Retrospective Analysis of Land Cover at Overton Bottoms North, Missouri

By Jeffrey D. Spooner and Keith F. Landgraf

Chapter 4 of

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Chapter 4
Retrospective Analysis of Land Cover at Overton Bottoms North, Missouri

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Abstract

We evaluated multi-year trends in land cover to assess how vegetation communities have been affected by hydrologic alteration of the Missouri River flood plain near Overton Bottoms, Missouri. Landsat multispectral satellite image data were used to map seven general classes of the vegetation and land cover on five different dates between September 1994 and September 2002. A supervised classification of the 2002 Landsat image was performed first, and then verified in the field in early September 2004. These observations, ancillary aerial photographs and Ikonos image data were used to produce land-cover maps from each of the four remaining Landsat images. Ten maps were produced: 5 showing the land-cover classes for each year, 4 showing the change in those classes from one date to the next, and 1 showing the overall changes in the classes between 1994 and 2002. Area and edge measurements and patch characteristics were calculated using the five land-cover maps.

The distribution and succession of land cover observed on Overton Bottoms from 1994 to 2002 are consistent with patterns at other sites along the Lower Missouri River. The distribution of cottonwood and willow trees on Overton Bottoms between 1994 and 2002 demonstrates the relation between the spatial and temporal distribution of flood plain land-cover classes and flood-plain landforms. While the total area of cottonwood and willow trees increased from 72 ha (hectares) in 1994 to 702 ha in 2002, the increase was not uniform across Overton Bottoms, but generally limited to areas on the flood plain that are adjacent to the river, unprotected by levees, and undisturbed by human activities. They also demonstrated a preference for surficial geologic units mapped as channel-fill allounits (Holbrook and others, this volume, chapter 2). This suggests a strong relation between surficial Lower Missouri River stratigraphy and the distribution of specific types of Lower Missouri River land cover.

Introduction

The construction of levees, bank revetments, and wing dikes along the Lower Missouri River has resulted in a substantial reduction in the quantity (spatial and temporal extent) and quality (diversity) of terrestrial and aquatic habitats (Funk and Robinson, 1974; National Research Council, 2002). Efforts during the late 1990's to rehabilitate the river corridor have included modifying the existing channel control structures, rehabilitating flood-plain wetlands, and constructing side channels (Galat and others, 1996; Chapman and others, 2004; Jacobson and others, 2004). The success of these and other habitat rehabilitation and restoration efforts along the Lower Missouri River is dependent on an appreciation for the complexity of terrestrial riverine ecosystems. Questions regarding the interdependence of flood-plain processes and ecosystem structure and function are in the forefront of ecological research interests. The answers to these questions are important to natural resource managers practicing adaptive management along the Lower Missouri River.

A critical component of flood-plain ecology is the spatial and temporal distribution of vegetation. Flood plains typically are dynamic surfaces that are continuously reshaped by erosion and deposition. These processes play an important role in the distribution of flood-plain vegetation within space and time (Hupp and Osterkamp, 1996; Kalliola and Puhakka, 1998; Robertson and Augspurger, 1999). These spatial and temporal patterns of flood-plain vegetation are particularly complex along the Lower Missouri River where recent conversion of agricultural land to conservation purposes has resulted in rapid changes.

Much of the flood plain of the Lower Missouri River, including Overton Bottoms (fig. 1), has been cleared for agriculture since settlement in the early 1800's. The surface has been reworked by plows, row crops have replaced natural

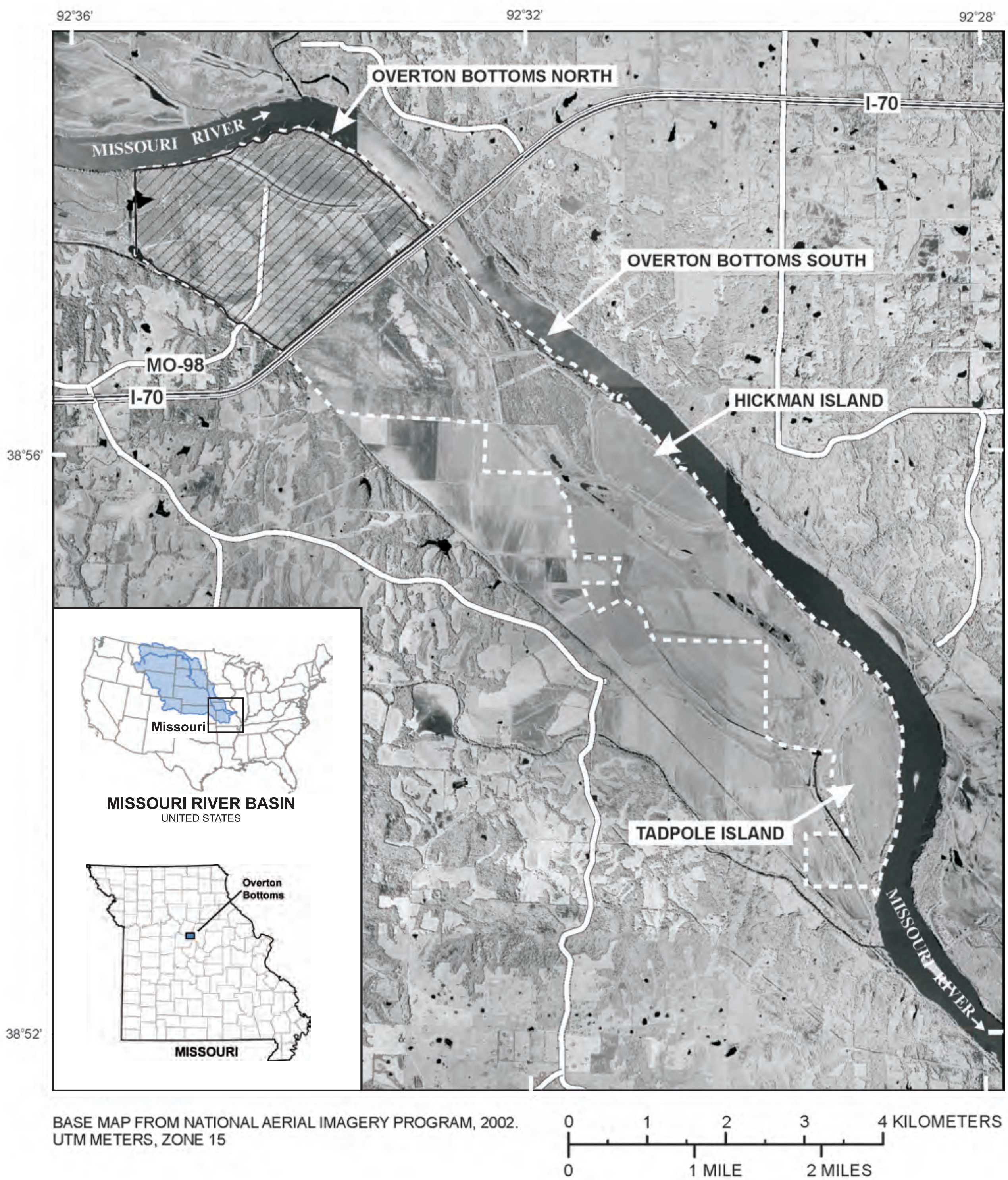

Figure 1. Location of Overton Bottoms North Unit and South Unit conservation areas.

vegetation, and construction of levees has disconnected the flood plain from the river. These modifications effectively suppressed or substantially altered natural flood-plain biophysical processes. Since acquiring Overton Bottoms in the mid 1990's, managers within the U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), and the Missouri Department of Conservation (MDC) have allowed much of Overton Bottoms to return to more natural conditions. Levee failures associated with the flood of 1993 were not repaired, and a side-channel chute was constructed in 2000 (Jacobson, this volume, chapter 1). Consequently, much of Overton Bottoms has been subjected to seasonal flooding, and naturally occurring vegetation now occurs over much of the area, especially Overton Bottoms North Unit (fig. 1).

Remotely sensed imagery, which includes multispectral digital satellite image data and aerial photographs, are an ideal source for a retrospective analysis of land-cover changes on the Lower Missouri River flood plain. Nearly continuous multispectral satellite image data acquired since 1972 are available. Less regular aerial photographs acquired since the late 1930's also are available. These two types of data and associated analytical techniques provide an opportunity to map land cover over a large area like the Lower Missouri River flood plain, or at a specific area like Overton Bottoms. Two simple comparisons can be used to evaluate land-cover change on the flood plain: the measured increase or decrease in the total area of a specific land-cover class from one date to another, and the measured changes in their spatial patterns.

Area and edge are two fundamental measures of terrestrial landscapes. They typically are used to help characterize patterns of land cover. One of the simplest and most useful measures of a landscape is the total area of particular land-cover type (or its proportional abundance across a specific place), and whether it increases or decreases with time. The total area of a particular land-cover type can be easily calculated, especially when the source of the measurement is raster-image data. Once individual cells in the image are classified, the area of a particular class is calculated by multiplying the total number of cells by the area of a single cell. Changes with time can be determined by arithmetically comparing area measurements derived from one image to those derived from another.

Edges also are an important feature of most terrestrial landscapes. Their presence, complexity, and distribution provide an indication of the structure, abundance, and variability of habitats across a particular landscape. Although not as easily calculated as area, the total length of the edge of a land-cover type provides a useful landscape measure.

Purpose and Scope

The purpose of this report is to document the effects of altered hydrology and land use at Overton Bottoms on broad-scale characteristics of vegetation communities. The areal extent is the valley-bottom land within the boundaries of the Overton Bottoms North Unit, a part of the Big Muddy National Fish and Wildlife Refuge (managed by the USFWS) and the Overton Bottoms South Unit (managed by MDC). The time period under consideration is from 1994 to 2002. This period covers the adjustment of Overton Bottoms vegetation communities to breached levees and side-channel chute construction after the 1993 flood.

Methods of Image Classification and Change Analysis

A hybrid method of land-cover change analysis developed by Loveland and others (2002) was used to estimate the rates of land-cover change on Overton Bottoms since the flood of 1993. This method combines supervised image classification and visual interpretation of Landsat multispectral satellite image data using aerial photographs, additional high resolution satellite imagery, and field observations. Seven general classes of land cover were defined and mapped for each of 5 different dates between September 1994 and September 2002. The seven classes included water, bare ground, weeds/grasses/forbs, cottonwoods/willows, mature trees, agricultural fields, and roads.

Five Landsat images, three digital aerial orthophotographs and two Ikonos multispectral images were acquired. The Landsat data have an early September acquisition date (table 1). Four images (1994, 1996, 1998 and 2002) are Landsat 5 Thematic Mapper (TM) data. A suitable Landsat 5 TM image for 2000 was not available, so a Landsat 7 image was used. Landsat 7 carries an improved TM sensor called the Enhanced Thematic Mapper (ETM+) that records the same seven bands as the TM sensor aboard Landsat 5, plus an additional sensor that records high resolution panchromatic data. The spatial resolution of bands one through five and seven of both the TM and ETM+ data is 30 m (meters), with a positional accuracy of +/-15 m. Although they are less than 30 m wide, roads could be mapped because of their distinct shape, distinct spectral signature, and high contrast with the land-cover classes that they cross. The ancillary data that were used included digital aerial orthophotographs and Ikonos multispectral and panchromatic image data. The orthophotographs were acquired in 1995, 2000, and 2003. The 1995 data are black and white, the 2000 data are natural color, and the 2003 data are color infrared. The Ikonos data were acquired in 2000.

Table 1. Landsat images.

Sensor	Scene ID	Acquisition Date
TM-5	5025033009425710	September 19, 1994
TM-5	5025033009624710	September 3, 1996
TM-5	5025033009825210	September 9, 1998
ETM+	7025033000025050	September 6, 2000
TM-5	5025033000224710	September 4, 2002

A template was used to clip each of the five Landsat images to the extent of the Overton Bottoms conservation areas to limit the amount of processing and the extent of the analysis. A general center line of the Missouri River formed one side of the template, and a combination of the valley wall and the boundary of the Overton Bottoms conservation area formed the other. Training sets were defined for each of the seven classes by visually interpreting the TM scene, the orthophotographs, and the Ikonos imagery. A supervised classification of the 2002 TM scene was completed using a maximum likelihood classifier. The classification was verified in the field in September 2004 and edited by the analyst using the ancillary photographs and images. The overall thematic accuracy of the classification was 92.8 percent. The thematic accuracy was determined by following the procedures developed for the U.S. Geological Survey (USGS)/National Park Service Vegetation Mapping Program (USGS, 2005).

Land-cover maps for each of the four remaining dates of Landsat imagery were produced by visually interpreting each Landsat scene, supplemented by the ancillary orthophotographs and imagery. For example, the September 2000 land-cover data were collected by visually comparing the September 2002 land-cover map to the September 2000 Landsat scene and looking for land-cover changes that had occurred between September 2000 and September 2002. Any identified changes in land cover were manually digitized on-screen to produce a September 2000 land-cover map. The resulting land-cover map was then used as a starting point to interpret the 1998 TM scene, and so forth. Land-cover change estimates were calculated by comparing the area and the total perimeter length of each land-cover class from one year to the next. Patch characteristics were derived from the land-cover maps using the FRAGSTATS program (McGarigal and Marks, 1995).[1]

Land-Cover Changes at Overton Bottoms

Ten data sets were produced using the Landsat TM images: 5 maps showing the land cover for each year, 4 maps showing the change in those classes from one date to the next, and 1 map showing the overall changes in land cover between 1994 and 2002. The area of each of the classes is summarized by year in table 2. More detailed information about the total area of change from one date to the next, and from the earliest to the latest date is provided in table 3. The total length of the perimeter, or edge of each of the classes for each year is summarized in table 4.

The map of Overton Bottoms that was produced using the September 19, 1994 TM data is shown in figure 2. The total land area in conservation areas at Overton Bottoms is 2,017 ha. The total area of the image, which includes a portion of the Missouri River channel, is 2,348 ha. The most abundant land-cover class in September 1994 was weeds/forbs/grasses, followed by agricultural fields (table 2). Before 1993, most of Overton Bottoms was being farmed, but by 1994, farming had been abandoned over large areas. Some areas, mostly in the northwest (Overton Bottoms North Unit), were covered with sand. A particularly large sand area extends away from Interstate 70 (I-70) towards the southeast; this deposit is a splay produced from scour under I-70 during the 1993 flood. The mature trees-community class is limited to the riparian corridor along the river, a large area just upstream of Hickman Island and an area adjacent to Tadpole Island extending upstream along an abandoned side channel. Most of the area classified as mature tree community is on the river side of the levees. The water class is limited to the main channel of the Missouri River, the abandoned side channel at Tadpole Island, and several flood-plain depressions. The most notable of these is the scour bisected by I-70 just west of the Missouri River. The cottonwoods/willows class is limited to very small areas, and other than roads, represents the least abundant land-cover class in 1994.

The map of Overton Bottoms that was produced using the September 3, 1996 TM data is shown in figure 3. The most notable difference between this map and the one generated using the 1994 TM data is the increased area of the cottonwoods/willows class. This class increased from 72 ha in 1994 to 248 ha in 1996. The total area of cottonwoods/willows in 1996 included 10 ha that had been bare ground, 162 ha that had been weeds/forbs/grasses, and 4 ha that had been agricultural fields in 1994 (table 3). A map of the areas where the land cover had changed between 1994 and 1996 is shown in figure 4. Areas where the land-cover classes did not change are blank (gray-scale background image shows through); areas where the land cover did change are shown in the color of the land-cover class that they became. This figure clearly shows large areas where the land-cover class had changed to cottonwoods/willows. The largest contiguous areas of cottonwoods/willows are Hickman Island, located near the midpoint of Overton Bottoms, and Tadpole Island located at the southeastern end of Overton Bottoms. Both areas are delimited by abandoned river channels. A third, smaller area occupied by discontinuous polygons of cottonwoods/willows is on an unnamed island on the northeastern part of Overton Bottoms. The fourth area occupied by cottonwoods/willows is an area of small discontinuous polygons in the northwestern part of Overton Bottoms.

The weeds/forbs/grasses class continued to be the most abundant land-cover class in September 1996 (table 2). Small discontinuous areas of bare ground or agricultural fields became weeds/forbs/grasses (fig. 4). These areas include a total of 38 ha that had been bare ground, and 24 ha that had been agricultural fields (table 3). Flooding in 1995 resulted in additional damage to agricultural land on Overton Bottoms. It also was during this time that ownership of Overton Bottoms was changing from private to public through the willing sale by private land owners to the USACE, MDC, and USFWS.

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

The total area of water, mature trees, and roads remained unchanged from September 1994 to September 1996.

The map of Overton Bottoms that was produced using the September 9, 1998 TM data shows large continuous areas of cottonwoods/willows on the northwest, east, and southeast parts of Overton Bottoms (fig. 5). The total area of cottonwoods/willows increased from 248 ha in September 1996, to 487 ha in September 1998 (table 2). The increased area included 16 ha that had been bare ground and 223 ha that had been weeds/forbs/grasses (table 3). Substantial change from bare ground and weeds/forbs/grasses to cottonwoods/willows can be seen along the northwestern and southeastern margins of Overton Bottoms by comparing figure 3 and figure 5. A map of the change from one land-cover class to another is shown in figure 6. In addition to the large continuous areas that became cottonwoods/willows between September 1996 and September 1998, it is interesting to note small discontinuous areas on the northwestern part of the bottoms west of Missouri Route 98 that changed to cottonwoods/willows during the same time period. Equally interesting is the change that occurred along the western and southern margin of the large area of bare ground southeast of I-70. This area changed from bare ground to a patchwork of weeds/forbs/grasses and cottonwoods/willows. The northern and eastern margin of the same area changed from bare ground to weeds/forbs/grasses (fig. 6). Elsewhere, 8 ha of agricultural fields changed to weeds/forbs/grasses (table 3). The total areas of water, roads, and mature trees remained unchanged.

The map of Overton Bottoms that was produced using the September 6, 2000 ETM+ data shows additional areas of cottonwoods/willows (fig. 7). The total area of cottonwoods/willows increased from 487 ha to 614 ha (table 2). The majority of change occurred on the northern end of Overton Bottoms and along the margin of the large area of bare ground southeast of I-70 (fig. 7). The total area of cottonwoods/willows also increased on Tadpole Island, and a new area of bare ground can be seen on the northern end of Overton Bottoms (figs. 7 and 8). This new area of bare ground is a side channel that was being constructed by the USACE in 2000. The construction activity increased the total area of bare ground from 66 ha in September 1998 to 90 ha in September 2000 (table 3).

In addition, a new road constructed on the northwest part of the bottoms west of Missouri Route 98 is shown on figures 7 and 8. This new road increased the total area of roads from 51 ha in September 1998 to 61 ha in September 2000. The total area of water increased by 1 ha because a small floodplain depression on the northwestern part of the bottoms was inundated when the ETM+ data were acquired. The construction of the side-channel chute by the USACE on the Overton Bottoms North Unit also reduced the total area of mature trees by 2 ha, which became bare ground or weeds/forbs/grasses. The weeds/forbs/grasses class continued to be the most abundant land-cover class in September 2000 (table 2). A large area near the central part of Overton Bottoms that was classified as agricultural fields in September 1998 changed to weeds/forbs/grasses in September 2000 (fig. 8). Similarly, 6 ha of bare ground, 2 ha of cottonwoods/willows, and 1 ha of mature trees changed to weeds/forbs/grasses between September 1998 and September 2000 (table 3).

The map of Overton Bottoms that was produced using the September 4, 2002 TM data (fig. 9) shows continued changes in land cover compared to the map of land cover in 2000 (fig. 7). A particularly interesting area is the long linear area of bare ground that borders agricultural fields through the central part of Overton Bottoms shown on figures 9 and 10. This area of bare ground is the result of the construction associated with the relocation of a levee by the USACE. Similarly, the area of bare ground shown in figures 7 and 8 that was cleared to construct the side-channel chute on Overton Bottoms North Unit changed to weeds/grasses/forbs. A second notable change is the increased area of cottonwoods/willows on the northern end of Overton Bottoms North Unit, and on Hickman and Tadpole Islands. There also are more cottonwoods/willows areas replacing weeds/forbs/grasses along the western margin of the bare ground area to the southeast of I-70 and occupying narrow linear areas along the western side of the northwestern part of the bottoms. Overall, the area of cottonwoods/willows increased from 614 ha in September 2000 to 702 ha in 2002

Table 2. Area totals and proportional abundance for each land-cover class by year.

[ha, hectare; %, percent]

Land-cover Class	1994		1996		1998		2000		2002	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Water	112	5	112	5	112	5	113	5	119	5
Bare ground	139	6	99	4	66	3	90	4	114	5
Weeds/forbs/grasses	1,276	54	1,167	50	969	41	907	38	854	36
Cottonwoods/willows	72	3	248	10	487	21	614	26	702	30
Mature trees	228	10	228	10	228	10	226	10	223	9
Agricultural fields	470	20	443	19	435	18	337	14	275	12
Roads	51	2	51	2	51	2	61	3	61	3
Total	2,348		2,348		2,348		2,384		2,348	

Table 3. Specific area total changes for each land-cover class per year on Overton Bottoms North. The columns list the land-cover class area total for one year; the rows list the land-cover class and area total for the previous year. For example, the total area of bare ground was 139 ha in 1994. By 1996, 90 ha remained bare ground, but 38 ha became weeds/forbs/grasses, 10 ha became cottonwoods/willows, and 1 ha became agricultural fields.

	Water	Bare Ground	Weeds/forbs/ grasses	Cottonwoods/ willows	Mature trees	Agricultural fields	Roads	Totals
				1996				**1994**
Water (1994)	112	0	0	0	0	0	0	112
Bare ground (1994)	0	90	38	10	0	1	0	139
Weeds/forbs/grasses (1994)	0	9	1105	162	0	0	0	1,276
Cottonwoods/willows (1994)	0	0	0	72	0	0	0	72
Mature trees (1994)	0	0	0	0	228	0	0	228
Agricultural fields (1994)	0	0	24	4	0	442	0	470
Roads (1994)	0	0	0	0	0	0	51	51
Total (1996)	112	99	1,167	248	228	443	51	2,348
				1998				**1996**
Water (1996)	112	0	0	0	0	0	0	112
Bare ground (1996)	0	56	27	16	0	0	0	99
Weeds/forbs/grasses (1996)	0	10	934	223	0	0	0	1167
Cottonwoods/willows (1996)	0	0	0	248	0	0	0	248
Mature trees (1996)	0	0	0	0	228	0	0	228
Agricultural fields (1996)	0	0	8	0	0	435	0	443
Roads (1996)	0	0	0	0	0	0	51	51
Total (1998)	112	66	969	487	228	435	51	2,348
				2000				**1998**
Water (1998)	112	0	0	0	0	0	0	112
Bare ground (1998)	1	54	6	5	0	0	0	66
Weeds/forbs/grasses (1998)	0	24	801	135	0	0	9	969
Cottonwoods/willows (1998)	0	11	2	474	0	0	0	487
Mature trees (1998)	0	1	1	0	226	0	0	228
Agricultural fields (1998)	0	0	98	0	0	337	0	435
Roads (1998)	0	0	0	0	0	0	51	51
Total (2000)	113	90	907	614	226	337	61	2,348
				2002				**2000**
Water (2000)	113	0	0	0	0	0	0	113
Bare ground (2000)	0	42	42	6	0	0	0	90
Weeds/forbs/grasses (2000)	3	39	779	83	0	3	0	907
Cottonwoods/willows (2000)	0	1	2	611	0	0	0	614
Mature trees (2000)	0	3	0	0	223	0	0	226
Agricultural fields (2000)	3	29	31	2	0	272	0	337
Roads (2000)	0	0	0	0	0	0	61	61
Total (2002)	119	114	854	702	223	275	61	2,348
				2002				**1994**
Water (1994)	112	0	0	0	0	0	0	112
Bare ground (1994)	0	32	29	77	0	0	1	139
Weeds/forbs/grasses (1994)	2	22	709	531	0	3	9	1,276
Cottonwoods/willows (1994)	0	0	0	72	0	0	0	72
Mature trees (1994)	0	3	1	1	223	0	0	228
Agricultural fields (1994)	4	56	116	21	0	273	0	470
Roads (1994)	0	0	0	0	0	0	61	51
Total (2002)	119	114	854	702	223	275	61	2,348

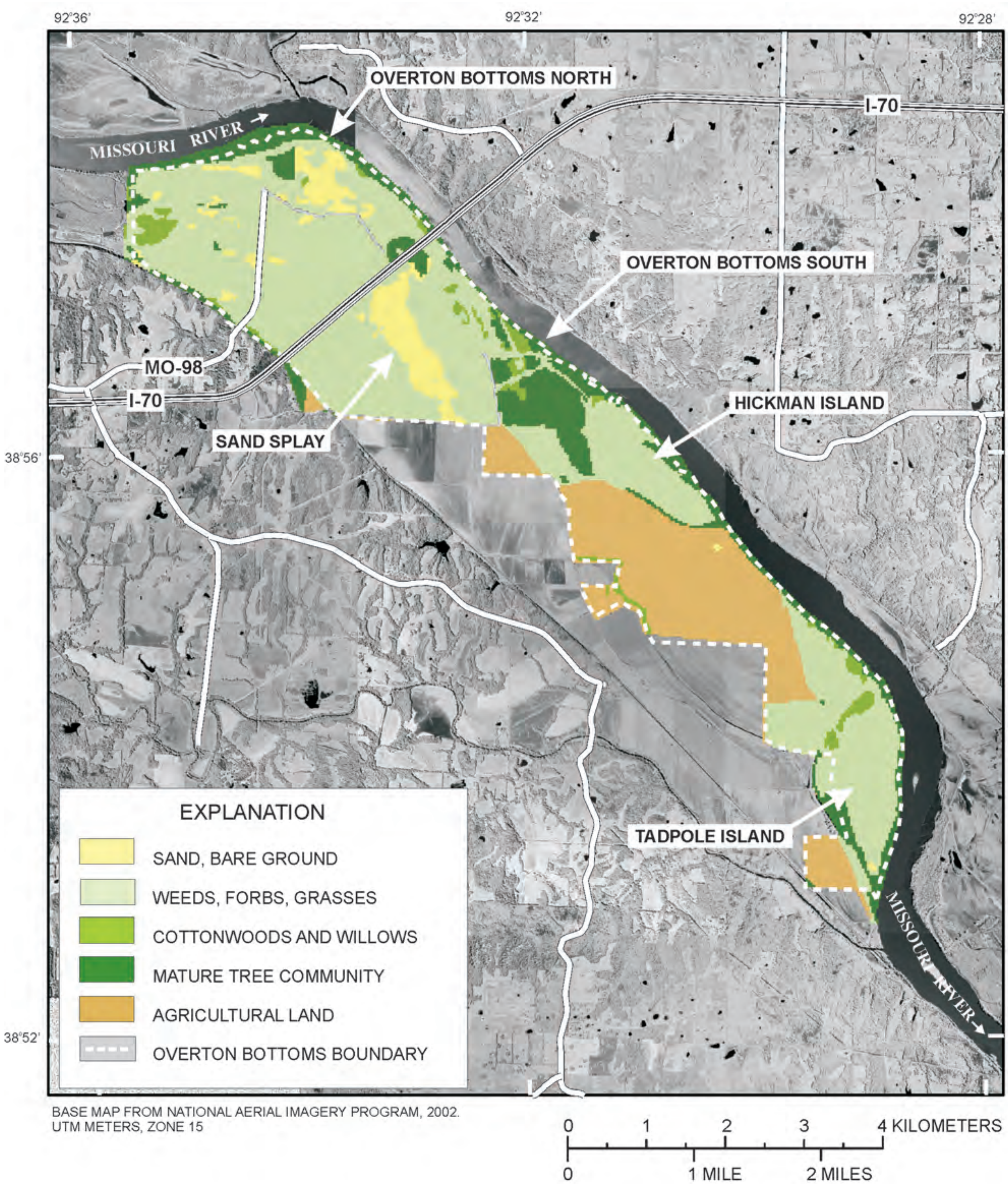

Figure 2. Overton Bottoms showing land-cover classes derived from Landsat TM-5 data acquired September 19, 1994.

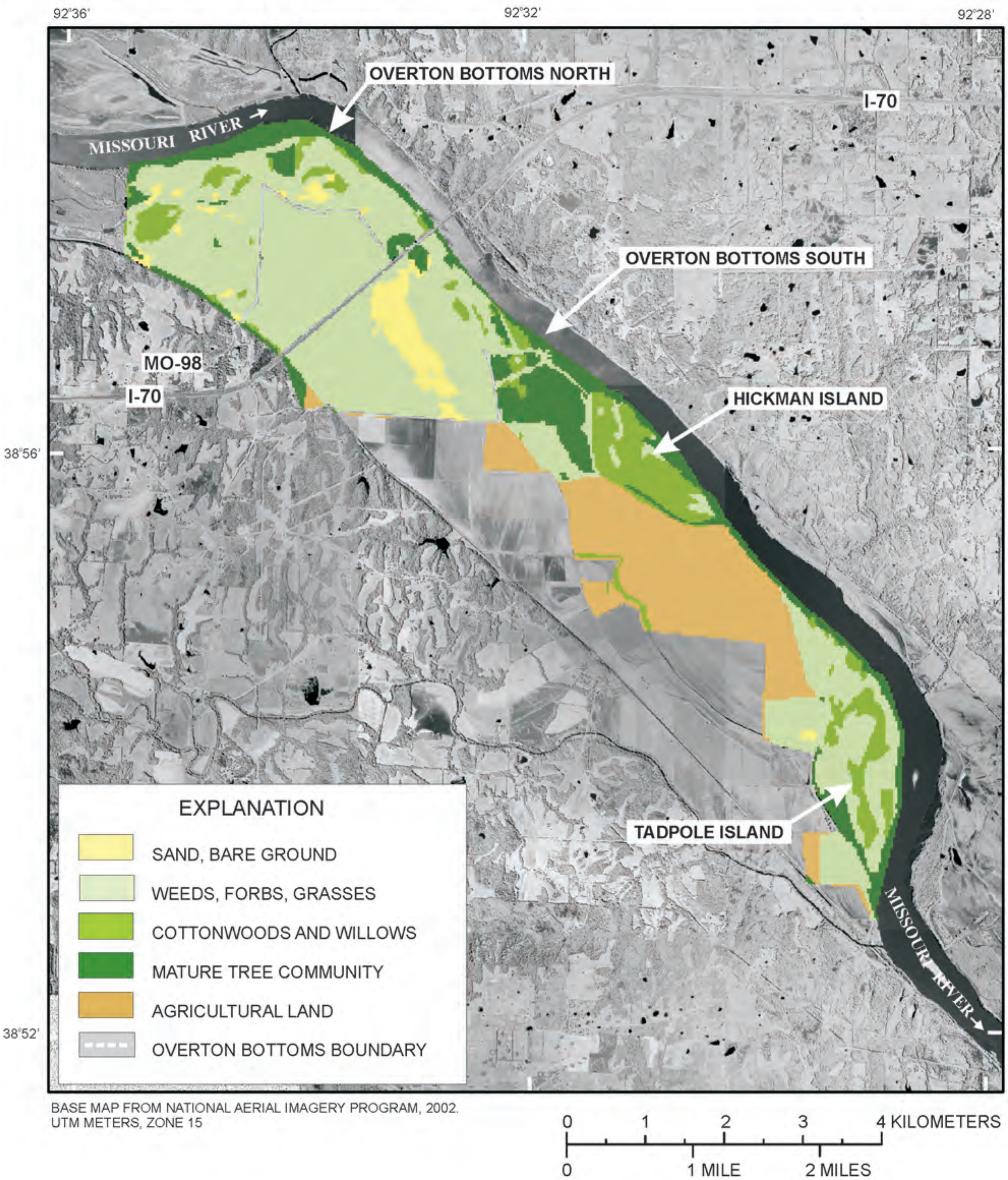

Figure 3. Overton Bottoms showing land-cover classes derived from Landsat TM-5 data acquired September 3, 1996.

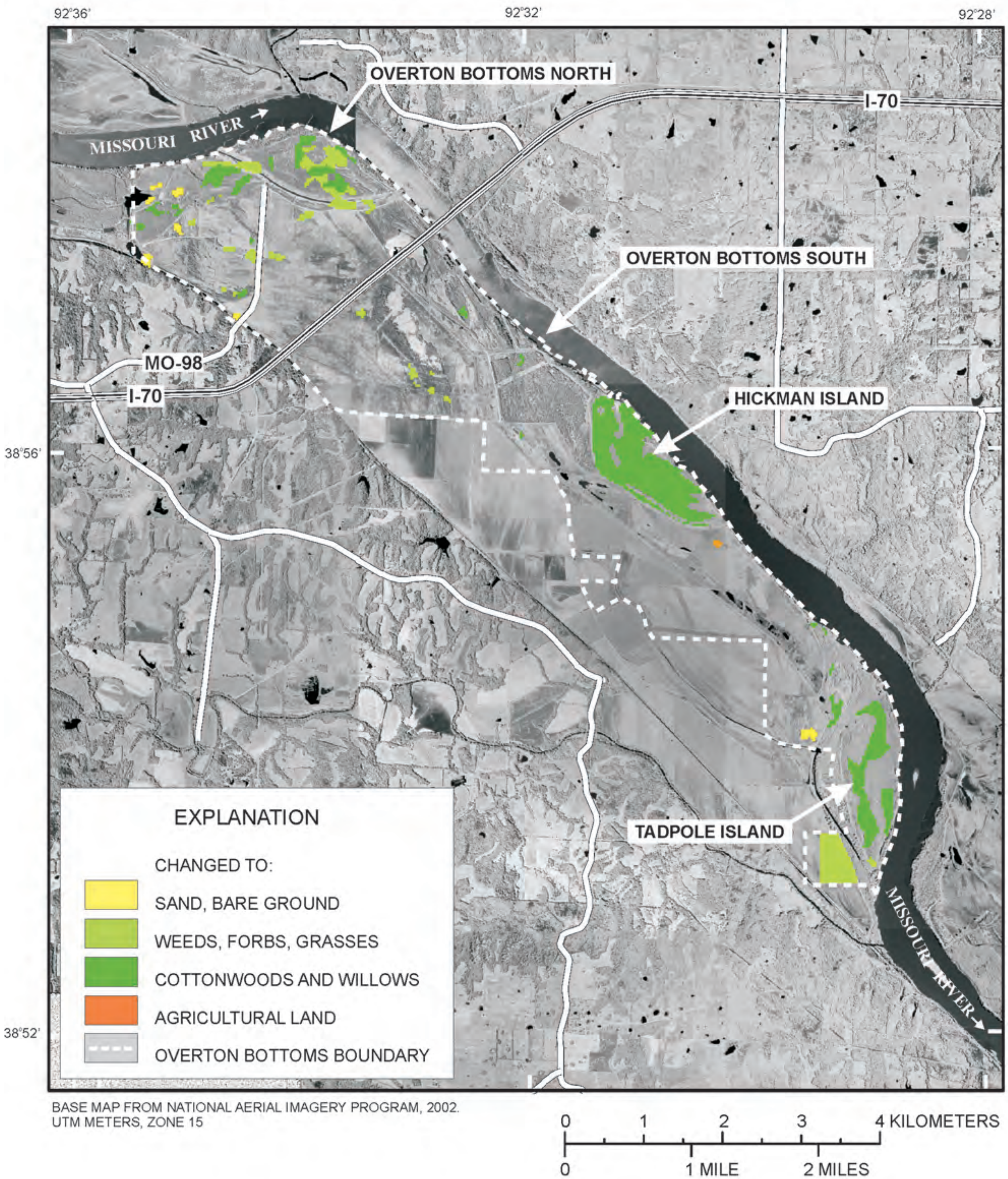

Figure 4. Overton Bottoms showing the change in vegetation and land-cover classes that occurred between September 19, 1994 and September 3, 1996. Areas where the vegetation and land-cover classes did not change are uncolored. Areas where they did change are shown in the color of the vegetation and land-cover class that they became.

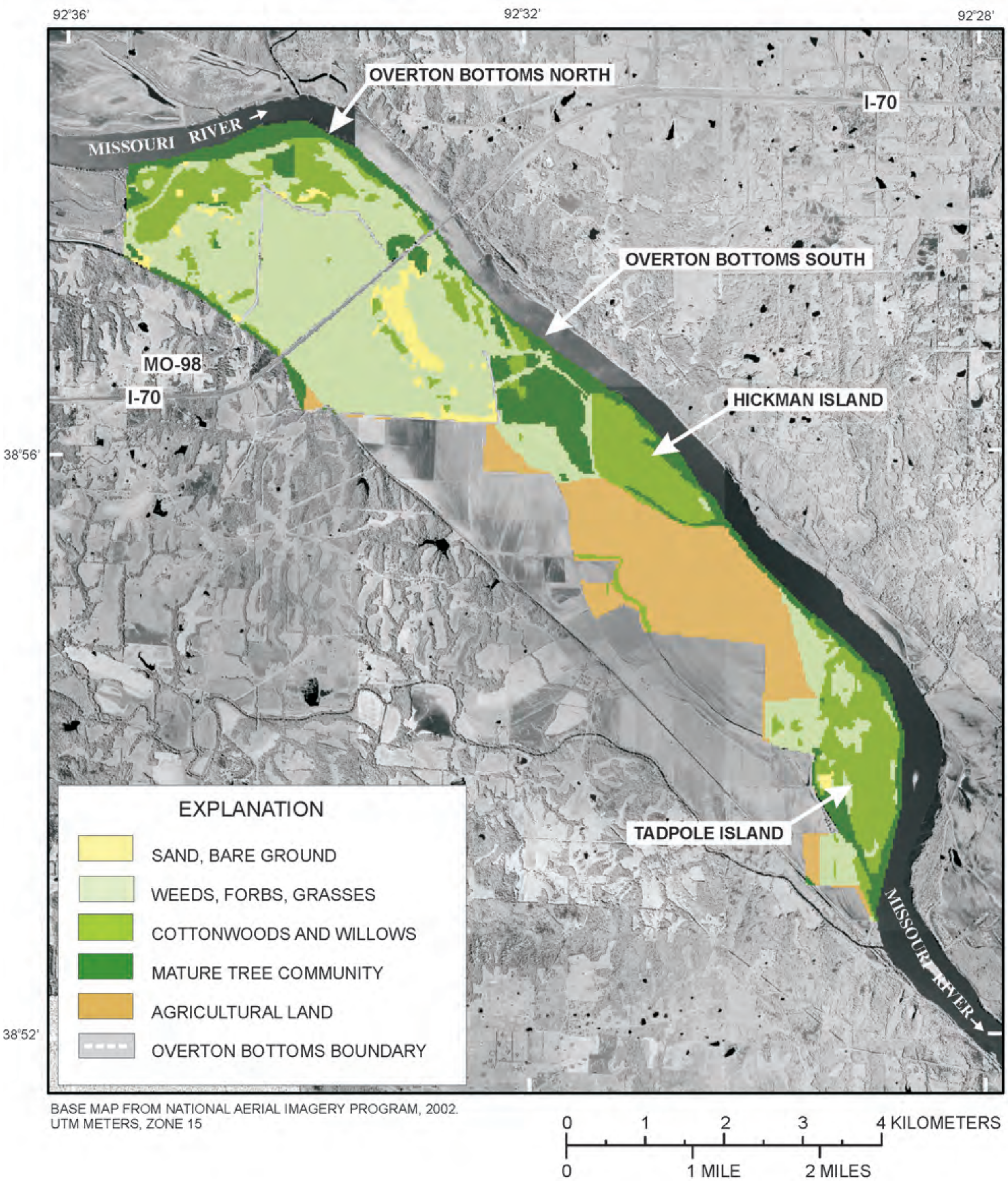

Figure 5. Overton Bottoms showing seven vegetation and land-cover classes derived from TM-5 data acquired September 9, 1998.

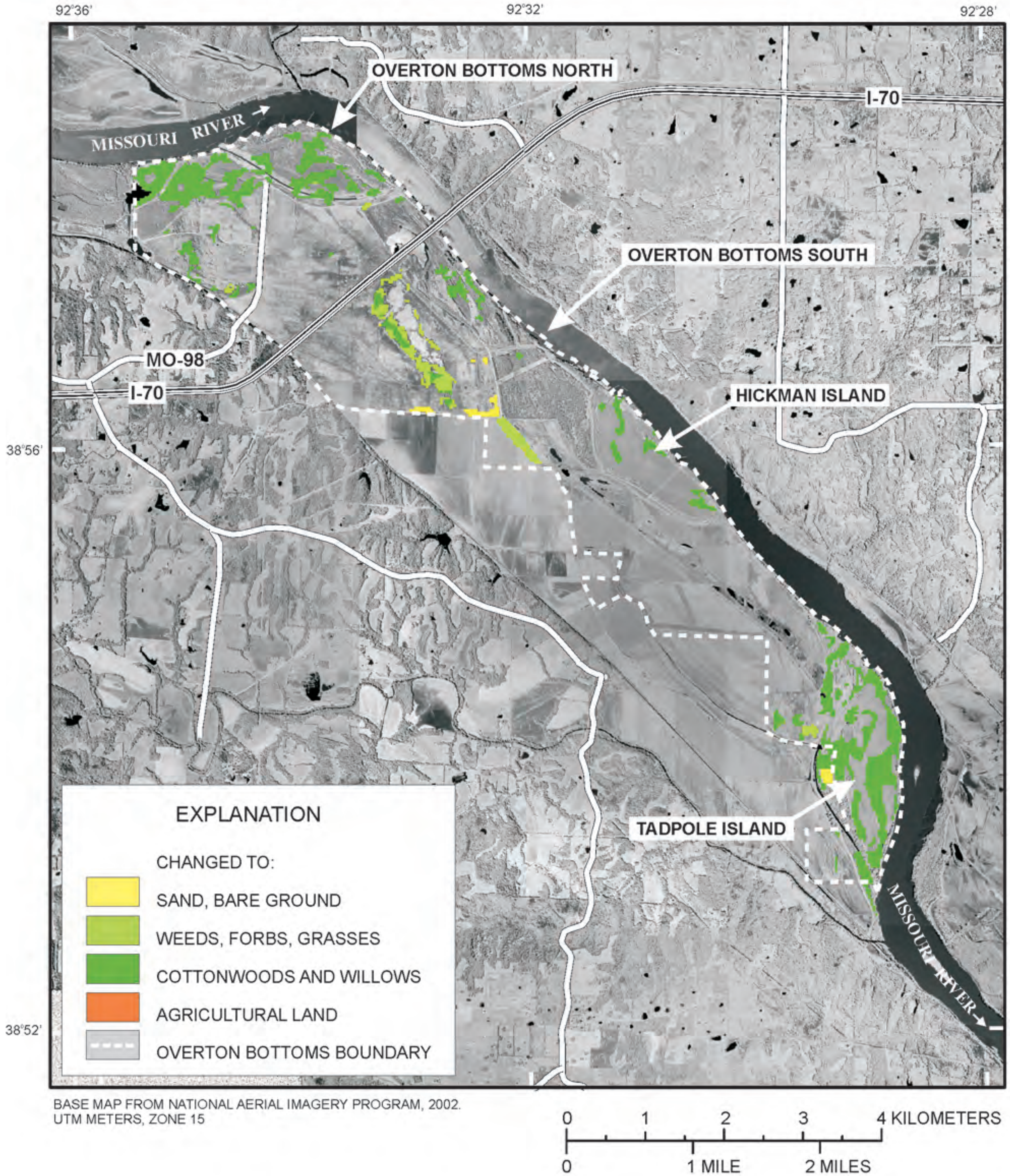

Figure 6. Overton Bottoms showing the change in vegetation and land-cover classes that occurred between September 3, 1996 and September 9, 1998. Areas where the vegetation and land-cover classes did not change are uncolored. Areas where they did change are shown in the color of the vegetation and land-cover class that they became.

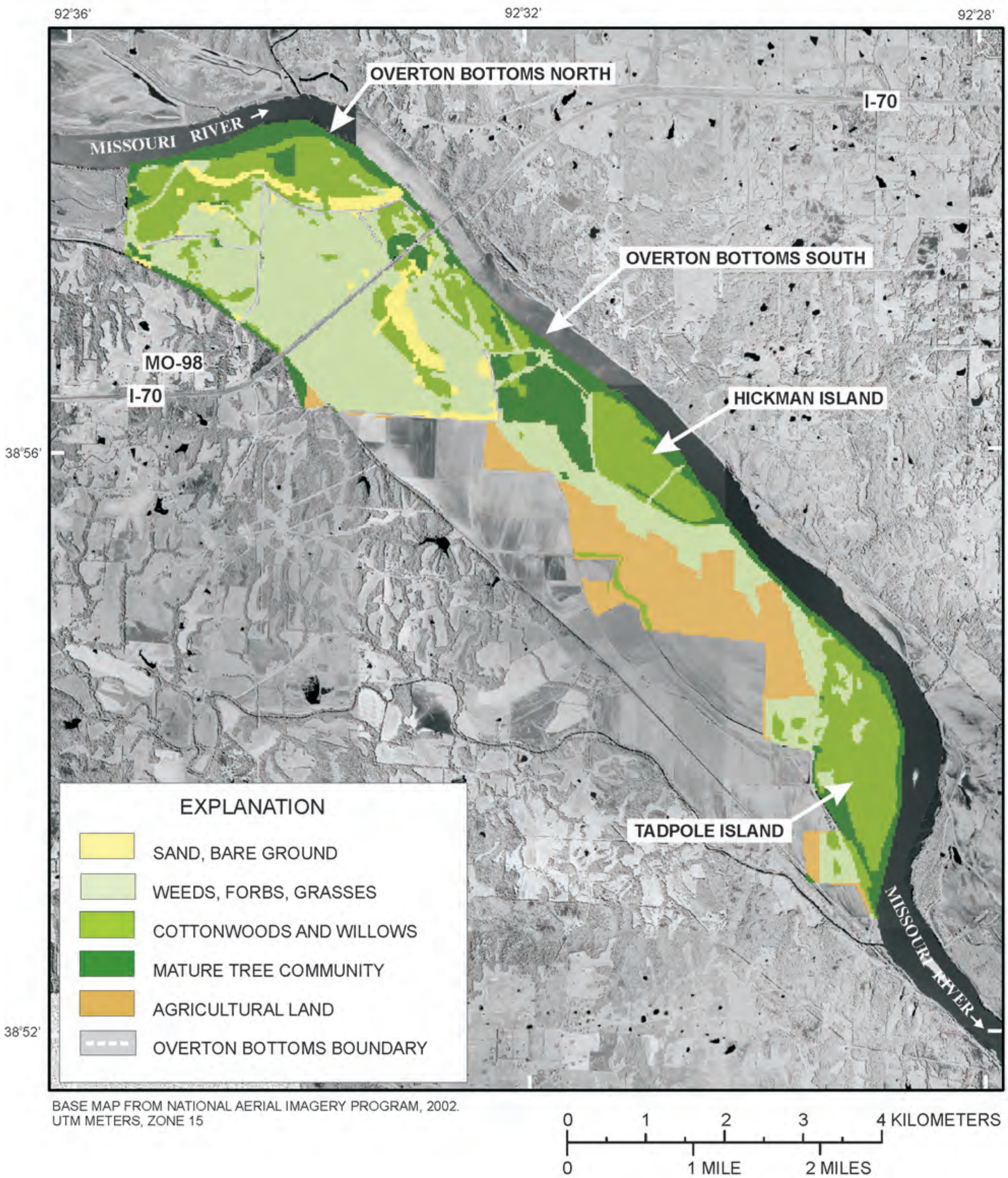

Figure 7. Overton Bottoms showing seven vegetation and land-cover classes derived from ETM+ data acquired September 6, 2000.

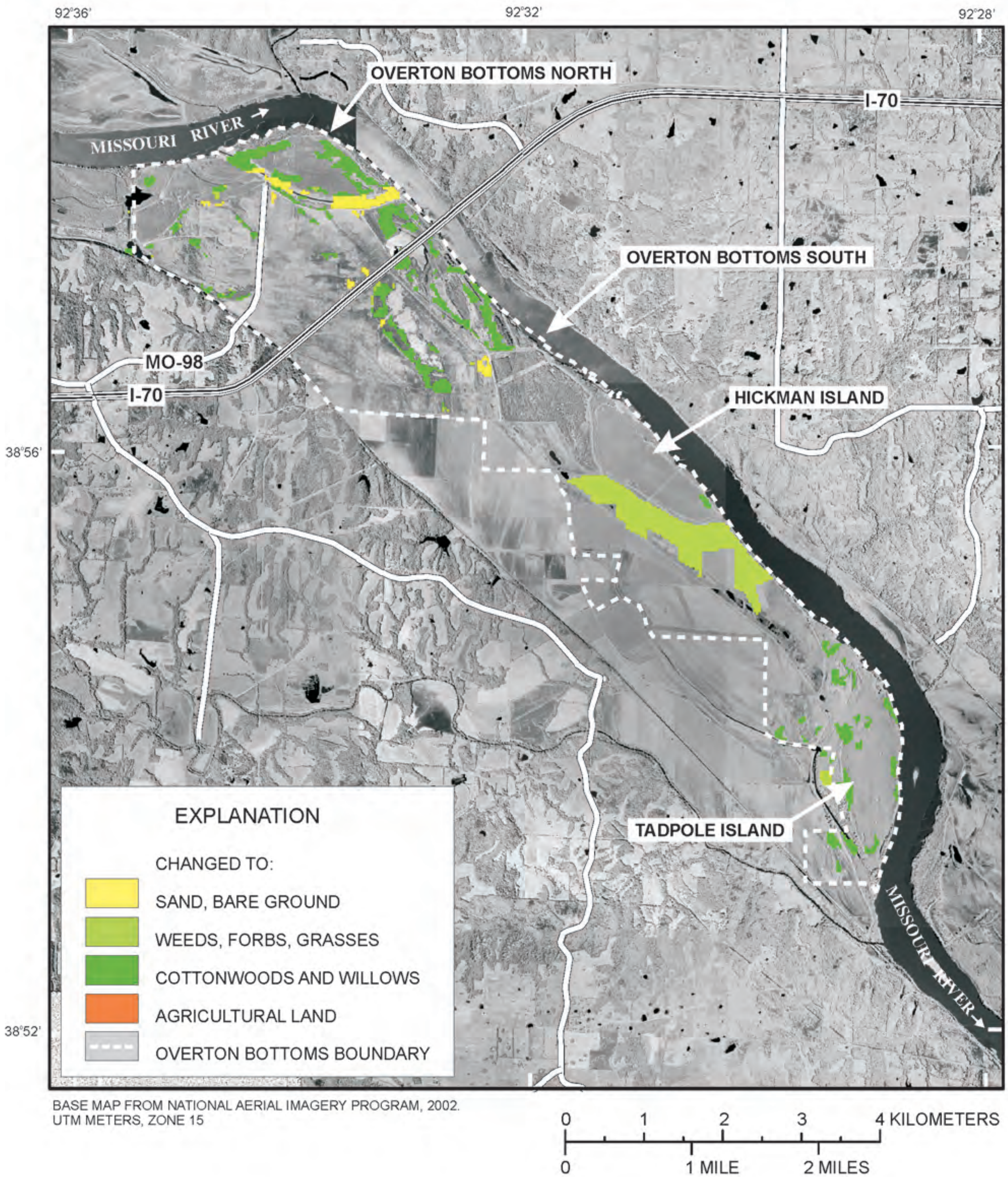

Figure 8. Overton Bottoms showing the change in vegetation and land-cover classes that occurred between September 9, 1998 and September 6, 2000. Areas where the vegetation and land-cover classes did not change are uncolored. Areas where they did change are shown in the color of the vegetation and land-cover class that they became.

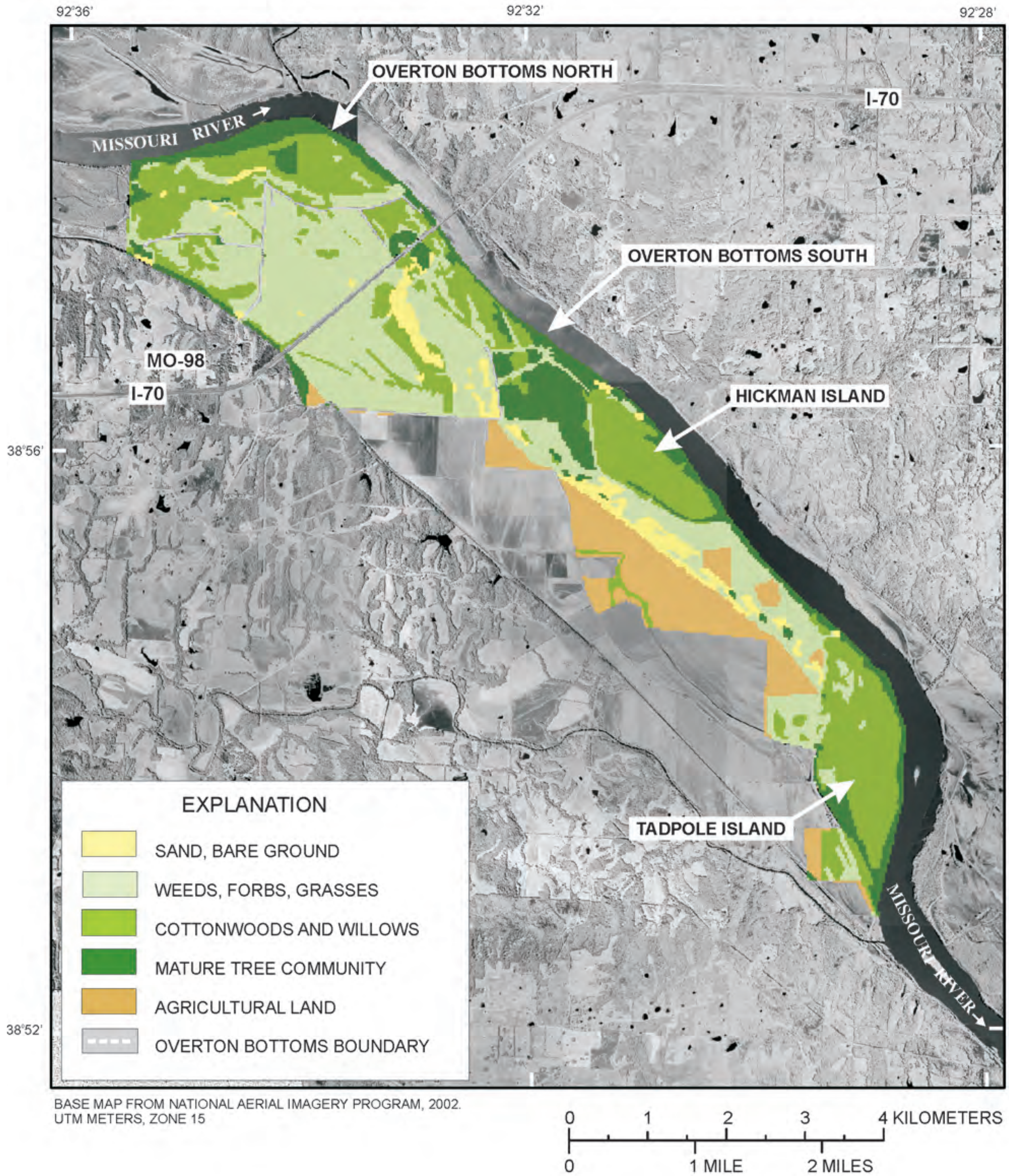

Figure 9. Overton Bottoms showing seven vegetation and land-cover classes derived from TM-5 data acquired September 4, 2002.

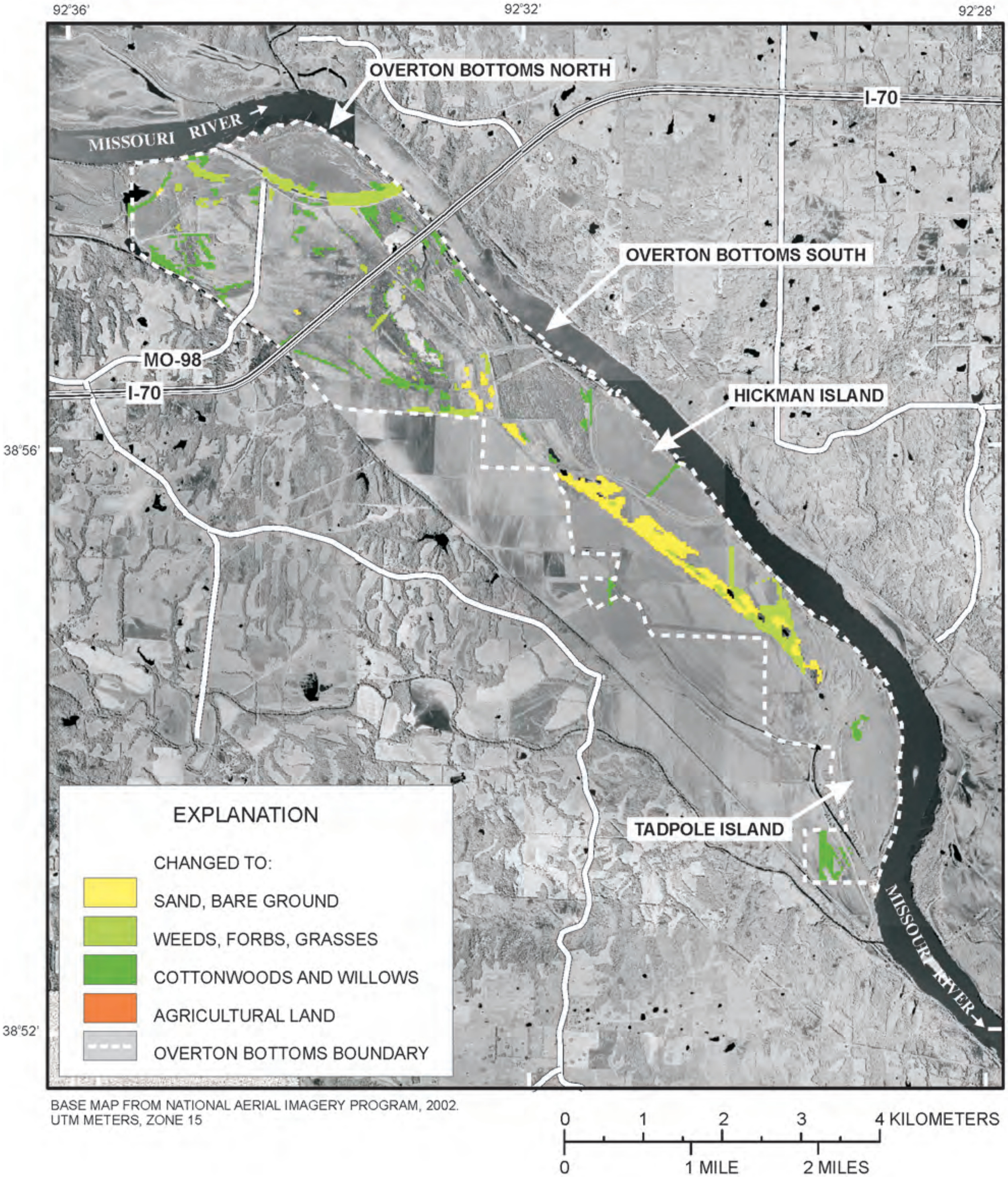

Figure 10. Overton Bottoms showing the change in vegetation and land-cover classes that occurred between September 6, 2000 and September 4, 2002. Areas where the vegetation and land-cover classes did not change are uncolored. Areas where they did change are shown in the color of the vegetation and land-cover class that they became.

(table 2). Of the total, 6 ha had been bare ground, 83 ha had been weeds/forbs/grasses, and 2 ha had been agricultural fields in September 2000 (table 3).

The total area of water increased 6 ha from 113 ha in September 2000 to 119 ha in September 2002. This change occurred within the area on Overton Bottoms where the levee had been relocated. Weeds/forbs/grasses continued to be the most abundant land-cover class in September 2002 (table 2). Of the total, 42 ha had been bare ground, 2 ha had been cottonwoods/willows, and 31 ha had been agricultural fields in September 2000 (table 3). The total area of mature trees decreased from 226 ha in 2000 to 223 ha in 2002, and the total area of agricultural fields was reduced from 337 ha in 2000 to 275 ha in 2002. Changes in the total area of water, weeds/forbs/grasses, mature trees, and agricultural fields were all associated with the relocation of the levee.

The most notable change in land cover that occurred on Overton Bottoms between September 1994 and September 2002 was the increase in the total area of cottonwoods/willows from 72 ha in 1994 to 702 ha in 2002 (table 3; figs. 11, 12*A*, 12*C*). Most of this change occurred on the northern part of Overton Bottoms, and on Hickman and Tadpole Islands (fig. 11). Between September 1994 and September 2002, 77 ha of bare ground, 531 ha of weeds/forbs/grasses, 1 ha of mature trees, and 21 ha of agricultural fields changed to cottonwoods/willows (table 3). Bottomland hardwood trees have also been planted in parts of Overton Bottom North and South, but these plantations were not developed sufficiently to be identified on the multispectral imagery.

The second major change is the reduction of agricultural fields from 470 ha in 1994 to 275 ha in 2002 (table 2). Most of this change occurred between 1998 and 2000 when 98 ha were converted to weeds/forbs/grasses, and between 2000 and 2002 in association with the relocation of the levee. The third most notable change occurred with weeds/forbs/grasses. The total area of this class decreased from 1276 ha in 1994, to 855 ha in 2002. This change occurred across the entire bottom, with 531 ha becoming cottonwoods/willows, and 22 ha becoming bare ground, the latter of which was largely because of the construction associated with the relocation of the levee by the USACE (table 3).

Changes in perimeter–or edge length–have accompanied changes in area between 1994 and 2002 (table 4; fig. 12*B*). Overall, the total length of the perimeters increased from 334,980 m in 1994 to 475,800 m in 2002. As with area, the length of the perimeters of weeds/forbs/grasses and cottonwoods/willows changed the most. Both increased, although the cottonwoods/willows changed more. The total length of the perimeter of water increased slightly in 2000 and again in 2002. The total perimeter of roads also increased slightly in 2000 and again in 2002, whereas the total perimeter of mature trees decreased slightly in 2000 and again in 2002.

Processes and Implications of Land-Cover Change at Overton Bottoms

The flood plain of the Lower Missouri River is a dynamic landform that has been shaped by a variety of natural processes and human activities. Complex interactions among these processes and activities have affected the structure, dynamics, and composition of its habitats. In the absence of human activities, flood-plain vegetation classes will occupy sites suitable to their class-specific requirements. The distribution and succession of vegetative land cover observed on Overton Bottoms from 1994 to 2002 are consistent with general patterns observable at other sites along the Lower Missouri River: bare ground is first occupied by weeds/forbs/grasses, and subsequently, depending on site-specific circumstances, by cottonwoods/willows and mature trees. Certainly, human activities affect the patterns of vegetative land-cover distribution or succession, such as the construction associated with the relocation of a levee by the USACE on Overton Bottoms. Bare ground replaced agricultural fields during construction, which was subsequently replaced by weeds/forbs/grasses after the construction was completed.

Table 4. Total perimeter length for each land-cover class per year.

[values are in meters]

Land-cover Class	1994	1996	1998	2000	2002
Water	50,400	50,400	50,400	50,700	53,820
Bare ground	27,360	19,860	21,060	26,700	35,280
Weeds/forbs/grasses	107,100	115,140	115,920	115,500	136,740
Cottonwoods/willows	28,320	57,540	86,220	103,620	119,820
Mature trees	62,220	62,220	62,220	61,860	60,780
Agricultural fields	28,380	27,900	27,840	29,700	31,740
Roads	31,200	31,200	31,200	37,620	37,620
Total	334,980	364,260	394,860	425,700	475,800

Similarly, natural processes and associated landforms seem to affect the distribution or succession of vegetative land-cover classes. Flood-plain depressions associated with channel meandering, abandonment, and filling are likely to support a much different assemblage of plants than natural levees or sand splays associated with channel avulsions (for example, Heimann and Mettler-Cherry, 2004; Hupp and Osterkamp, 1996; Scott and others, 1996). The distribution of cottonwoods/willows on Overton Bottoms between 1994 and 2002 suggests a relation between the distribution or succession of vegetative land-cover classes and Lower Missouri River landforms. While the total area of cottonwoods/willows increased from 72 ha in 1994 to 702 ha in 2002, the increase was not uniform across Overton Bottoms, but limited to specific areas on the flood plain. Most notable are those areas that are adjacent to the river, unprotected by levees, and undisturbed by human activities.

A more specific example of the interdependence of the distribution of cottonwoods/willows and landform can be seen on the western side of Overton Bottoms. Along the valley wall northwest of I-70 there are a series of curvilinear polygons of cottonwoods/willows (figs. 7 and 8). Their location correlates well with channel fill allounits mapped by Holbrook and others (this volume, chapter 2, fig. 3). The resolution of the satellite imagery is coarser than the typical width of these features. However, the shape of the polygons mimics the shape of several secondary channels mapped by Holbrook suggesting a land-cover/landform relation between cottonwoods/willows and filled channels.

This relation likely is dependent on the structure and composition of the channel fill features. Channel-fill allounits tend to occupy low areas on the flood plain, and are U-shaped in cross section and filled with fined-grained low permeability strata with internal bedding that is concave up. This structure slows the infiltration of surface water sufficiently to cause water to collect at the surface. The cottonwoods/willows land-cover class has expanded along these features since 1994. This preferential pattern of occupation can be seen by comparing the distribution pattern of cottonwoods/willows from 1994 through 2002 to the surfical alluvium map of the area (this volume, chapter 2, fig. 2).

Vegetation community distributions and locations of change also relate broadly to land-surface altitude, presumably through controls on ground-water availability. In the Overton Bottoms North Unit, low-lying land surfaces adjacent to the channel on the north and northwest consistently show shallower depths to ground water compared to areas closer to I-70 (Kelly, this volume, chapter 3, figs. 10–12). As shown in the land-cover maps, the lower areas have preferentially grown up in the cottonwoods/willows community while the higher areas with deeper ground water are dominated by the weeds/forbs/grasses class (figs. 2, 3, 5, 7, 9, 11).

The only locations with relatively deep ground-water table and cottonwoods/willows growth are curvilinaer channel-fill areas (fig. 9) where depth to ground water is presumably less and water retention is probably greater than surrounding areas. Adjacent areas mapped as point-bar allounits have persisted in weeds/forbs/grasses presumably because point-bar allounits are not as effective in retaining water near the surface. Point-bar allounits typically include inter-bedded and inclined permeable sand and mud that direct water down and away from the surface. Weeds/forbs/grasses appear to be more tolerant of this situation than cottonwood or willow seedlings. In each of his scenarios, Kelly's figures 10–15 (this volume, chapter 3) show lower estimated depths to ground water adjacent to I-70 where it crosses Overton Bottoms.

With time, cottonwoods/willows likely will occupy more of Overton Bottoms if trends of the last 10 years continue (fig. 12). During 1994–2002 cottonwoods/willows expanded at the expense of weeds/forbs/grasses so now each class covers approximately one-third of the Overton Bottoms area (fig. 12*A*).

Mature forest community, agricultural land, bare ground/sand, and water classes occupy the last one-third of area within the conservation areas. Rates of change of total area of cottonwoods/willows and weeds/grasses/forbs have slowed since 1998. As the area of cottonwoods/willows has increased at the expense of the weeds/forbs/grasses class, the total edge of these two classes has increased (fig. 12*B*). This trend is indicative of complex intergrowth of patches, in part resulting from preferential growth of cottonwoods/willows along arcuate channel fills. The trend in total core area (area within a 30-m edge buffer around each patch) is similar to percent area in each class (fig. 12*C*). Mean core area per patch has been decreasing markedly for weeds/forbs/grasses and increasing modestly for cottonwoods/willows (fig. 12*D*).

These changes in patch characteristics may have implications for habitat quality and quantity for wildlife at Overton Bottoms. Growth of flood-plain forest has been associated with increase of smaller, more scattered patches on the Wisconsin River flood plain (Freeman and others, 2003). These authors noted that increased core patch size is often associated with increased species richness of forest birds (for example, Robbins and others, 1989; Freemark and Merriam, 1986, Yahner and Scott, 1988). However, similar to Overton Bottoms, the Wisconsin River example indicated that forest patches were growing in convolute shapes with abundant edge. While edge has often been considered to increase wildlife habitat value (Leopold, 1933; Logan and others, 1985), forest edges also have been associated with increased predation of some bird species (Paton, 1994). Hence, changes in patch size and shape at Overton Bottoms will probably continue to have substantial effects on habitat quality and availability, but assessment is required on a species by species basis. The underlying template of surficial geology and topography will likely continue to influence a complex spatial pattern of land-cover patches.

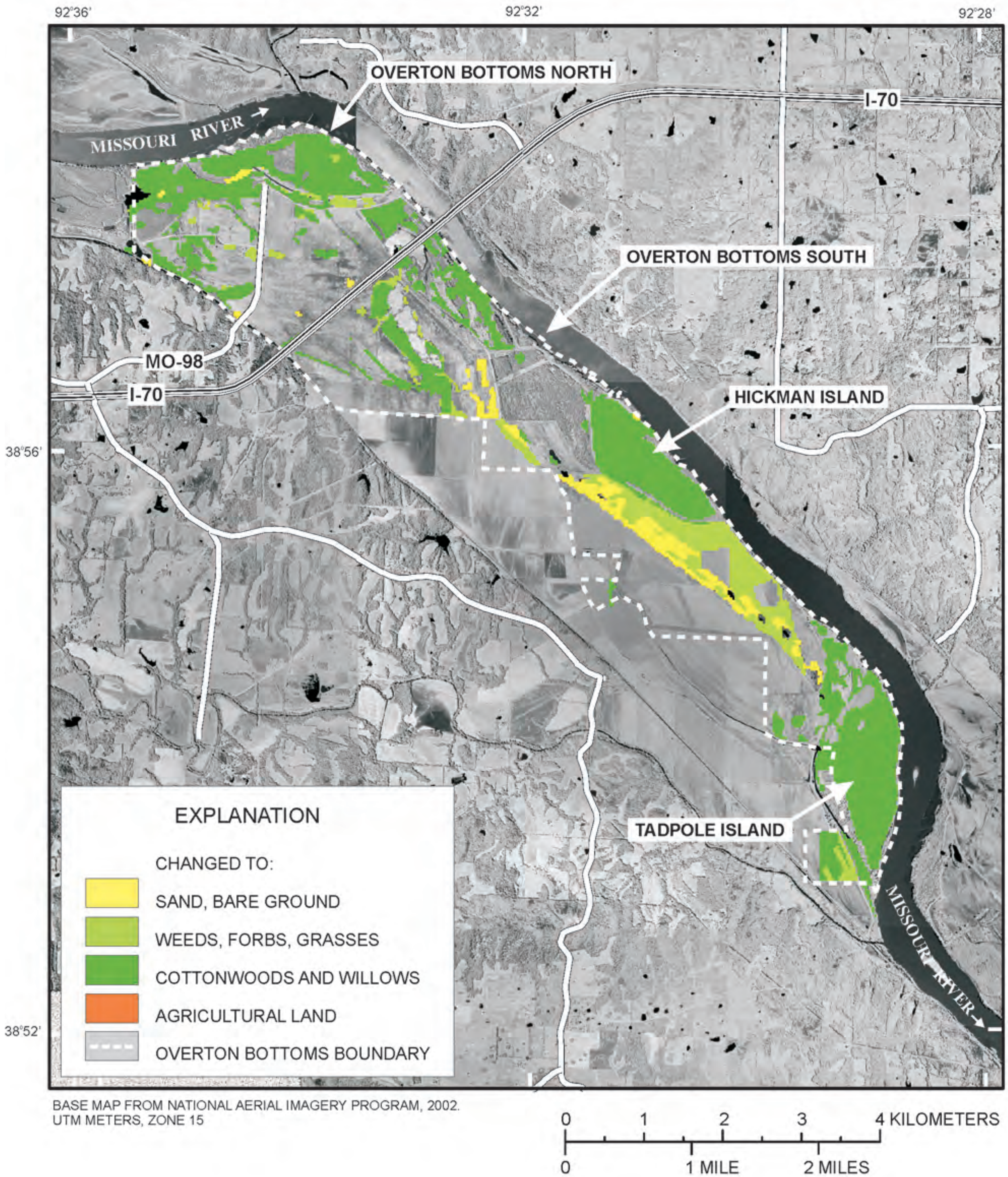

Figure 11. Overton Bottoms showing the change in vegetation and land-cover classes that occurred between September 19, 1994 and September 4, 2002. Areas where the vegetation and land-cover classes did not change are uncolored. Areas where they did change are shown in the color of the vegetation and land-cover class that they became.

Conclusions

This investigation demonstrated that Landsat TM satellite image data can be used to map and monitor the spatial and temporal distribution of general land-cover classes along the Lower Missouri River. General patterns observed between 1994 and 2002 are consistent with vegetation succession at other sites along the Lower Missouri River, and there appears to be a strong relation between physical processes and the distribution of vegetative-land cover on the flood plain.

This study has also documented a relation between the distribution of flood-plain land cover and flood-plain land form. This is important to natural resource managers who are interested in rehabilitating or re-establishing specific flood-plain habitats along the Lower Missouri River. This project has shown that land-cover distribution patterns are affected by underlying allostratigraphic structures.

Knowing one can help predict the occurrence of the other. Approximately 25 years of TM data is available to map the spatial and temporal distribution of vegetation and general land use of the Lower Missouri River Valley. At sites like Overton Bottoms, land-cover changes can be mapped and analyzed, and used to monitor land-use management strategies and practices, or combined with geologic and hydrologic data to identify sites that are suitable for habitat restoration or rehabilitation.

Additional studies, using higher resolution image data should be conducted to refine our understanding of the relationships between landform, landform processes, and land cover. Our understanding can be further refined by incorporating high-resolution terrain data to look at site-specific surface features, such as the surface expression of filled channels, or small meander-scroll depressions. It would also be useful to continue monitoring Overton Bottoms to determine if land-cover trends conform to habitat management objectives. The

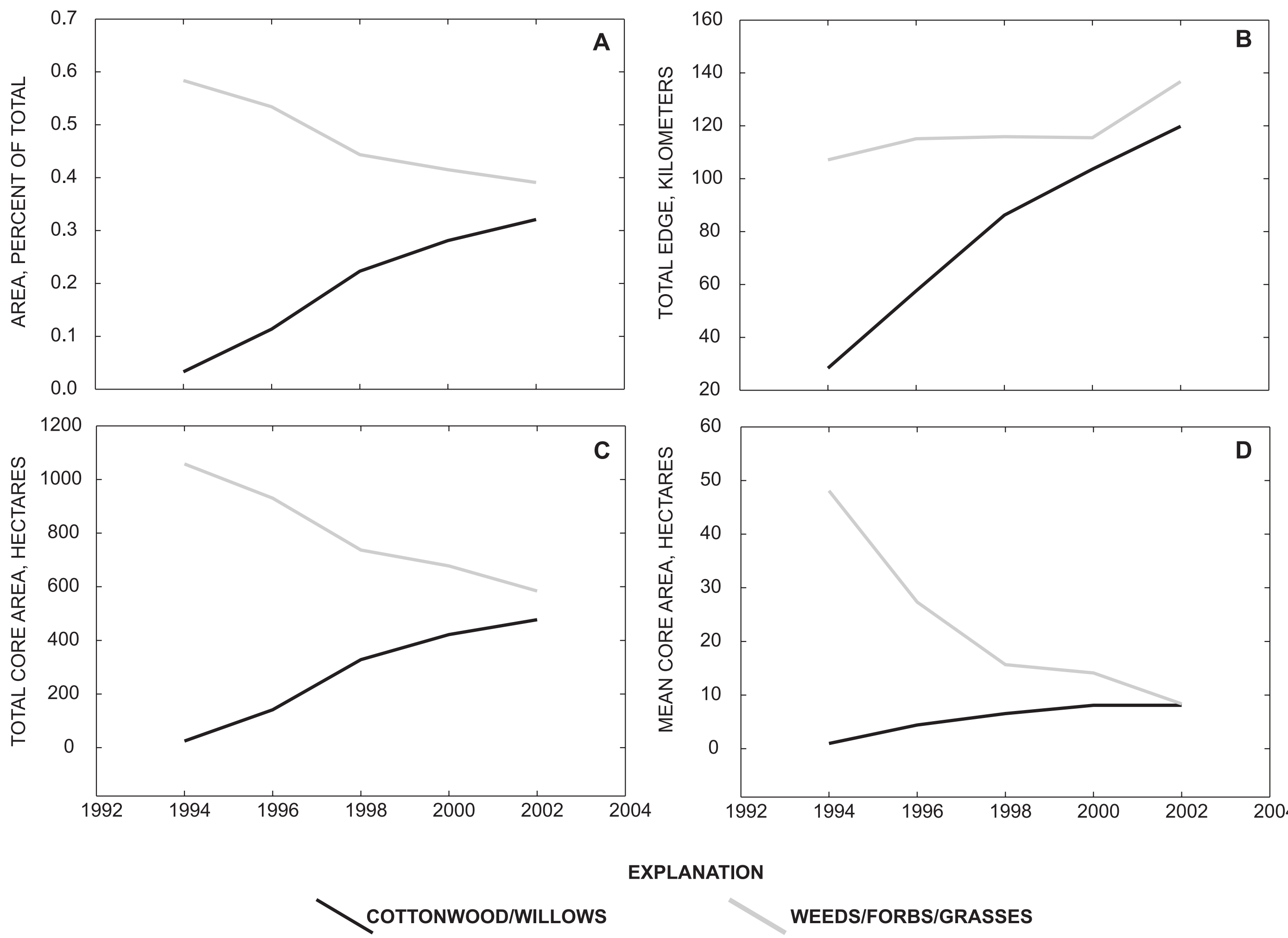

Figure 12. Patch characteristics of Overton Bottoms land-cover classes. A. Changes in area of cottonwoods/willows and weeds/forbs/grasses classes through time as percent of total area in conservation areas. B. Changes in edges of cottonwoods/willows and weeds/forbs/grasses classes through time as total edge length. C. Changes in core area in cottonwoods/willows and weeds/forbs/grasses classes through time as total core area. D. Changes in core area in cottonwoods/willows and weeds/forbs/grasses classes through time as mean core area per patch.

increase in the total edge of the weeds/forbs/grasses and cottonwoods/willows suggest increasing complexity of the edges of these land-cover classes. Additional monitoring is required to document trends in these relations and assess effects on wildlife.

References Cited

Chapman, D.C., Ehrhardt, E. A., Fairchild, J.F., Jacobson, R.B., Kelly, B.P., Mabee. W.R., Poulton, P.C., Sappington, L.C., 2004, Ecological dynamics of wetlands at Lisbon Bottoms, Big Muddy National Fish and Wildlife Refuge, Missouri: U.S. Geological Survey Open-File Report 2004–1036, 160 p.

Chen, J., and Franklin, J.F., 1990, Microclimatic pattern and basic biological responses at the clearcut edges of old-growth Douglas-fir stands: Northwest Environmental Journal, v. 6, p. 424–425.

Freeman, R.E., Stanley, E.H., and Turner, M.G., 2003, Analysis and conservation implication of landscape change in the Wisconsin River floodplain, USA: Ecological Applications, v. 13, p. 416–431.

Freemark, K.E., and Merriam, H.G., 1986, Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments: Biological Conservation, v. 36, p. 115–141.

Funk, J.L., and Robinson, J.W., 1974, Changes in the channel of the Lower Missouri River and effects on fish and wildlife: Missouri Department of Conservation Aquatic Service, 112 p.

Galat, D.L., Robinson, J.W., and Hesse, L.W., 1996, Restoring aquatic resources to the Lower Missouri River–issues and initiatives, *in* Galat, D.L., and Frazier, A.G., eds., Overview of river-flood plain ecology in the upper Mississippi River Basin, v. 3 *of* Kelmelis, J.A., ed., Science for flood plain management into the 21st century: Washington, D.C., U.S. Government Printing Office, p. 49–71.

Heimann, D.C., and Mettler-Cherry, P.A., 2004, Hydrologic, soil, and vegetation gradients in remnant and constructed riparian wetlands in West-Central Missouri, 2001-2004: U.S. Geological Survey Scientific Investigations Report 2004-5216, 160 p.

Hupp, C.R., and Osterkamp, W.R., 1996, Riparian vegetation and fluvial geomorphic processes: Geomorphology, v. 14, p. 277–295.

Jacobson, R.B., Johnson, H.E., Laustrup, M.S., D'Urso, G.J., and Reuter, J.M., 2004, Physical habitat dynamics in four side-channel chutes, Lower Missouri River: U.S. Geological Survey Open-File Report 2004-1071, 60 p.

Kalliola, R., and Puhakka, M., 1998, River dynamics and vegetation mosaicism–case study of the river Kamajohka, northernmost Finland: Journal of Biogeography, v. 15, p. 703–719.

Leopold, A., 1933, Game management: New York, Charles Scribners, 481 p.

Logan, W., Brown, E.R., Longrie, D., Herb, G. [and others], 1985, Edges, *in* Brown, E.R., ed., Management of wildlife and fish habitats in forests of western Oregon and Washington, R6-F&WL-192-1985: Portland, Oreg., U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, p. 115–127.

Loveland, T.R., Sohl, T.L., Stehman, S.V., Gallant, A.L., Sayler, K.L., and Napton, D.E., 2002, A strategy for estimating the rates of recent United States land-cover changes: Photogrammetric Engineering and Remote Sensing, v. 68, p. 1091–1099.

McGarigal, K., and Marks, B.J., 1995, FRAGSTATS–spatial pattern analysis program for quantifying landscape structure, Gen. Tech. Rep. PNW-GTR-351: Portland, Oreg., U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 122 p.

National Research Council, 2002, The Missouri River ecosystem–exploring the prospects for recovery: Washington, D.C., National Academies Press, 141 p.

Paton, P.W.C., 1994, The effect of edge on avian nest success–how strong is the evidence?: Conservation Biology, v. 8, p. 17–26.

Robbins, C.S., Dawson, D.K., and Dowell, B.A., 1989, Habitat area requirements of breeding forest birds of the middle Atlantic states: Wildlife Monographs, v. 103, 34 p.

Robertson, K.M., and Augspurger, C.K., 1999, Geomorphic processes and spatial patterns of primary forest succession on the Bogue Chitto River, USA: Journal of Ecology, v. 87, p. 1052–1063.

Scott, M.L., Friedman, J.M., and Auble, G.T., 1996, Fluvial process and the establishment of bottomland trees: Geomorphology, v. 14, p. 327–339.

U.S. Geological Survey, 2005, USGS–NPS national vegetation mapping program–program documents and standards: U.S. Geological Survey, Reston, Va., accessed November, 2005, at URL http://biology.usgs.gov/npsveg/standards.html.

Yahner, R.H., and Scott, D.P., 1988, Effects of forest fragmentation on depredation of artificial nests: Journal of Wildlife Management, v. 52, p. 158–161.