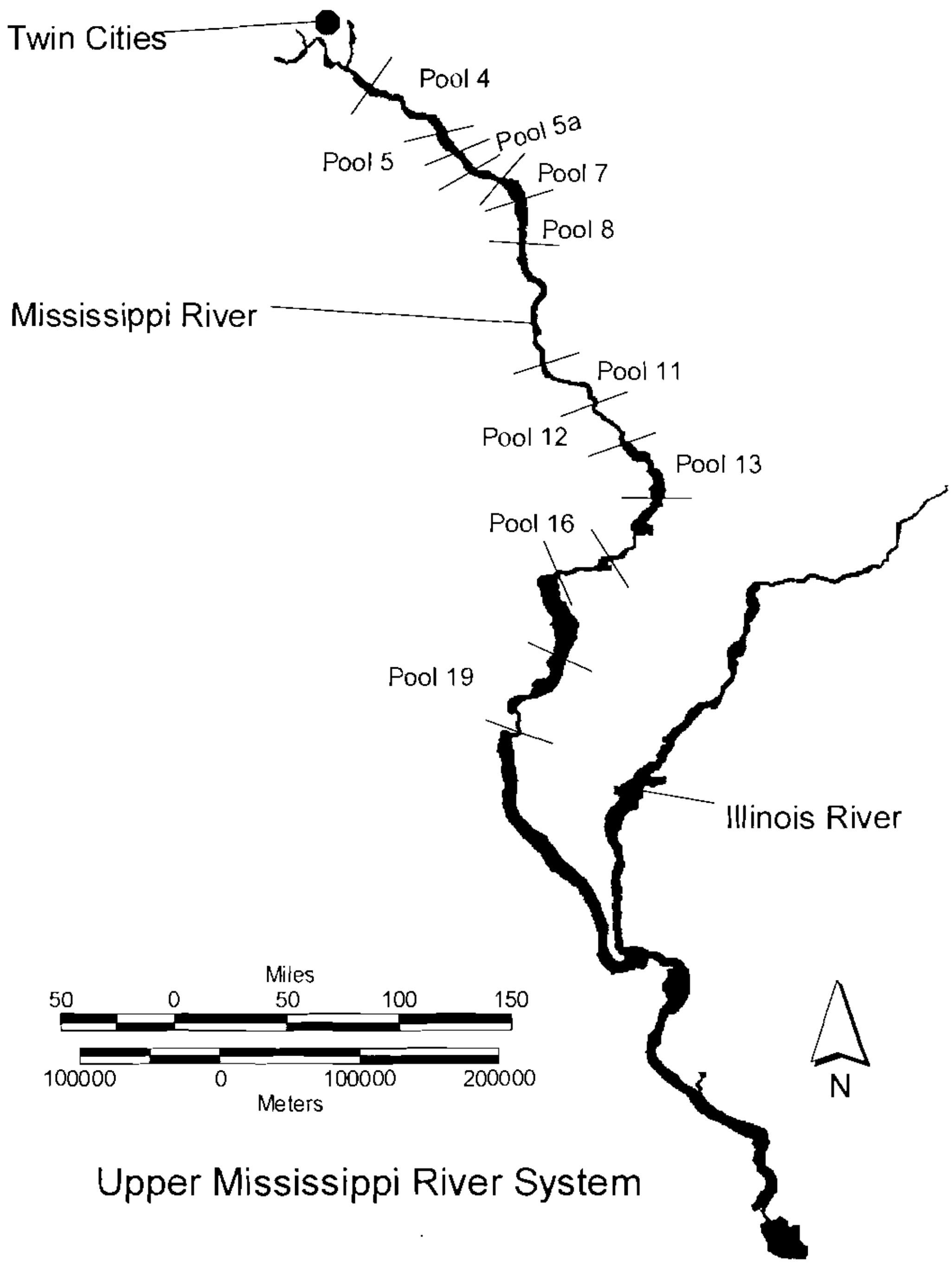

Figure 1. Pools included in this research and their location along the Upper Mississippi River System.

Table 1. Study site location and surface area in the Upper Mississippi River.

Study Site	Size (ha)
Pool 4	558.8
Pool 5	550.4
Pool 5a	443.2
Pool 7	505.0
Pool 8	447.2
Pool 11	696.3
Pool 12	588.5
Pool 13	775.6
Pool 16	1016.6
Pool 19	851.8
Total	6433.4

to assess aquatic habitat change over the time period considered in this investigation. When multiple candidate study sites occurred in a given pool, one was randomly selected for study.

Photointerpretation and Preparation of Data

Color infrared aerial photography (scale = 1:9,600 to 1:24,000), taken in 1975 and 1977 during the Great River Environmental Action Team studies was located for the 10 UMR pools noted above. Color infrared photography (scale: 1:24,000) from 2000 was contracted by UMESC as part of their monitoring program, authorized by the Water Resources Development Act of 1986 (Public Law 99-662). Photographs were taken between August and mid-September of each year.

Photointerpretation followed standard operating and classification procedures as described by Owens and Hop (1995) and Dieck and Robinson (2004). The UMESC General Classification for photointerpretation was condensed, however, from over 30 classes to four. Contiguous polygons were traced based on vegetation on photographs (10% minimum coverage) and categorized into one of four classes: Class 1 (permanently flooded), Class 2 (semi-permanently flooded), Class 3 (seasonally flooded), and Class 4 (temporarily or infrequently flooded) (Table 2). These four classes form a general hydrological gradient from open water to more terrestrial conditions. The minimum map unit was set at 0.47 ha (1 acre). Transfer of manual linework from the photographs to digital data for analysis was done following standard operating procedures as described by Owens and Robinson (1996) and Arndt and Olsen (1995). Appendix B details linework transfer and data automation.

Table 2. Vegetation life forms and important genera associated with cover classes recognized in this study.

Cover class	Predominant vegetation life form	Predominant genera
Class 1 (permanently flooded)	Submersed/rooted floating	*Lemna spp.* *Nelumbo* *Nymphaea* *Wolffia spp.*
Class 2 (semi-permanently flooded)	Emergent	*Sagittaria* *Sparganium* *Typha* *Zizania*
Class 3 (seasonally flooded)	Emergent/grasses/forbs	*Lythrum* *Phragmites* *Scirpus* *Salix*
Class 4 (temp/infrequently flooded)	Grasses/forbs/woody vegetation	*Leersia* *Phalaris* *Populus*

Data Analysis

In assessing aquatic habitat change from 1975 to 2000, three general outcomes were recognized: (1) no change -- areas within a site that retained their 1975 cover classifications in 2000, (2) successional changes -- areas with new cover classifications from 1975 to 2000 that were consistent with allogenic succession, or (3) other changes – areas with new cover classifications from 1975 to 2000 inconsistent with allogenic succession models. Six cover classification changes that occurred from 1975 to 2000 were recognized that were generally consistent with allogenic succession: Class 1 to Class 2, 3 or 4; Class 2 to Class 3 or 4; and Class 3 to Class 4. All other cover classification changes that occurred, such as Class 2 to Class 1, were considered inconsistent with allogenic succession.

Changes in vegetation were evaluated using a paired t-test with the null hypothesis, $|S_A = O_A|$, where S_A = cumulative area of allogenic successional changes observed in a study site and O_A = cumulative area of "other" changes.

RESULTS

In both 1975 and 2000, the cumulative area of Class 1 and Class 4 exceeded that of the other two cover classes (Table 3). For example, in Pool 4 in 1975, Class 1 and Class 4 represented 434.2 ha and 95.7 ha, respectively, compared with 34.2 ha and 0.3 ha of Class 2 and Class 3 (Figure 2). In two pools (5a and 7), however, coverage of Class 2 and Class 3 was relatively high in 1975 or in 2000. For example, in 2000 coverage of Class 2 and Class 3 in Pool 5a represented 47.9 ha and 88.2 ha, and exceeded the coverage of Class 4 (41.3 ha) (Figure 2).

Table 3. Cumulative areas (ha) of the four cover classes in the Upper Mississippi River recognized in this study.

Cover class	1975	2000
Class 1 (permanently flooded)	3790.3	3749.4
Class 2 (semi-permanently flooded)	566.0	338.5
Class 3 (seasonally flooded)	282.3	382.0
Class 4 (temporarily or infrequently flooded)	1794.8	1963.5

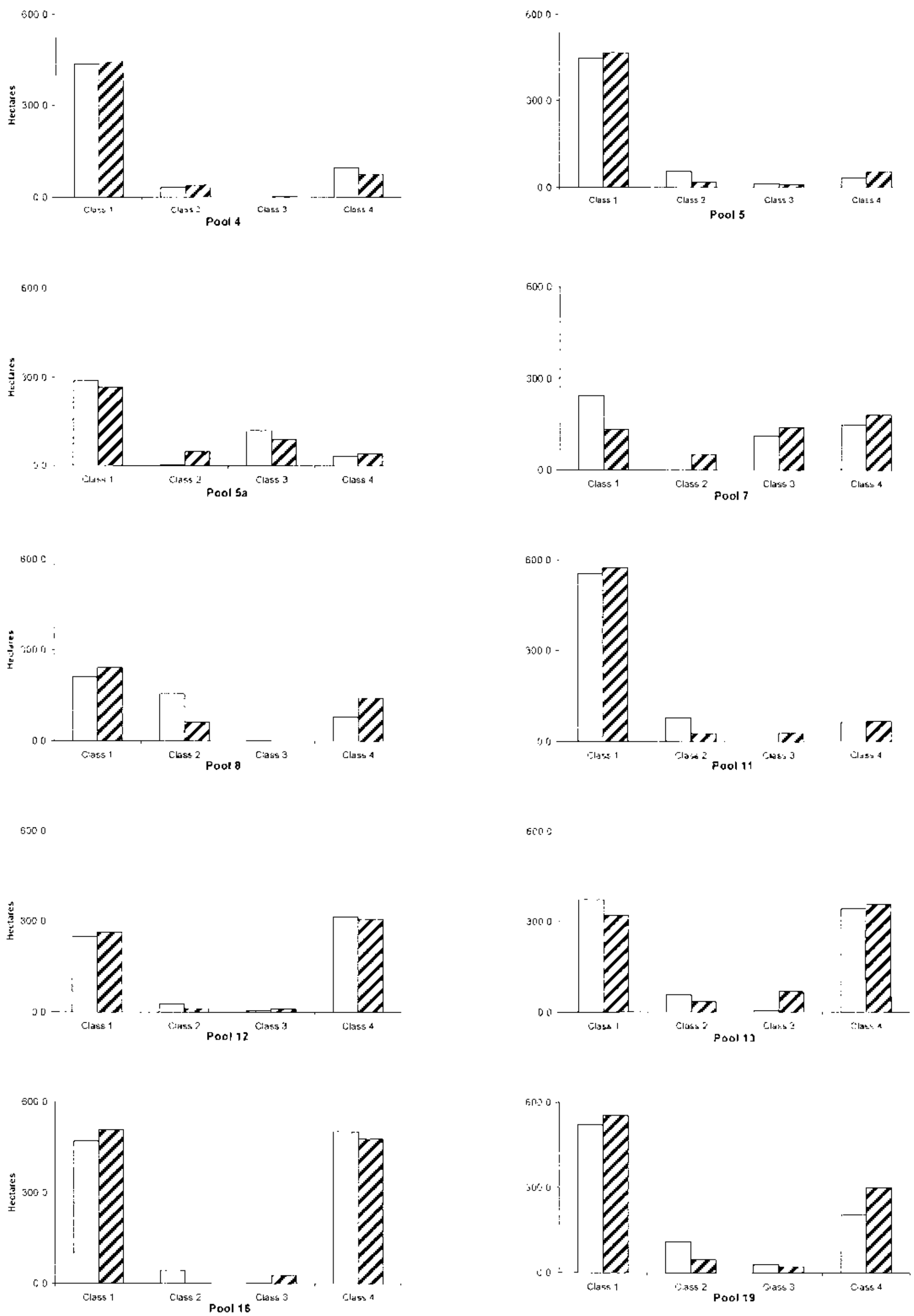

Figure 2. Vegetation changes in each of 10 study sites from 1975 to 2000. Clear bars represent 1975 and hatched bars represent 2000.

Across all sites, few areas (ca. 15%) identified as Class 1 or Class 4 in 1975 were reclassified in 2000 (Table 4). However, relatively large changes occurred in these cover classes in Pools 7 and 8. For example in Pool 7, from 1975 to 2000 the amount of area identified as Class 1 decreased 110.7 ha (45%) and Class 4 increased 31.1 ha (21%) (Figure 2).

Areas identified as Class 2 and Class 3 were less likely to retain their classification from 1975 to 2000 (Table 4). Although only 15.3% and 15.8% of areas identified as Class 1 and Class 4 were reclassified in 2000, 82.3% and 59.0% of areas classified as Class 2 and Class 3 in 1975 were reclassified in 2000 (Table 4). In 9 of 10 individual sites, greater than 15% of areas identified as Class 2 or Class 3 in 1975 were reclassified in 2000 (Appendix E).

Table 4. Summary of cover class reclassification from 10 study sites from 1975 to 2000 on the Upper Mississippi River.

Cover Class	Hectares reclassified	Percent of cover class reclassified
Class 1 (permanently flooded)	578.2	15.3
Class 2 (semi-permanently flooded)	465.8	82.3
Class 3 (seasonally flooded)	166.5	59.0
Class 4 (temporarily or infrequently flooded)	283.4	15.8
Total[1]	1493.9	23.2

[1]Note: Cumulative area of all study sites was 6433.4 hectares.

Although large proportions of areas identified as Class 2 and Class 3 did not retain their 1975 classifications, the number of hectares that were reclassified was relatively small. Transitions turned out to be small, local, and site specific. For example, in Pool 5a, areas identified as Class 2 increased over 1400% (3.4 ha to 47.9 ha) and in Pool 7 that same cover class was non-existent in 1977 and grew to 51.7 ha in 2000 (Appendix C). These were large areas of transitions proportionally, but not in hectares.

Across all sites, cumulative area of Class 3 and Class 4 increased substantially while the cumulative area of Class 2 decreased. Coverage of Class 1 remained essentially unchanged (Table 3, Figure 3 and Appendix D). Interestingly, the transition within Class 2 and Class 3 was inconsistent with predicted successional change (Table 5). Of the area identified as Class 2, 46.9% transitioned to Class 1 in 2000, compared with just of 35.3% transitioning to a later successional stage (9.4% Class 3, 25.9% Class 4). For Class 3, 32.7% of the area transitioned to an earlier successional stage (19.6% Class 1, 13.1% Class 2) compared to 26.2% that transitioned to Class 4 (Table 5).

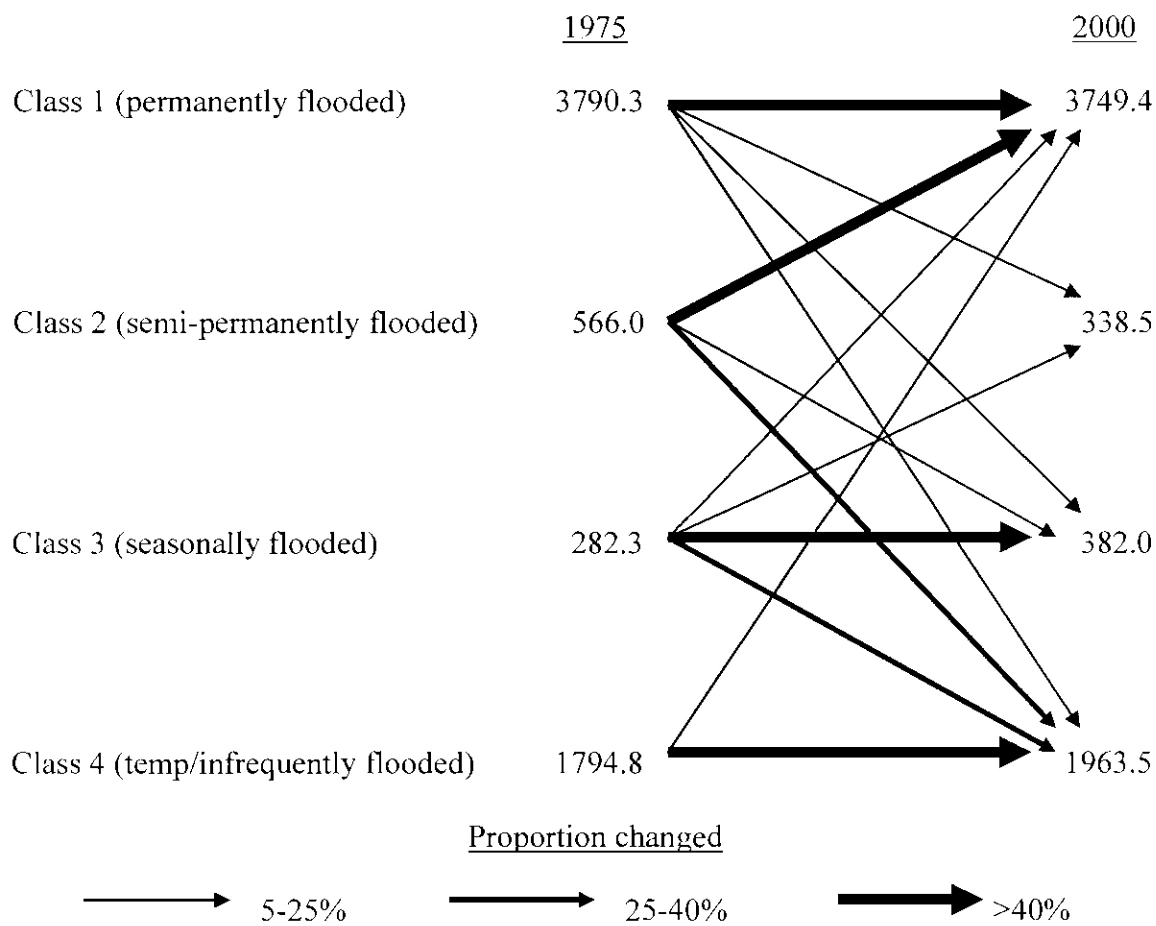

Figure 3. Cover class changes across all sites from 1975 to 2000. Solid lines represent proportions changed from 1975 to 2000. Only proportions changed > 5% are reported.

Table 5. Transition matrix summarizing changes in vegetation from 1975 to 2000 across all study sites.

		1975 Data				
		Class 1	Class 2	Class 3	Class 4	Totals
2000 Data	Class 1	3212.1 (84.7)[1]	265.6 (46.9)	55.3 (19.6)	216.4 (12.1)	3749.4
	Class 2	171.6 (4.5)	100.2 (17.7)	37.1 (13.1)	29.6 (1.6)	338.5
	Class 3	175.4 (4.6)	53.4 (9.4)	115.8 (41.0)	37.4 (2.1)	382.0
	Class 4	231.2 (6.1)	146.8 (25.9)	74.1 (26.2)	1511.4 (84.2)	1963.5
	Totals	3790.3 (99.9)	566.0 (99.9)	282.3 (99.9)	1794.8 (100.0)	

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Across all sites from 1975 to 2000, 852.5 hectares transitioned to a later successional stage while 641.4 hectares transitioned to an earlier successional stage (Table 6). Site-by-site examination of transitions that occurred among cover classes from 1975 to 2000 were generally inconclusive with regards to predicted successional changes (Table 6). Changes in cover class area that conformed to predicted successional transitions (Pools 5a, 7, 8, 12, 13, 19) did exceed "other" transitions (Pools 4, 5, 11 and 16), however this difference was not statistically significant (paired t-test, $t = 1.47$, $df = 9$, $P > 0.05$) (Table 6).

Table 6. Summary of changes occurring among cover classes from 1975 to 2000 that were consistent/inconsistent with predicted successional changes.

Study site	Changes consistent with succession (ha)	Changes inconsistent with succession (ha)	No change (ha)
Pool 4	33.5	48.3	477.0
Pool 5	54.7	62.4	433.3
Pool 5a	69.8	63.8	309.6
Pool 7	162.3	42.2	300.5
Pool 8	97.2	79.9	270.1
Pool 11	61.2	70.0	565.1
Pool 12	58.7	54.0	475.8
Pool 13	128.0	50.1	597.5
Pool 16	71.5	91.7	853.4
Pool 19	115.6	79.0	657.2
Total	852.5	641.4	4939.5

DISCUSSION

Anthropogenic factors have affected UMR backwaters for nearly 200 years (Wlosinski, et al., 1995), though the most significant alterations occurred after lock and dam construction was completed in the 1930s. Although considerable expansion of backwater habitat occurred, impoundment also increased sedimentation by slowing current velocities (Fremling & Claflin, 1984). Because several studies have documented relatively high rates of sediment deposition in backwater habitats (Bhowmik & Adams, 1989; Bhowmik & Demissie, 1989; Eckblad et al., 1977; McHenry et al., 1984), observations in this study were expected to be consistent with allogenic succession. Thus, because of sediment deposition, permanently flooded areas with open water or rooted floating vegetation (Class 1) were expected to be replaced by emergent vegetation (Class 2), which in turn were expected to be replaced by more terrestrial vegetation (grasses and woody vegetation - Classes 3 or 4) that was seasonally or infrequently flooded. In other words, study sites were generally expected to become more terrestrial from 1975 to 2000.

Three prominent cover class transitions observed in this study were consistent with expected successional changes. First, a substantial fraction (35.3%) of Class 2 area in 1975 was reclassified as Class 3 or 4 in 2000. Second, Class 3 and Class 4 cover classes were substantially larger in 2000 than in 1975, which is also consistent with predicted changes. Finally, net changes in cover class area in several individual pools (e.g., Pool 7) were generally consistent with allogenic succession. In these cases, accumulation of sediment and other allogenic materials may have increased elevation sufficiently to alter the hydrological regimes of affected areas within the study sites.

Though several changes observed in this study were consistent with the allogenic succession model, several changes were not. The vast majority of area (>80%) in most study sites either retained their original classification or were classified to a lower class. In particular, most (>75%) of Class 1 areas retained that classification from 1975 to 2000, though a substantial proportion of Class 1 area (>25%) was converted to Class 2 in one pool (Pool 7). Secondly, although a significant portion (35.3%) of Class 2 was reclassified into a higher cover class in 2000, an even larger proportion (46.9%) was reclassified as Class 1. Hence, exceptions to expected successional trends occurred, and these exceptions included either the persistence of open water/submersed vegetation (Class 1) areas or the conversion of emergent vegetation (Class 2) to open water conditions (Class 1).

Several studies have documented conversion of emergent vegetation to open water (Fischer & Claflin, 1995; Tyser et al., 2001). Fischer and Claflin (1995) suggested aquatic vegetation in the UMR has been affected by several prominent factors associated with impoundment. One of these factors, wave action created by fetch, resulted from the creation of large expanses of open water coupled with the loss of small islands in the lower reaches of many pools. These effects may be exacerbated by wave action from commercial navigation and recreational boat traffic, which adversely affect aquatic vegetation (Peck & Smart, 1986). Wave action resulting from fetch can also increase turbidity within shallow areas of the river system, including backwater areas, resulting in light reduction and resuspension of flocculent sediments during periods of low flow, impacting the growth of aquatic vegetation (Sparks, 1984).

Our observations and those by others (Tyser et al., 2001) suggest that lock and dam construction may have created conditions that are promoting conversion of emergent vegetation to open water. Prior to the lock and dam system, routine flood events likely reset aquatic systems, creating a dynamic mosaic of successional stages, including emergent vegetation (Junk et al., 1989; van der Valk & Bliss, 1971; Ward & Stanford, 1995). Additionally, river stages on the UMR have remained relatively stable from 1975 to 2000 with elevation changes in most sites less than ca. $\pm$ 9 cm (Ickes, 2005). Therefore, under current conditions, the persistence of emergent vegetation may require implementation of effective restoration activities. For example, habitat restoration projects in the UMR basin, including construction of island complexes, may effectively reduce fetch and thereby increase aquatic macrophyte plant communities (Yin & Langrehr, 2005). In addition, drawdowns of UMR pool levels may improve ecological conditions by compacting flocculent sediments in backwater areas, thus allowing the development of new plant beds. Wlosinski et al. (2000) have shown that drawdowns can promote plant growth and expansion without affecting the fish community, navigation, or recreation interests.

In conclusion, this study found several changes in aquatic habitat that occurred over a 25 year period that were consistent with allogenic succession, most notably the increase in coverage of grass, forb, and woody vegetation. Allogenic succession, however, does not adequately account for other changes in this study, including a decrease in emergent vegetation and the apparent stability of open water. Given the loss of emergent vegetation and prevalence of open water that has been observed in this and other studies of UMR vegetation, additional factors, including the role of fetch and wave action and the effects of flood and drought on flocculent sediments may account for changes in aquatic habitats observed in this study.

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APPENDIX A

COMPARISION OF AQUATIC AREAS

Appendix A. Comparison of aquatic areas (in ha).

Pool	Contiguous Floodplain Shallow Aquatic (CFSA)	Contiguous Floodplain Lake	Isolated Floodplain Shallow Aquatic	Isolated Floodplain Lake	Total Backwater Habitat	%CFSA
4	1,567	1,152	-	396	3,115	0.50
5	733	155	-	179	1,067	0.69
5a	1,170	81	57	367	1,675	0.70
7	349	455	-	137	941	0.37
8	1,574	1,125	-	337	3,036	0.52
11	1,282	455	-	178	1,915	0.67
12	545	401	-	176	1,122	0.49
13	1,902	1,242	343	371	3,858	0.49
16	246	196	-	197	639	0.39
19	1,201	948	-	622	2,771	0.43

APPENDIX B

PREPARATION OF SPATIAL DATABASES

Appendix B. Preparation of spatial databases.

Procedure	Description
Linework transfer[a]	Compensates for spatial distortion caused by the round Earth, plane movement, and/or camera lens distortion. Photointerpretation linework was copied to a Digital Orthophoto Quarter Quadrangle (DOQQ; scale: 1:12,000; resolution 4m[b]; pools: 4, 5, 5a, 7, 8, 11, and 12) or a Digital Raster Graphic (DRG; scale: 1:15,000; resolution: 10-15m[b]; pools 13, 16, and 19) with a manual Zoom Transfer Scope (ZTS).
Data Automation[c]	Manually transferred linework is automated for analysis. Linework was scanned, de-speckled and moved to a Unix system via File Transfer Protocol (FTP) software for automation with ARC/INFO v.8.0 (ESRI Inc, Redlands, CA, USA) software. Images were rectified to the Earth's surface, traced, and edited with ARC/INFO software. 1975 GIS layers and their corresponding 2000 GIS layer were combined into a single layer in ArcInfo and exported to ArcView 3.1 and Arc Map 8.3 for analysis.

[a] Transfer procedures followed rules established by Owens and Robinson (1996).

[b] Larry Robinson, UMESC, Onalaska, WI, personal communication.

[c] Standard operating procedures for data automation set forth by Arndt and Olsen (1995).

APPENDIX C

CHANGES (IN HA) IN VEGETATION TYPES IN EACH STUDY SITE FROM 1975 TO 2000

Appendix C. Changes (in ha) in vegetation types in each study site from 1975 to 2000.

Pool	Cover class	1975	2000
4	Class 1	434.2	443.1
	Class 2	34.2	39.9
	Class 3	0.3	2.2
	Class 4	95.7	74.9
5	Class 1	445.7	465.5
	Class 2	56.4	19.9
	Class 3	13.2	11.0
	Class 4	34.0	56.1
5a	Class 1	288.2	265.7
	Class 2	3.4	47.9
	Class 3	119.2	88.2
	Class 4	32.4	41.3
7	Class 1	244.7	134.0
	Class 2	0.0	51.7
	Class 3	111.4	139.4
	Class 4	149.8	180.9
8	Class 1	212.1	242.4
	Class 2	155.3	62.6

Appendix C, continued.

Pool	Cover class	1975	2000
	Class 3	0.6	0.0
	Class 4	79.4	142.3
11	Class 1	555.6	574.6
	Class 2	79.5	27.5
	Class 3	0.1	28.9
	Class 4	64.6	65.3
12	Class 1	249.3	262.2
	Class 2	27.4	11.7
	Class 3	4.4	9.9
	Class 4	314.4	308.0
13	Class 1	372.9	321.9
	Class 2	57.6	34.0
	Class 3	5.3	67.4
	Class 4	342.4	356.8
16	Class 1	470.9	509.8
	Class 2	44.2	0.6
	Class 3	1.1	27.7
	Class 4	503.1	478.9
19	Class 1	520.7	552.8

Appendix C, continued.

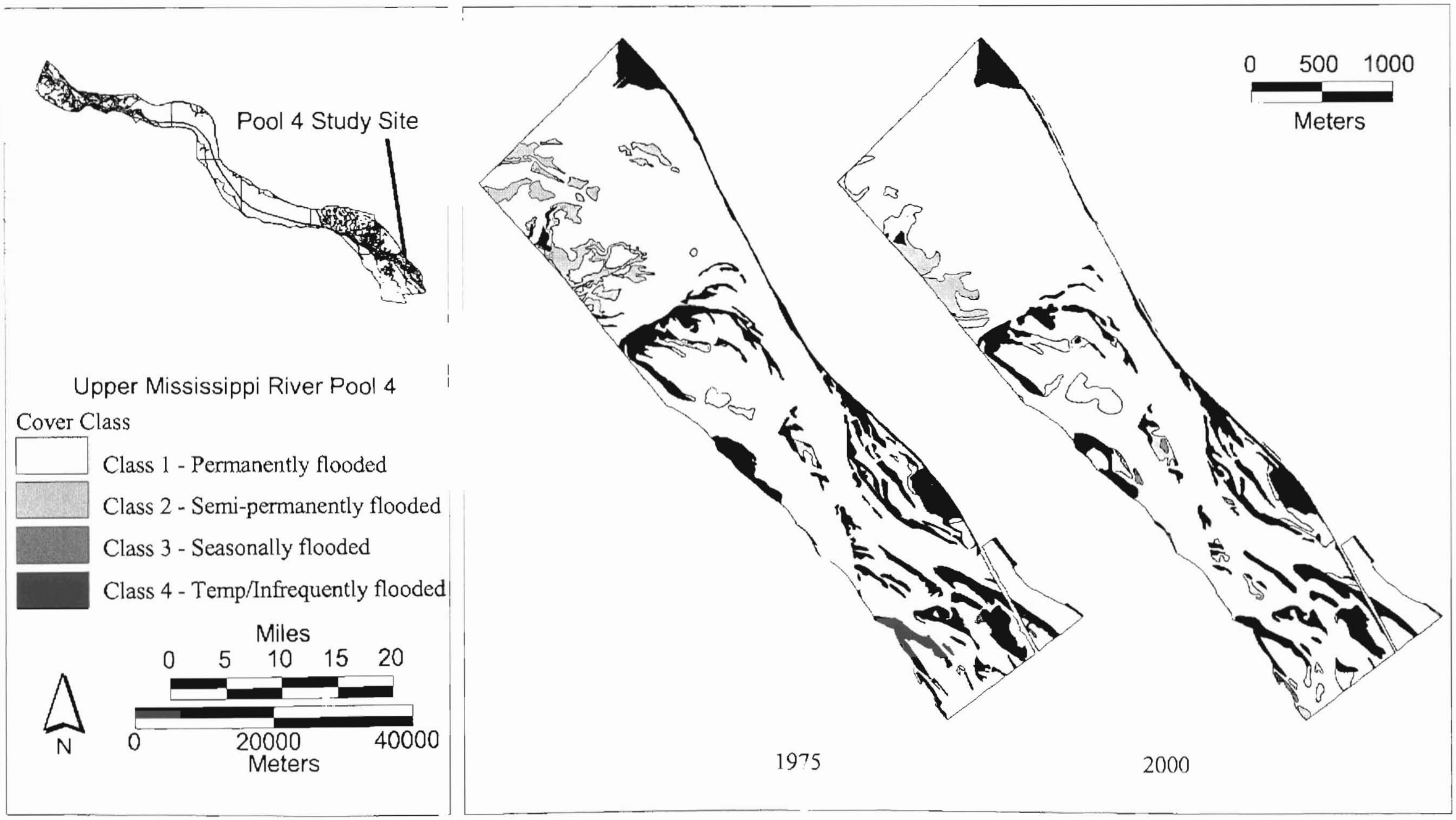
Pool	Cover class	1975	2000
	Class 2	109.0	46.5
	Class 3	29.3	21.6
	Class 4	203.6	300.0

APPENDIX D

MAPS OF AQUATIC HABITAT CHANGES IN STUDY AREAS

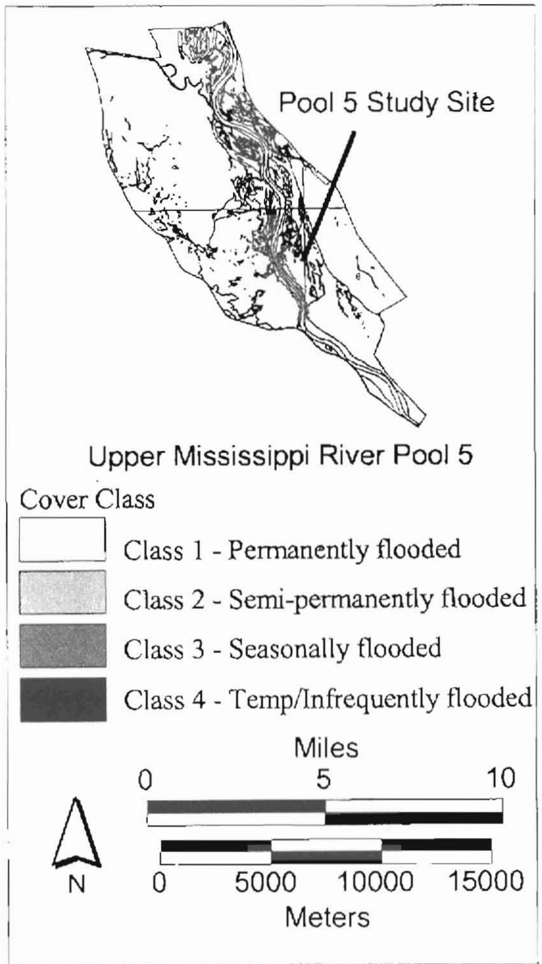
Appendix D. Maps of aquatic habitat changes in study areas.

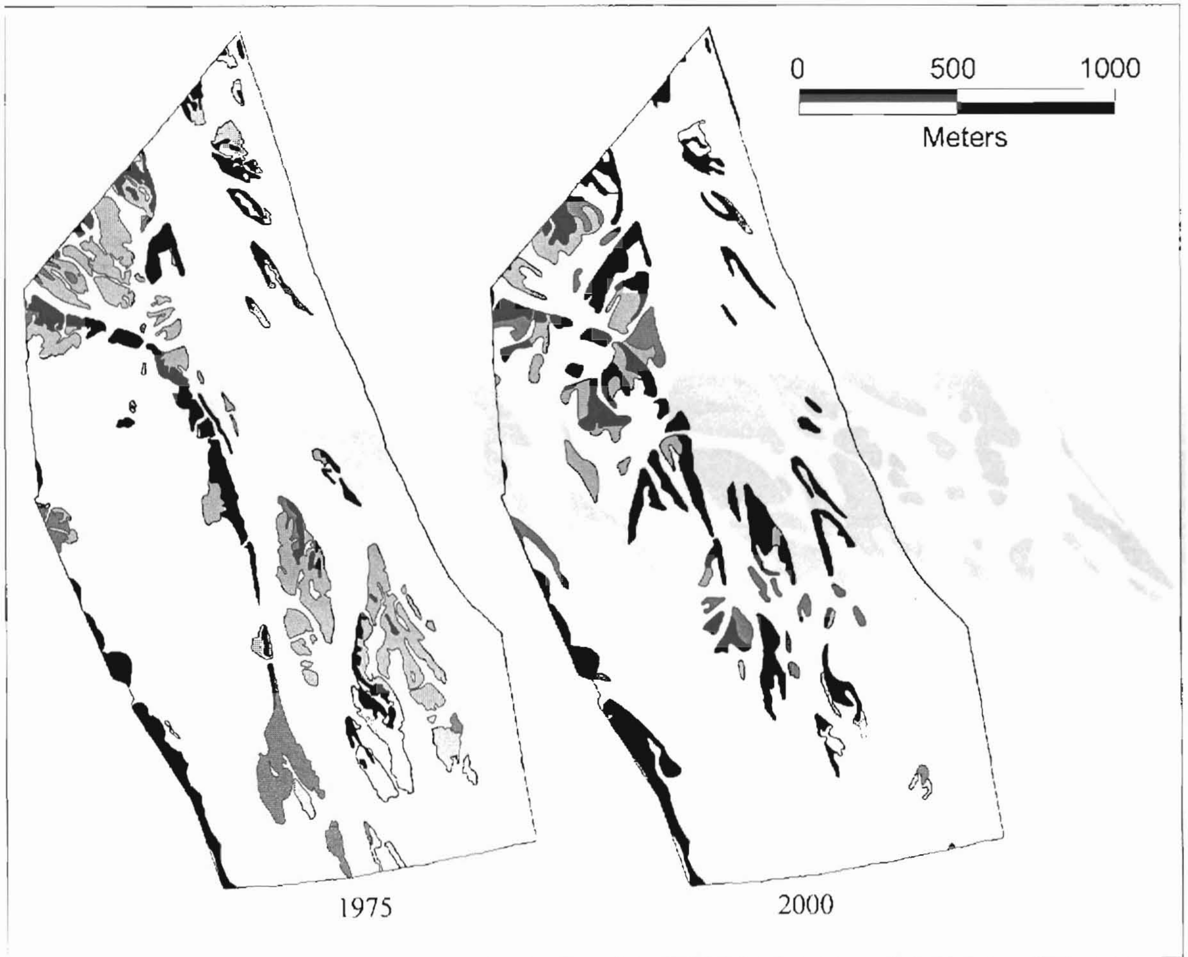
Pool 4.



Appendix D, continued.

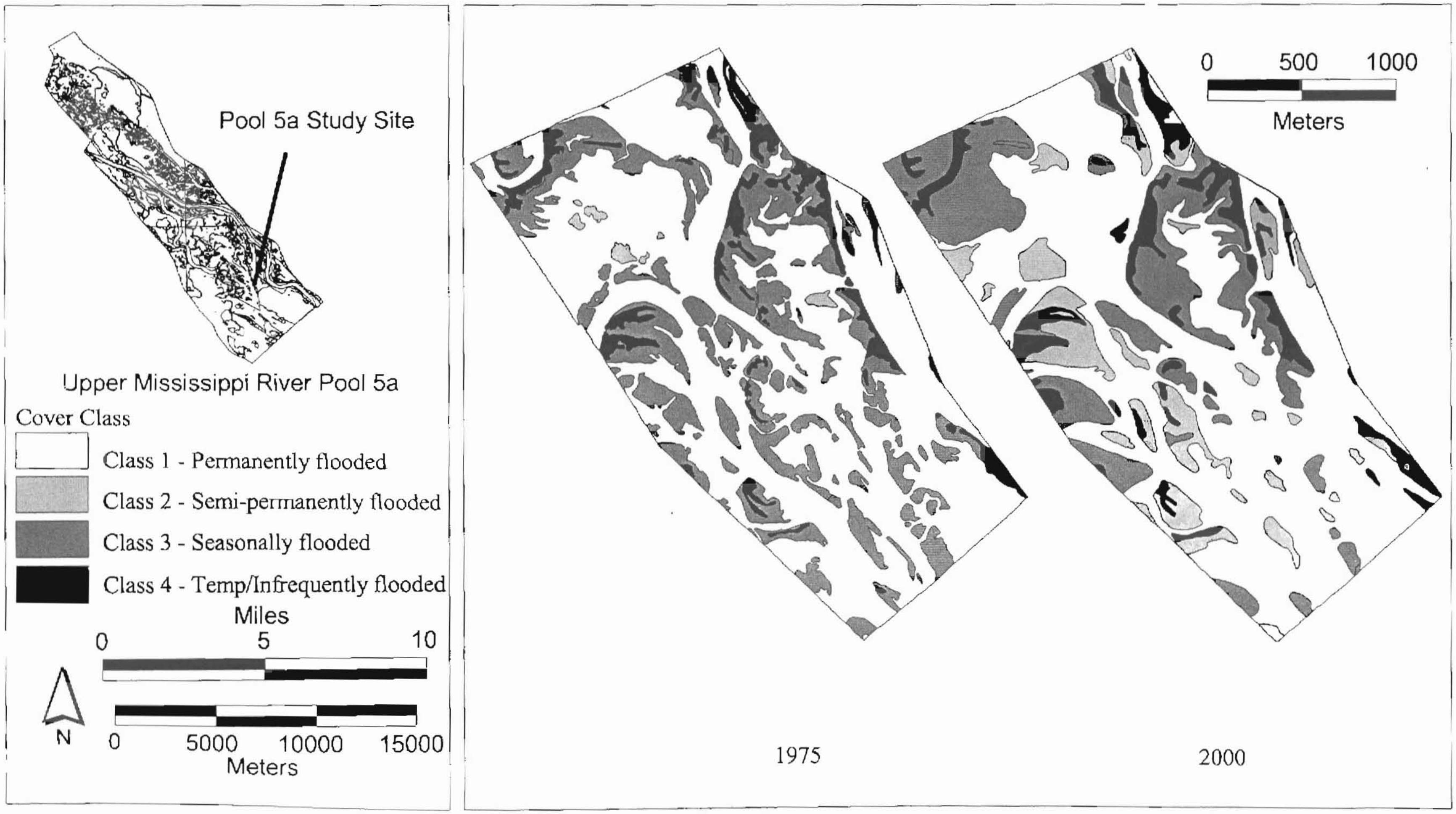
Pool 5.





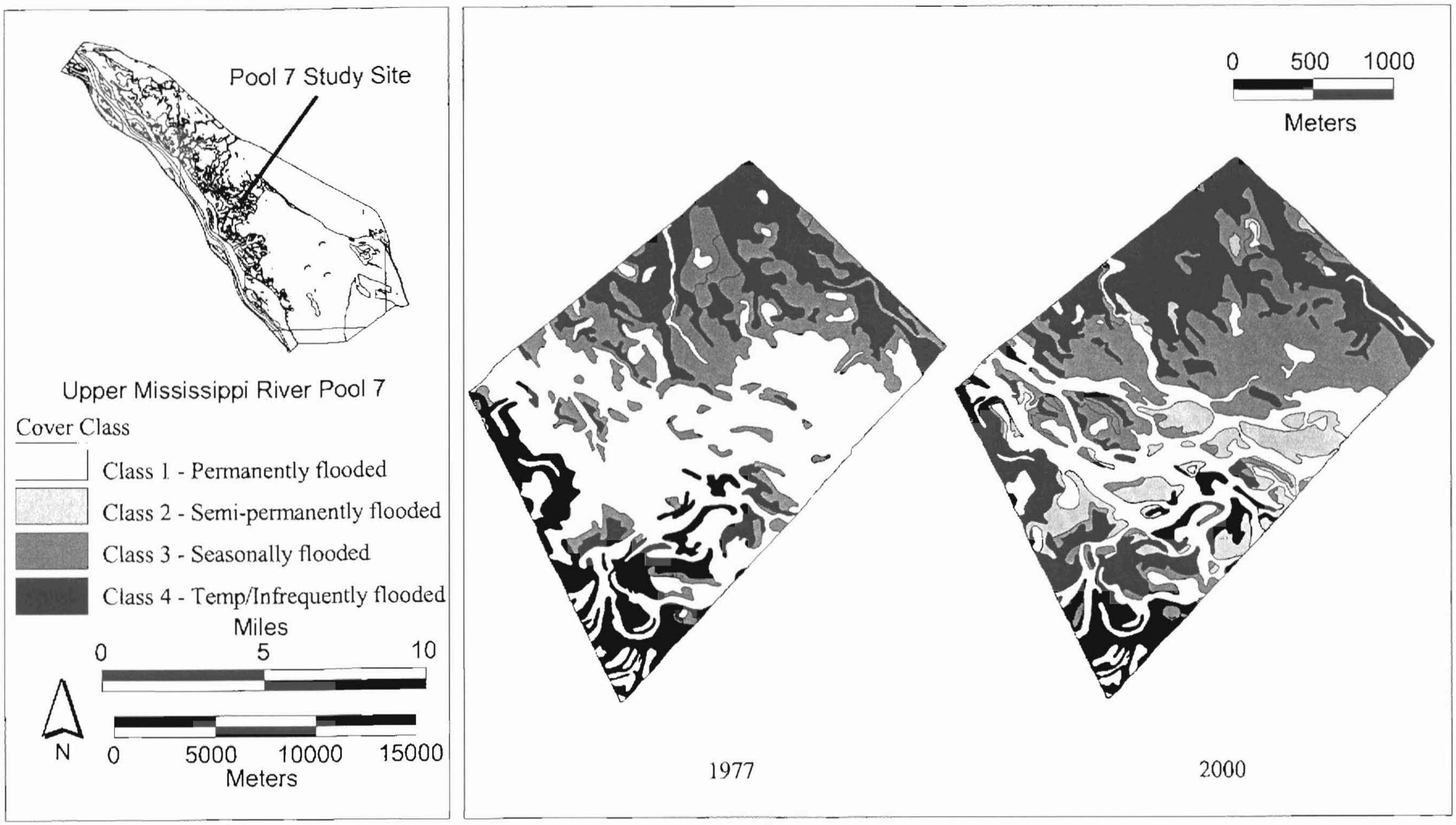
Appendix D, continued.

D3. Pool 5a



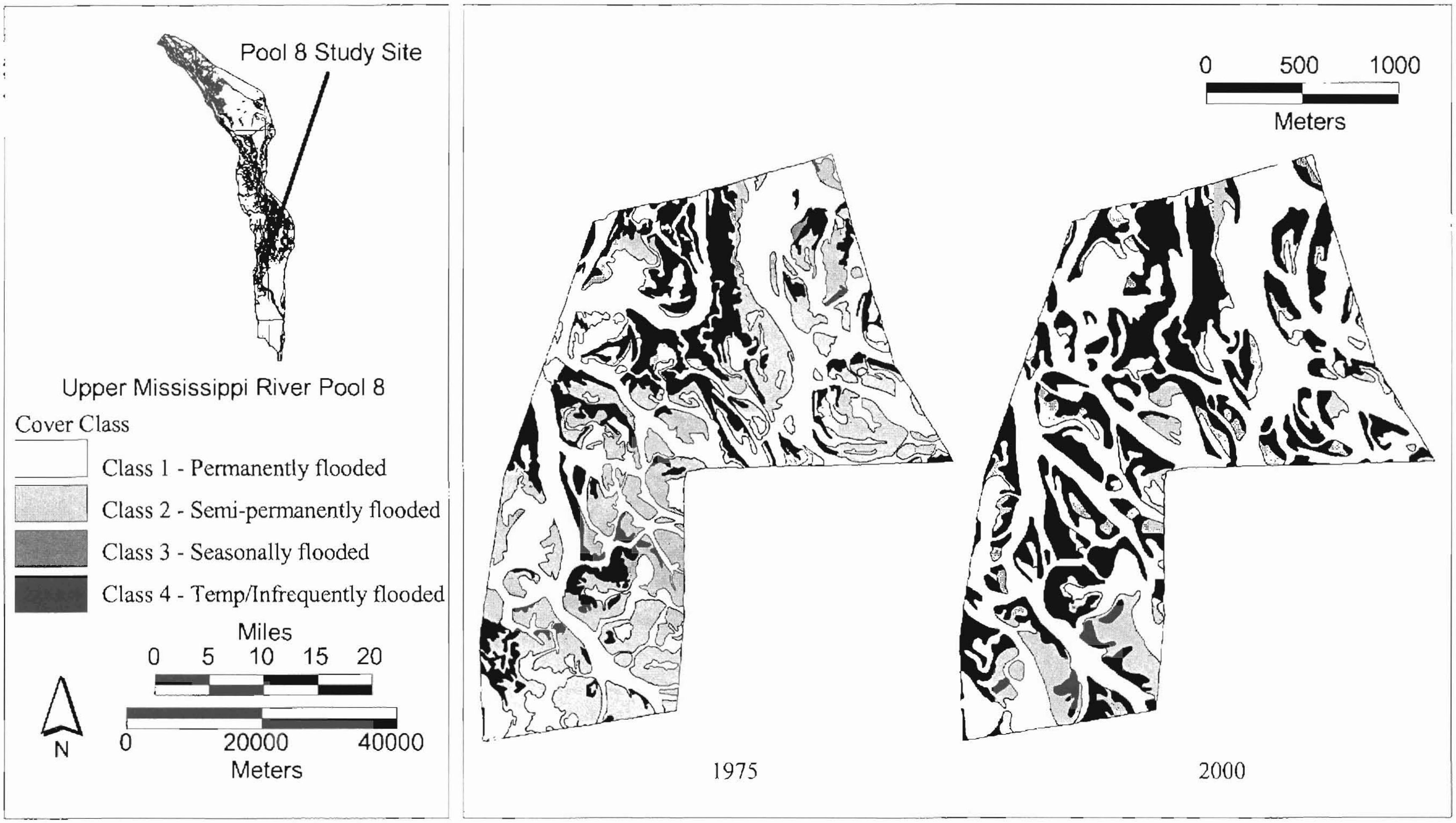
Appendix D. continued.

D4. Pool 7.



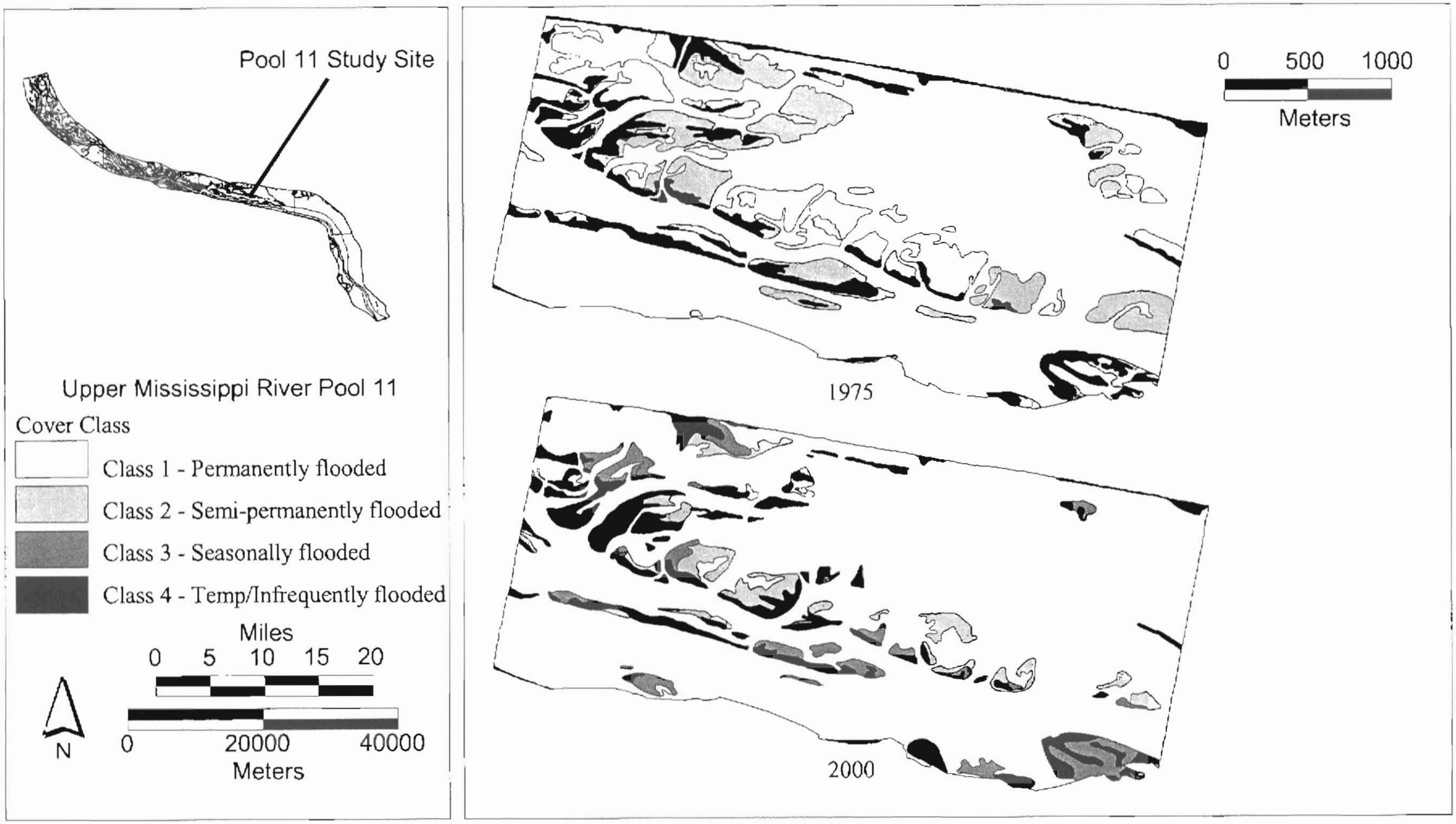
Appendix D, continued.

D5. Pool 8.



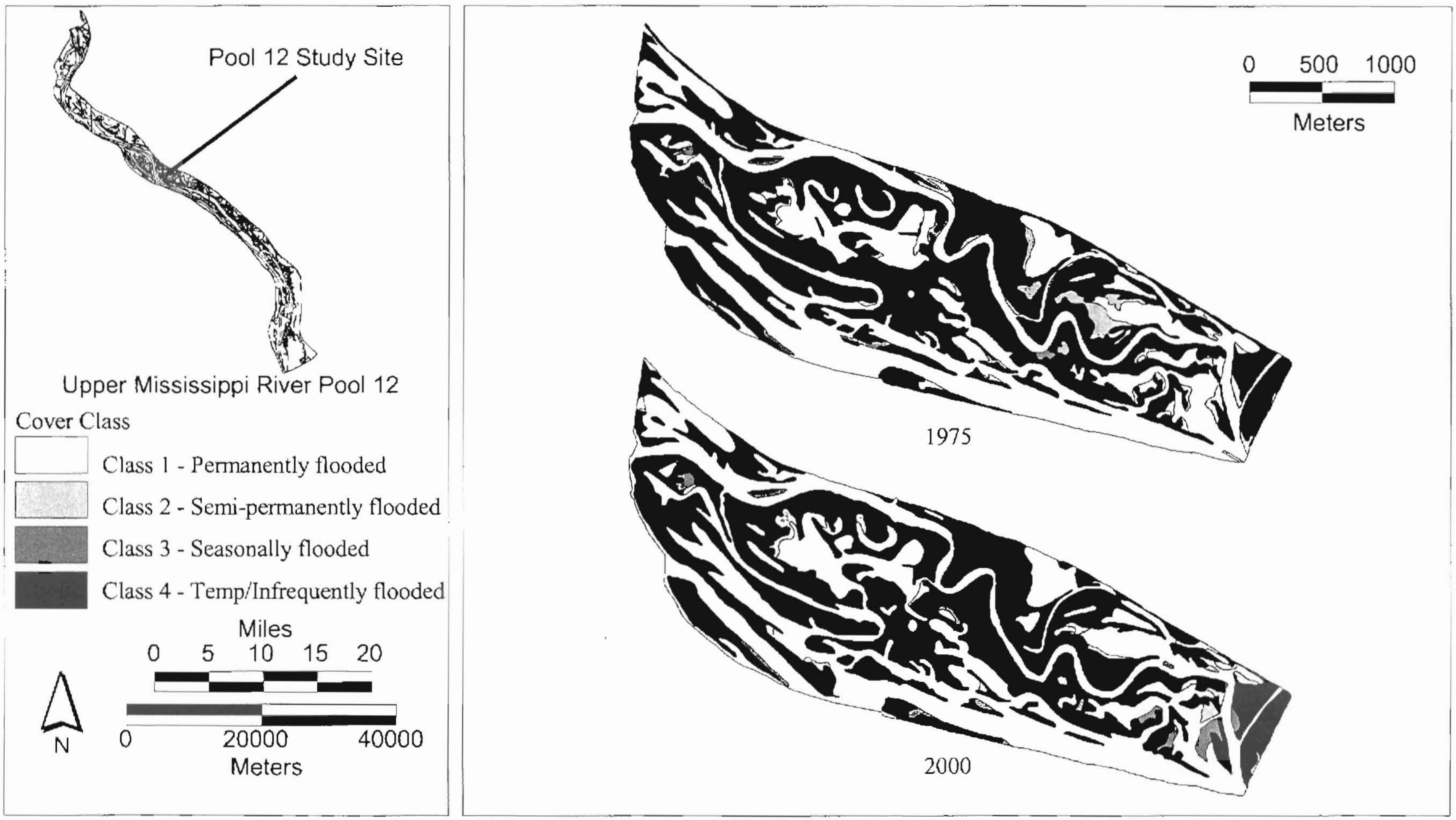
Appendix D, continued.

D6. Pool 11.



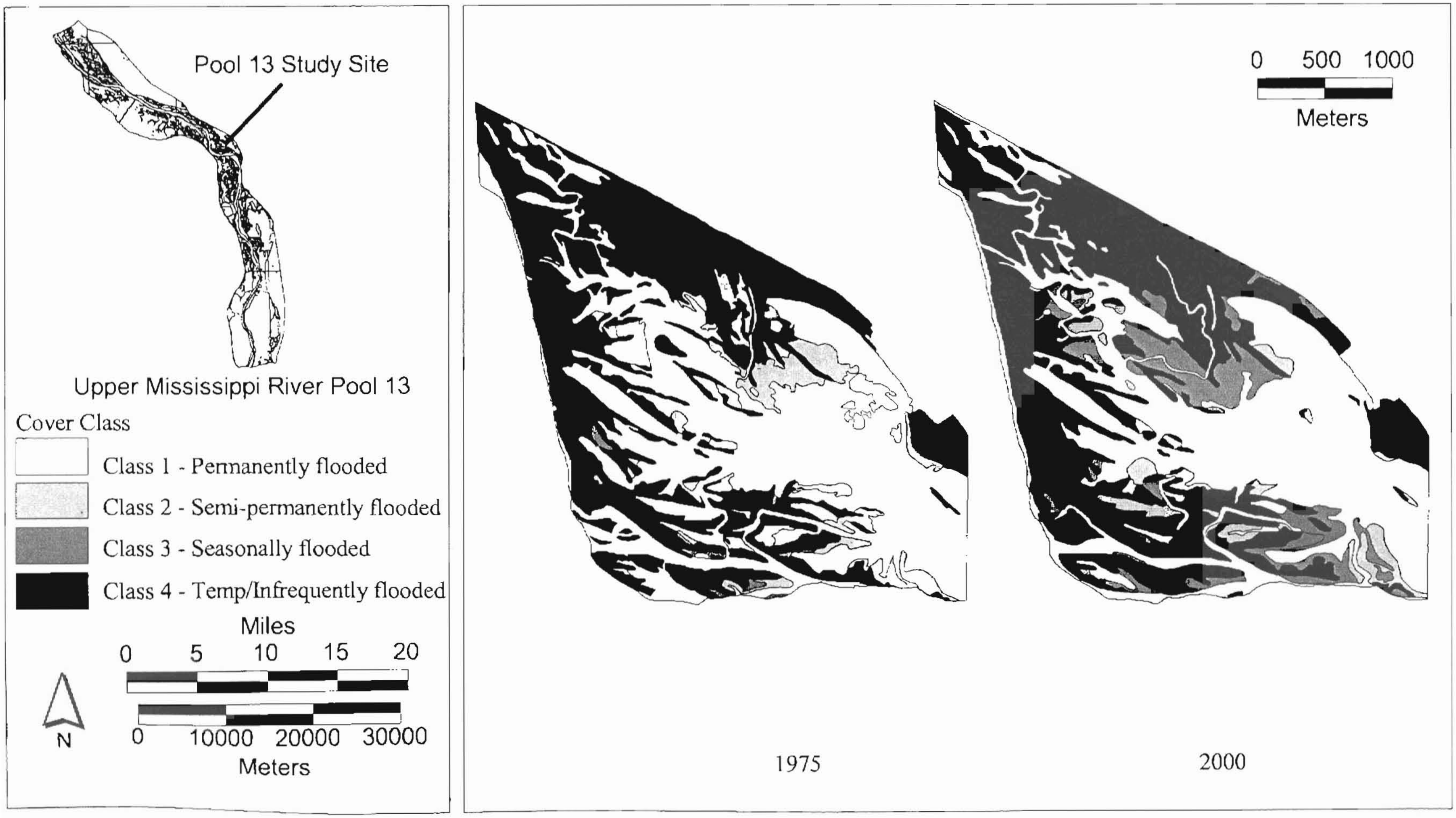
Appendix D, continued.

D7. Pool 12.



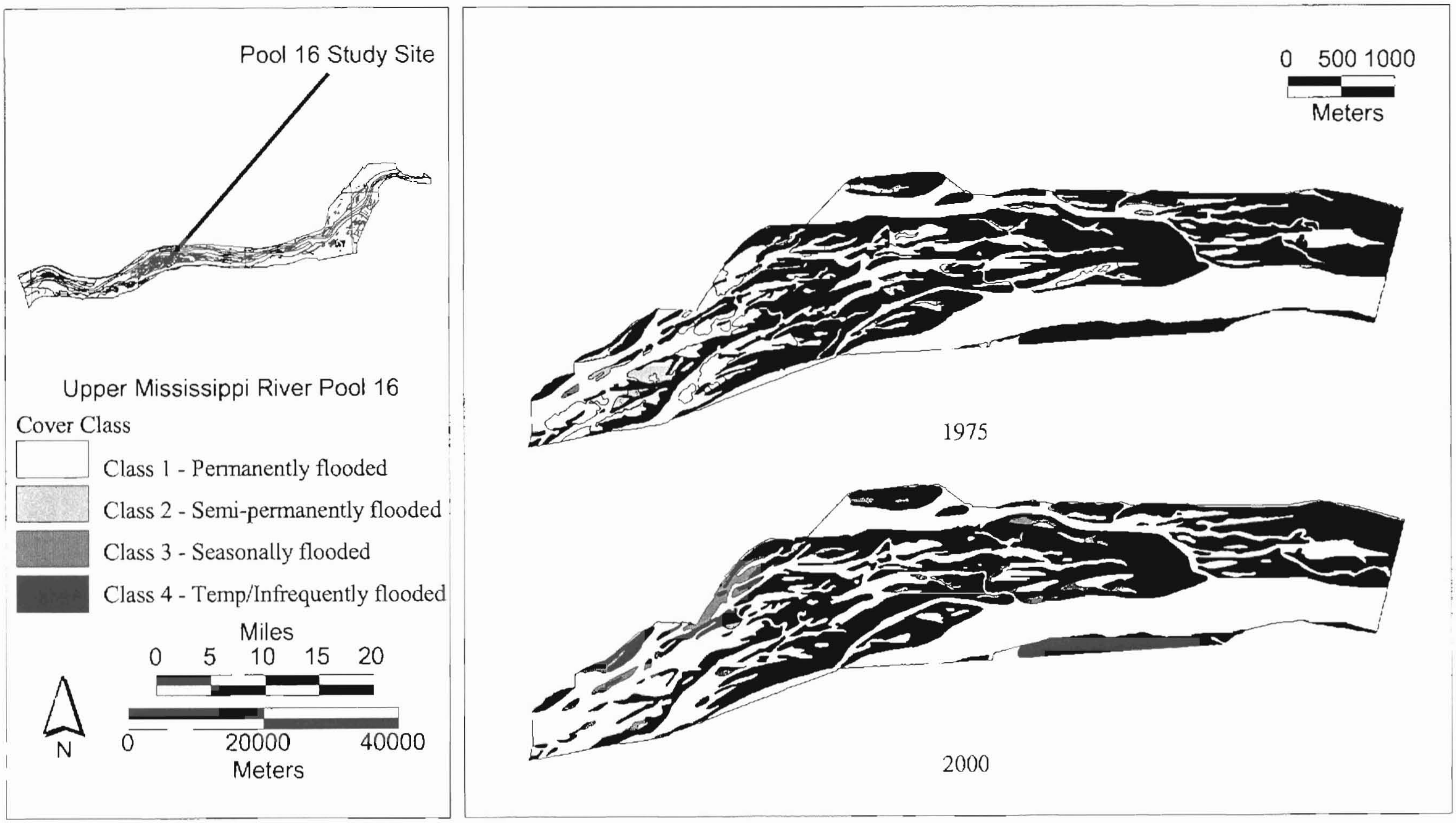
Appendix D, continued.

D8. Pool 13.

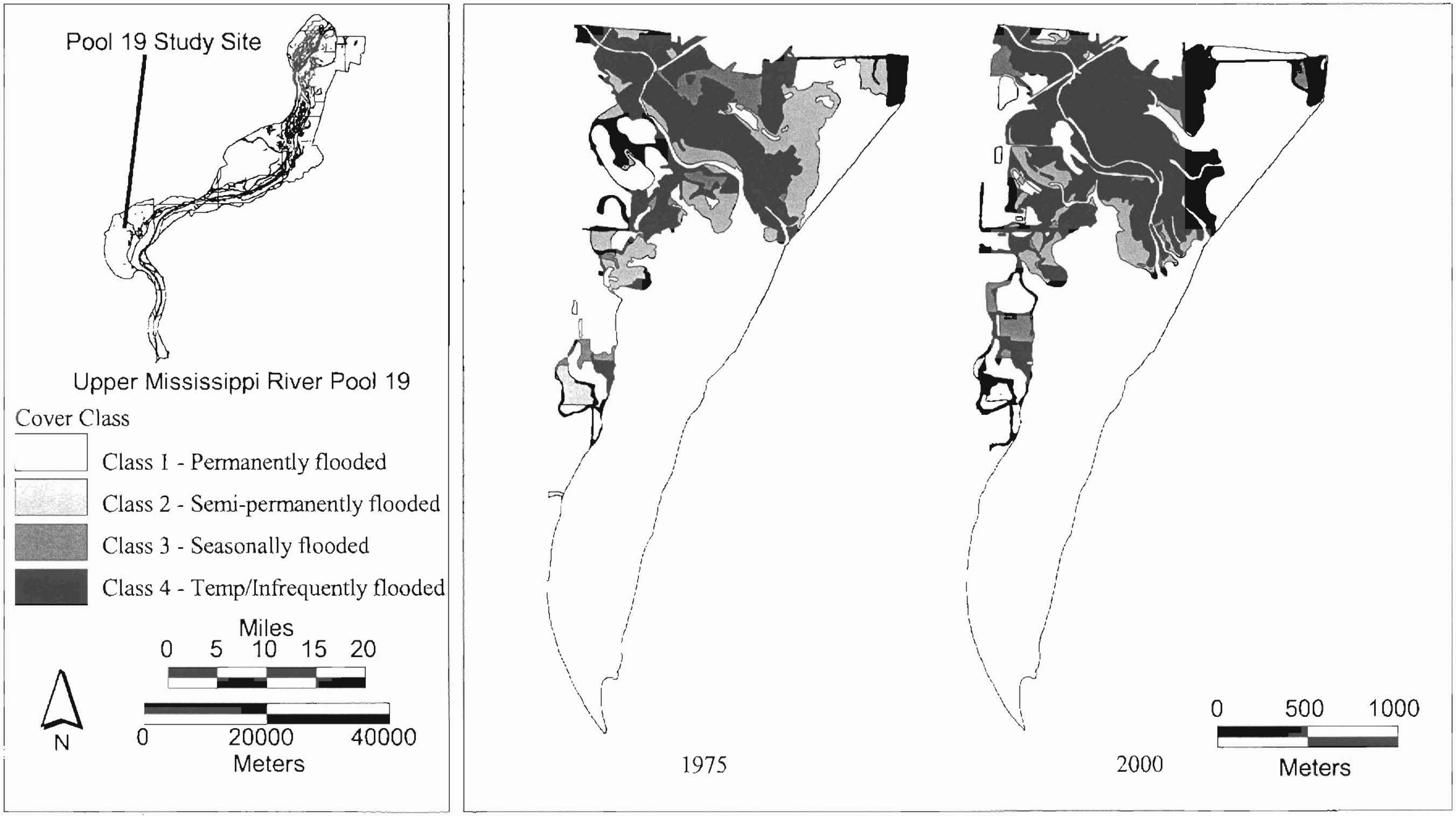


Appendix D, continued.

D9. Pool 16.



D10. Pool 19.



Pool 19 Study Site
Upper Mississippi River Pool 19
Cover Class
Class 1 - Permanently flooded
Class 2 - Semi-permanently flooded
Class 3 - Seasonally flooded
Class 4 - Temp/Infrequently flooded
Miles
0 5 10 15 20
0 20000 40000
Meters
N
1975
2000
0 500 1000
Meters

APPENDIX E

TRANSITION AREAS FOR INDIVIDUAL STUDY SITES

Appendix E. Transition matrices for individual study sites.

Pool 4		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	400.6 (92.4)[1]	20.1 (58.8)	0.1 (50.0)	21.6 (23.8)
	Class 2	20.5 (4.7)	13.6 (39.8)	0.1 (50.0)	5.7 (6.3)
	Class 3	1.2 (0.3)	0.2 (0.6)	0.0 (0.0)	0.7 (0.8)
	Class 4	11.3 (2.6)	0.3 (0.9)	0.0 (0.0)	62.8 (69.2)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 5		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	404.0 (90.6)[1]	38.3 (67.8)	11.0 (83.3)	9.4 (26.9)
	Class 2	11.3 (2.5)	6.6 (11.7)	0.4 (3.0)	1.7 (4.9)
	Class 3	6.9 (1.5)	3.1 (5.5)	0.4 (3.0)	1.6 (4.6)
	Class 4	23.5 (5.3)	8.5 (15.0)	1.4 (10.6)	22.3 (63.7)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 5a		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	231.1 (80.2)[1]	0.3 (9.1)	31.8 (26.7)	2.5 (7.7)
	Class 2	20.4 (7.1)	1.0 (30.3)	25.0 (21.0)	1.4 (4.3)
	Class 3	31.8 (11.0)	2.0 (60.6)	51.7 (43.4)	2.8 (8.6)
	Class 4	4.9 (1.7)	0.0 (0.0)	10.7 (9.0)	25.8 (79.4)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 7		1977			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	115.7 (47.3)[1]	0.0 (0.0)	9.7 (8.8)	8.6 (5.7)
	Class 2	39.4 (16.1)	0.0 (0.0)	8.6 (7.8)	3.8 (2.5)
	Class 3	68.9 (28.1)	0.0 (0.0)	58.9 (53.4)	11.5 (7.7)
	Class 4	20.8 (8.5)	0.0 (0.0)	33.2 (30.1)	125.9 (84.0)

[1] Figures in parenthesis represent percentage of cover class retained from 1977 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 8		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	167.6 (79.1)[1]	61.1 (39.3)	0.0 (0.0)	13.6 (17.1)
	Class 2	15.5 (7.3)	41.9 (27.0)	0.0 (0.0)	5.2 (6.5)
	Class 3	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Class 4	28.9 (13.6)	52.3 (33.7)	0.5 (100.0)	60.6 (76.3)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 11		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	512.1 (92.2)[1]	49.0 (61.6)	0.0 (0.0)	13.4 (21.8)
	Class 2	13.6 (2.4)	12.4 (15.6)	0.0 (0.0)	1.6 (2.6)
	Class 3	14.1 (2.5)	8.7 (10.9)	0.1 (100.0)	6.0 (9.8)
	Class 4	15.4 (2.8)	9.4 (11.8)	0.0 (0.0)	40.5 (65.9)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 12		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	209.6 (84.3)[1]	7.1 (26.1)	0.5 (11.1)	42.2 (13.7)
	Class 2	5.8 (2.3)	2.9 (10.7)	0.2 (4.4)	2.4 (0.8)
	Class 3	3.4 (1.4)	3.4 (12.5)	1.3 (28.9)	1.6 (0.5)
	Class 4	29.8 (12.0)	13.8 (50.7)	2.5 (55.6)	262.0 (85.0)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 13		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	282.4 (75.8)[1]	13.8 (24.0)	0.6 (11.1)	25.0 (7.4)
	Class 2	22.3 (6.0)	9.1 (15.8)	0.2 (3.7)	2.4 (0.7)
	Class 3	35.0 (9.4)	22.8 (39.6)	1.7 (31.5)	8.1 (2.4)
	Class 4	33.1 (8.9)	11.9 (20.7)	2.9 (53.7)	304.3 (89.6)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 16		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	422.3 (89.7)[1]	21.6 (49.0)	0.1 (8.3)	65.7 (13.1)
	Class 2	0.4 (0.1)	0.0 (0.0)	0.0 (0.0)	0.2 (0.0)
	Class 3	12.3 (2.6)	10.7 (24.3)	0.6 (50.0)	4.1 (0.8)
	Class 4	35.8 (7.6)	11.8 (26.8)	0.5 (41.7)	430.5 (86.0)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.

Appendix E, continued.

Pool 19		1975			
		Class 1	Class 2	Class 3	Class 4
2000	Class 1	466.7 (90.0)[1]	54.3 (50.1)	1.5 (5.4)	14.4 (7.3)
	Class 2	22.4 (4.3)	12.7 (11.7)	2.6 (9.4)	5.2 (2.6)
	Class 3	1.8 (0.3)	2.5 (2.3)	1.1 (4.0)	1.0 (0.5)
	Class 4	27.7 (5.3)	38.8 (35.8)	22.4 (81.2)	176.7 (89.6)

[1] Figures in parenthesis represent percentage of cover class retained from 1975 to 2000. Percentages may not add up to 100% due to rounding.