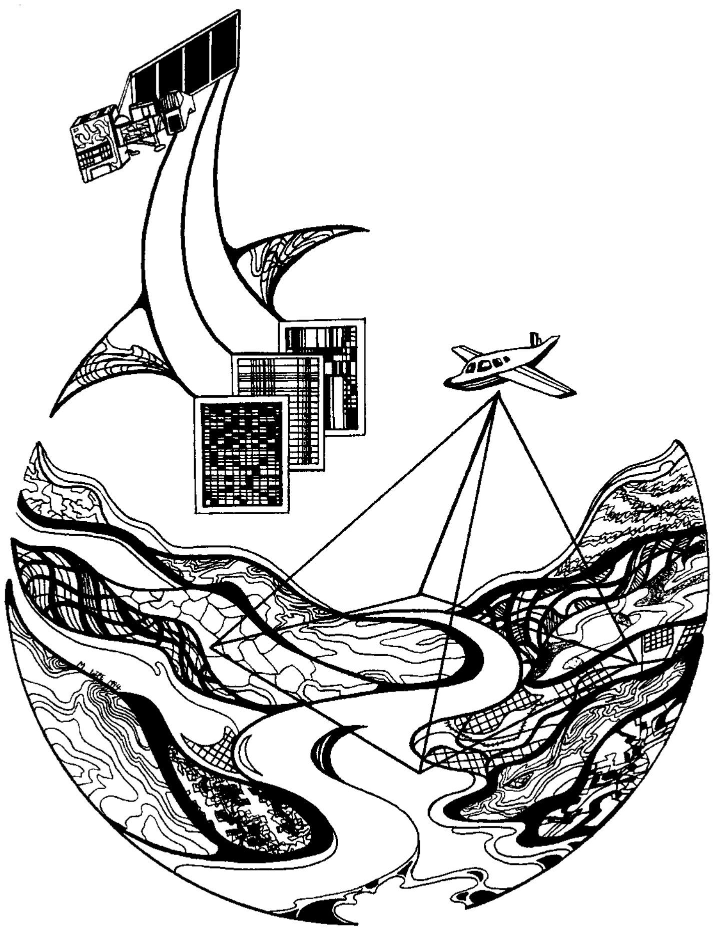
Long Term Resource Monitoring Program

Program Report

95-P009

Geospatial Application:

Evaluation of Multidate Landsat Multispectral Scanner Data



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September 1995

Geospatial Application: Evaluation of Multidate Landsat Multispectral Scanner Data for Determining Changes between Aquatic and Terrestrial Habitats on the Upper Mississippi River System

by
Mark Laustrup[1]

National Biological Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

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[1]Present address: Midwest Science Center, 4200 New Haven Road, Columbia, Missouri 65201

The Environmental Management Technical Center issues LTRMP Program Reports to provide Long Term Resource Monitoring Program partners with programmatic documentation, procedures manuals, training manuals, annual status reports, and geospatial applications.

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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Environmental Management Technical Center, an office of the National Biological Service, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, with guidance and Program responsibility provided by the U.S. Army Corps of Engineers. The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers.

The mission of the LTRMP is to provide decision makers with information to maintain the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and impacts, develop management alternatives, manage information, and develop useful products.

This report supports Strategy 2.2.6, *Monitor and Evaluate Aquatic and Floodplain Habitat*, as outlined in the LTRMP Operating Plan (USFWS 1992).

This report was developed with funding provided by the Long Term Resource Monitoring Program.

Additional copies of this report may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161 (1-800-553-6847 or 703-487-6847).

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Abstract

Landsat Multispectral Scanner data representing conditions in 1972, 1984, and 1992 were processed to identify open water conditions. The study area included the Upper Mississippi River floodplain between Genoa, Wisconsin, and south of Dubuque, Iowa. Data were analyzed to identify changes which occurred over the 20-yr period and these changes have been combined to represent gains and losses. Gains generally equate to a loss of aquatic plant beds and islands in the lower pools (erosion), while losses are generally restricted to off-channel habitats and represent the effects of sedimentation. Between 1972 and 1992, gains totaled 6,959 hectares; losses totaled 6,321 hectares.

Introduction

Beginning in the 1930s, a series of navigation dams (35) extending from Minneapolis, Minnesota, to St. Louis, Missouri, on the Upper Mississippi River and from Chicago to Alton, Illinois, on the Illinois River were constructed to aid inland navigation. A conversion of terrestrial environments to aquatic habitats resulted from construction of the navigation dams and superimposed palustrine and lacustrine habitats on what was once a braided riverine ecosystem. This change in water regime created vast expanses of off-channel marsh and was extremely beneficial to many species. Pools were formed upstream of a dam (this definition of "pool" includes the area between the dam and the next one upstream; e.g., Pool 8 is the water impounded between Lock and Dams 7 and 8). The habitats directly below a dam most closely represent pre-project condition, where a series of anastomosing channels bisect island complexes. The habitats directly above a dam are lacustrine and have been characterized as shallow reservoirs. A transition zone occurs between the upper and lower pools.

The portion of the Upper Mississippi River System (UMRS) which is characterized by locks and dams is experiencing morphological change as the system attempts to reach an equilibrium condition. Erosion of terrestrial island habitats is most notable in the lower portion of a pool and has been attributed to wind fetch and resulting wave action. Sedimentation is thought to occur throughout a pool but seems to be most notable directly below the dams and in the transition zone between the upper and lower pools. The sedimentation process is thought to be responsible for the conversion of aquatic habitats to terrestrial habitats.

Researchers require low-cost, rapid methods of assessing these changes. This investigation was undertaken to determine the utility of using multitemporal Landsat Multispectral Scanner (MSS) data to evaluate changes in the spatial distribution of land and open water on the UMRS over a 20-yr period.

Background

Landsat MSS Description

Photographs acquired during the Mercury and Gemini space missions in the 1960s provided information which, prior to these early orbital flights, had been unavailable to the resource management community. Because of interest in a space perspective, primarily by the U.S. Geological Survey (USGS) and the U.S. Department of Agriculture (USDA), the National Aeronautics and Space Administration (NASA) began design and development of a satellite-based remote sensing system in the mid-1960s (Freden and Gordon, Jr. 1983). In July 1972, NASA launched Earth Resources Technology Satellite-1, now known as Landsat 1. The successful launch and operation of Landsat 2 followed in 1975, and of Landsat 3 in 1978, essentially equivalent systems to Landsat 1.

The primary sensing system aboard Landsats 1-3 was the MSS. The MSS records the spectral response of the Earth's surface in the green (band 4), red (band 5), and two near-infrared (near-IR) wavelengths (bands 6 and 7) at a spatial resolution of 79 x 79 m. Each scene covers an area approximately 185 x 185 km. Analog signals for each band are initially converted to a 6-bit (64-level) digital range.

Near-IR radiation is almost totally absorbed by water and therefore bands recording the near-IR portion of the spectrum are well suited for identifying water bodies. That is, water returns relatively low radiance values in this portion of the spectrum, whereas terrestrial features produce relatively high radiance values. Band 7 (0.8-1.1 µm) was used in this investigation because it is considered the optimum choice for delineating surface water area (Salomonson 1983).

Landsat 4 (launched in 1982) and Landsat 5 (launched in 1984) each contained a second-generation sensor known as the Thematic Mapper (TM). Depending on the application, substantial cost savings occur when Landsat MSS data are chosen over the higher resolution TM (7 bands, 30- x 30-m pixels). For example, 17 Landsat MSS scenes (over 2 yr old) could be purchased at the time of this writing for the cost of one Landsat TM scene. The launch of Landsat 1 (MSS) predated the launch of Landsat 4 (TM) by 10 yr, facilitating long-term analysis needs.

Choosing MSS data on the basis of cost ($200/scene) results in a reduction in spatial and spectral resolution when compared to Landsat TM data. However, this is rapidly becoming a moot point for some applications because pricing of the higher resolution TM data is projected to drop dramatically for Federal users. At the time of this writing, TM data over 10 yr old could be purchased for $190; TM data over 2 yr old was priced between $300 and $500; and new acquisitions cost $2,500 (down from $3,500).

Study Area

Three scenes were purchased from the USGS EROS Data Center (EDC) for this pilot study. The dates of the satellite acquisitions were August 29, 1972, September 18, 1984, and September 8, 1992. The 1984 and 1992 data were acquired by the Landsat 5 satellite and cover the area from north of Winona, Minnesota, to south of Dubuque, Iowa. The 1972 data were recorded by Landsat 1, which had different orbit characteristics than the Landsat 5 satellite. The 1972 data cover the area from just north of Genoa, Wisconsin (lower Pool 8), to south of Dubuque, Iowa. The area coincident in all three time periods defines the geographic scope of this report (lower Pool 8 to upper Pool 12).

Methods

Constraints

This project was initially proposed as a method to identify changes in the land-water boundary. As work progressed, it became obvious that emergent aquatic plant beds could not be differentiated from vegetated islands and that submergent vegetation would have to be included in the open water category. The results, therefore, include information on gains and losses of emergent aquatic plant beds as well as on islands. In addition, open water losses due to accretion (deposition) in off-channel habitats and low velocity channel borders are accounted for.

Rectification

The Landsat scenes were system-corrected prior to shipment from the EDC and include radiometric corrections which compensate for changes in detector gain, and offset and geometric corrections which compensate for the Earth's rotation and variation in spacecraft altitude and attitude. In order to compare spatial datasets between different time periods, they must be registered to a common projection. The Universal Transverse Mercator (UTM) Projection was used (Zone 15, North American Datum 27) for this purpose. The process required identifying ground control points (GCPs) such as road intersections, intersections of roads and streams, and similar features that can be identified both in the satellite data and a map of the area. Map coordinates are recorded for the GCPs as well as the column/row location of the image pixel which represents the same feature.

Atmospheric Correction

Correcting for differences in sun angle and the additive effects of the atmosphere is especially important when multitemporal comparisons are being made (Casellis and Lopez Garcia 1989; Lopez Garcia and Casellis 1990). A simple procedure has been proposed to mitigate for the atmospheric signal caused by Rayleigh (molecular) scattering of downwelling radiation. The formulae proposed by Trautwein (USGS, Sioux Falls, SD, personal communication) are included as Appendix A. The bias introduced by sun angle and atmosphere was calculated for the 1972, 1984, and 1992 datasets using the procedure outlined in Appendix A and subtracted from the original band-7 files.

Water Level Elevations

Remote sensing investigations dealing with change detection issues must address the relationship between water level on the date of acquisition and the information content of the satellite scene. On the Upper Mississippi River, water elevations are recorded at the navigation dams (pool elevations) and directly below the dams (tailwater elevations). Table 1 includes water level information for the dates the satellite scenes were collected. Using 1992 as the year of reference, the average difference between respective pool elevations recorded in 1972 and 1992 is -0.75 ft. The average difference between respective tailwater elevations recorded in 1972 and 1992 is 3.74 ft. In other words, the 1972 average water level elevations directly above a dam were 0.75 ft less than in 1992, while the 1972 average water level elevations directly below the dams were 3.74 ft higher than in 1992. The average water elevation differences between 1984 and 1992 elevations = -0.52 ft pool elevation and -0.34 ft tailwater elevation. Changes mapped immediately below the dams between 1972 and 1984 or 1992 should be viewed as suspect because of the higher tailwater levels associated with the 1972 data.

Based on the Pool 9 data, the impact of differences in water levels is reduced moving downstream (i.e., Dam 9 tailwater = +3.84; McGregor gage = +2.88; Clayton = +1.38).

Table 1. River stage on date of acquisition

Station	River mile	Year	Elevation	Difference in elevation between year of acquisition and 1992
Dam 8 pool	679.32	1972	630.08	-0.89
		1984	630.10	-0.87
		1992	630.97	
Dam 8 tail	679.02	1972	626.34	+3.96
		1984	621.73	-0.65
		1992	622.38	
Lansing	662.97	1972	621.44	+0.90
		1984	619.97	-0.57
		1992	620.54	
Dam 9 pool	648.09	1972	619.31	-0.87
		1984	619.34	-0.84
		1992	620.18	
Dam 9 tail	647.72	1972	617.80	+3.84
		1984	613.64	-0.32
		1992	613.96	
McGregor	633.60	1972	615.62	+2.88
		1984	612.57	-0.17
		1992	612.74	
Clayton	628.80	1972	613.15	+1.38
		1984	no data	
		1992	611.77	
Dam 10 pool	615.20	1972	610.32	-0.85
		1984	610.90	-0.27
		1992	611.17	
Dam 10 tail	615.00	1972	609.16	+3.85
		1984	605.36	+0.05
		1992	605.31	
Cassville	606.30	1972	no data	
		1984	604.39	+0.18
		1992	604.21	
Spechts Ferry	592.30	1972	no data	
		1984	603.03	-0.14
		1992	603.17	
Dam 11 pool	583.10	1972	602.90	-0.38
		1984	603.20	-0.08
		1992	603.28	
Dam 11 tail	583.00	1972	597.00	+3.32
		1984	594.00	+0.32
		1992	593.68	
Dubuque	579.90	1972	no data	
		1984	593.87	+0.33
		1992	593.54	

This problem does not exist when comparing the 1984 data with the 1992 data. The changes identified over the 20-yr period should be viewed in the context of location within a pool and the relationship between location and river stage for the years in question.

Processing

Erdas Imagine software (Erdas, Atlanta, GA) was used for digital image processing. The range of band-7 digital numbers (DNs) describing water and submergents was identified interactively. Data representing each year were displayed on the monitor as a pseudocolor (8-bit) image. Beginning with 0 and incrementing a count at a time, the DNs were assigned to the open water class up to the point where streamside hill shadows would be inappropriately identified as the water/submergent class. To extract the water/submergent class for 1972 data, a range of 0-9 DNs was used; for 1984 and 1992 data, the range was 0-18. A new binary file representing open water/submergents and a background class (not water/submergents) was created for each year based on these ranges.

The binary files were edited to remove all water pixels lying outside the Mississippi River floodplain. The water/submergent files were then recoded to show water locations for each year, with 1972 = 1, 1984 = 2, and 1992 = 4. Files were then summed, creating a composite file with the following classes:

Class value	Description
1	Water only in 1972
2	Water only in 1984
3	Water in 1972 and 1984
4	Water only in 1992
5	Water in 1972 and 1992
6	Water in 1984 and 1992
7	Water in 1972, 1984, and 1992

Visual inspection of a display of this seven-class file indicated a large number of single, isolated pixels representing change. Based on geometry and distribution, these changes were identified as possibly being related to sensor noise, misregistration of the images, or to mixed pixels being omitted as a water class in one or two time periods. Because the pilot study was interested in identifying changes which could be substantiated by referencing historical aerial photography, a decision was made to eliminate any apparent change unless it was represented by four or more contiguous pixels, which equates to changes of ≥2.56 hectares.

The removal of isolated pixels was accomplished by assigning a unique identifier to each contiguous group of pixels representing a class. The file was then recoded as a binary image, where groups of four or more pixels were assigned a value of 1 and groups of one to three pixels were assigned a value of 0. The original seven-class file was then multiplied by this binary file to create a seven-class file which only included changes of ≥2.56 hectares. Figure 1 illustrates the results of this process for lower Pools 8 and 9.

Results

Explanation of Classes

Figure 1 includes all seven of the aforementioned possible combinations ≥2.56 hectares for the 3 yr under investigation for lower Pools 8 and 9. Table 2 includes summary information for the entire study area. Both the original and modified (≥2.56 hectares) statistics are provided.

The following description of the changes which have occurred over a 20-yr period are based on the modified file. The class "water only in 1972" represents areas where open water was mapped in 1972 but no open water was mapped in 1984 or 1992. These areas generally represent off-channel habitats located midpool and above. Over 1,035 hectares of open water were lost between 1972 and 1984, presumably to sedimentation. "Water only in 1984" and "water only in 1992" represent the same

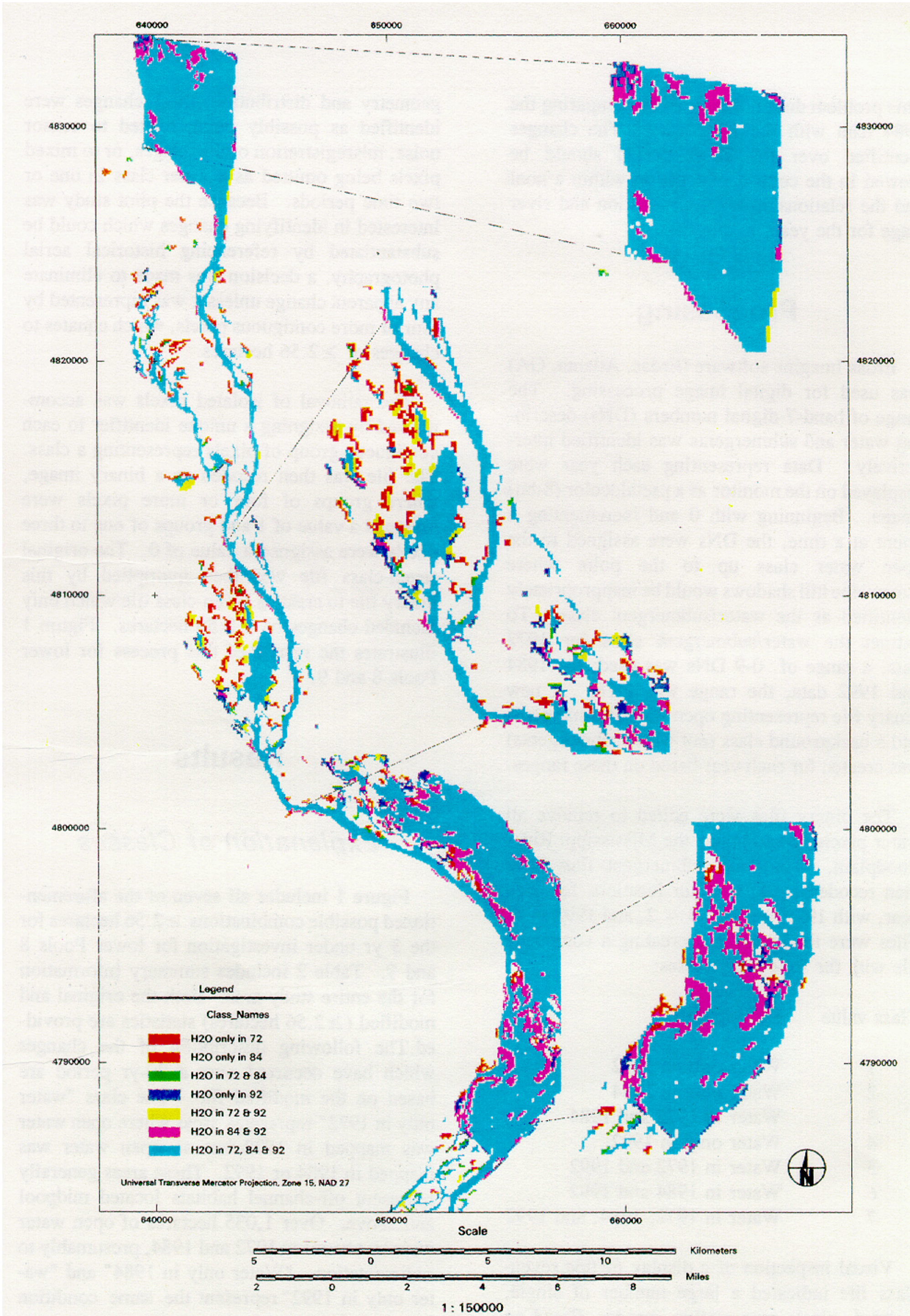

Figure 1. Water gains and losses, lower Pool 8 and Pool 9: 1972, 1984, 1992

Table 2. Open water conditions: 1972, 1984, and 1992

Class value/ description	Number of cells	Hectares	Percent
	All changes		
1 Water only in 1972	3,284	2,102	7
2 Water only in 1984	2,752	1,761	6
3 Water in 1972 and 1984	2,156	1,380	4
4 Water only in 1992	2,214	1,417	4
5 Water in 1972 and 1992	1,685	1,078	3
6 Water in 1984 and 1992	4,223	2,703	8
7 Water in 1972, 1984, and 1992	33,614	21,513	67
Total	49,928	31,954	
	Changes ≥2.56 hectares		
1 Water only in 1972	1,618	1,036	4
2 Water only in 1984	1,018	652	2
3 Water in 1972 and 1984	791	506	2
4 Water only in 1992	845	541	2
5 Water in 1972 and 1992	529	339	1
6 Water in 1984 and 1992	2,775	1,776	7
7 Water in 1972, 1984, and 1992	33,239	21,273	81
Total	40, 815	26,123	

condition for the respective year. The former seems to represent the dynamic nature of the system (652 hectares) while the latter indicates additional losses of plant beds/islands between 1984 and 1992 (541 hectares) and may also represent areas which were excavated/manipulated over the 8-yr period. "Water in 1972 and 1984" represents areas where open water existed in both years but not in 1992 (506 hectares). Based on location within the pools and the similarity of water levels between 1984 and 1992, this class seems to be related to sedimentation. "Water in 1972 and 1992" illustrates the condition where water was mapped at the extremes of the time line but not in 1984 (339 hectares). This class again illustrates the dynamic nature of the system. "Water in 1984 and 1992" shows areas where plant beds/islands existed in 1972 and were replaced by open water in 1984 which persisted through 1992 (1,776 hectares). This class is generally restricted to the lower pools and may represent the results of wind fetch on plant beds and islands. "Water in 1972, 1984, and 1992" represents areas which were mapped as open water in all three time periods (21,273 hectares).

Open Water Gains and Losses

To simplify interpretation of the multitemporal dataset, the seven classes represented in Figure 1 were recoded to represent open water gains and losses between 1972 and 1984 and between 1984 and 1992.

The seven classes were recoded as follows:

1	Water only in 1972	=	loss between 1972 and 1984
2	Water only in 1984	=	gain between 1972 and 1984
		=	loss between 1984 and 1992
3	Water in 1972 and 1984	=	loss between 1984 and 1992
4	Water only in 1992	=	gain between 1984 and 1992
5	Water in 1972 and 1992	=	loss between 1972 and 1984
		=	gain between 1984 and 1992
6	Water in 1984 and 1992	=	gain between 1972 and 1984
7	Water in 1972, 1984, and 1992	=	no gain or loss

Tables 3 and 4 summarize gains and losses between 1972 and 1984 and between 1984 and 1992, respectively. Both unmodified and modified (changes ≥2.56 hectares) statistics are provided. Figure 2 shows the spatial distribution of these gains and losses for the study area between 1972 and 1984 which are ≥2.56 hectares.

Quality Assurance

Historical color infrared aerial photography at scales between 1:15000 and 1:24000 was referenced in the process of defining the range of DNs attributable to the open water/submergent class for each time period. To evaluate the success of the Landsat MSS in defining the open water/submergent class, historical data for Pool 9 were evaluated. Geographic information system vector coverages representing the land-water boundary were available for 1975 and 1983; no historical data were available for 1992.

The digital files representing 1975 water classes and the 1972 Landsat water class were compared for spatial coincidence using ARC/INFO software (ESRI, Redlands, CA) to convert the 1975 vector data to a raster (grid) format. The 1975 "groundtruth" data (GREAT I land cover; Appendix B) were converted to a raster format with a cell size of 80 m and compared pixel-for-pixel with the 1972 satellite data. The 1975 land cover classes (open water, *Lemnaceae-Ceratophyllum-Potamogeton*, *Lemnaceae-Ceratophyllum*, and *Vallisneria-Potamogeton-Heteranthera*) were used for the comparison with the Landsat-derived open water/submergents class.

The results of this analysis appear in Table 5 and indicate that 71% of the cells matched as a water class. Errors of omission and commission are almost identical. The high error rate is unusual for a water class because the reflectance of water is markedly different than the reflectance of plants or bare surfaces. An additional test comparing the 1972 unmodified area totals to area totals for the 1975 digital land cover data indicated the 1975 Pool 9 water total = 8,963 hectares, the 1972 Landsat Pool 9 water total = 8,665 hectares, and (8,665/8,963) x 100 = 97%. Possible sources of error include (1) the difference of 3 yr between the satellite data and groundtruth data, (2) differences in water surface elevation in August 1973 versus July 1975, (3) the rules used by the photointerpreters to generate the 1975 land cover database, (4) the vector to raster conversion, and (5) errors of omission and commission.

The USGS 1:100,000-scale hydrography data generated from maps which were photo-revised in 1982-1983 were used to evaluate the 1984 unmodified satellite data. The 1982-1983 USGS hydrography data were converted to a raster format with a cell size of 80 m. The digital files representing the 1982-1983 water class and the 1984 Landsat water class were also compared for spatial coincidence.

Table 3. Open water gains and losses: 1972 to 1984

Class value/ description	Number of cells	Hectares	Percent
	All gains and losses		
1 Water loss, 1972 to 1984 (1,5)	4,969	3,180	10
2 Water gain, 1972 to 1984 (2,6)	6,975	4,464	15
3 Water, 1972 and 1984 (3,7)	35,570	22,893	75
Total	47,714	30,537	
	Gains and losses ≥2.56 hectares		
1 Water loss, 1972 to 1984	2,147	1,374	5
2 Water gain, 1972 to 1984	3,793	2,428	9
3 Water, 1972 and 1984	34,030	21,779	85
Total	39,970	25,581	

Table 4. Open water gains and losses: 1984 to 1992

Class value/ description	Number of cells	Hectares	Percent
	All gains and losses		
1 Water loss, 1984 to 1992 (2,3)	4,908	3,141	11
2 Water gain, 1984 to 1992 (4,5)	3,899	2,495	8
3 Water, 1984 and 1992 (6,7)	37,837	24,216	81
Total	46,644	29,852	
	Histogram *Gains and losses >2.56 hectares*		
1 Water loss, 1984 to 1992	1,809	1,158	5
2 Water gain, 1984 to 1992	1,374	879	3
3 Water, 1984 and 1992	36,014	23,049	92
Total	39,197	25,086	

The results of this analysis indicate that 73% of the cells matched as a water class (Table 6). Errors of omission and commission are very close. The test comparing the 1984 unmodified area totals to area totals for the 1982-1983 hydrography data indicate the 1983 USGS data mapped as open water = 9,085 hectares, the 1984 Landsat MSS total = 9,157 hectares, and (9,085/9,157) x 100 = 99%. Possible sources of error include (1) the 1982-1983 photo-revision process, (2) differences in water levels, (3) the USGS mapping convention for the identification and mapping of open water, (4) the vector to raster conversion, and (5) errors of omission and commission.

In both instances, the first row in Tables 5 and 6 identifies errors of omission or the sum of areas which were classified as water in the groundtruth data but not in the satellite data. The second row identifies errors of commission or the sum of areas identified as water in the satellite data but not in the groundtruth data.

Table 5. Spatial coincidence between 1975 groundtruth data and 1972 satellite data, Pool 9

	Number of cells	Hectares	Percent
Water in 1975 and not 1972	2,304	1,475	14
Water in 1972 and not 1975	2,367	1,515	14
Water in 1972 and 1975	11,665	7,466	71
Total	16,336	10,456	

Table 6. Spatial coincidence between 1982-1983 groundtruth data and 1984 satellite data, Pool 9

	Number of cells	Hectares	Percent
Water in 1983 and not 1984	1,873	1,199	12
Water in 1984 and not 1983	2,361	1,511	15
Water in 1983 and 1984	11,619	7,436	73
Total	15,853	10,146	

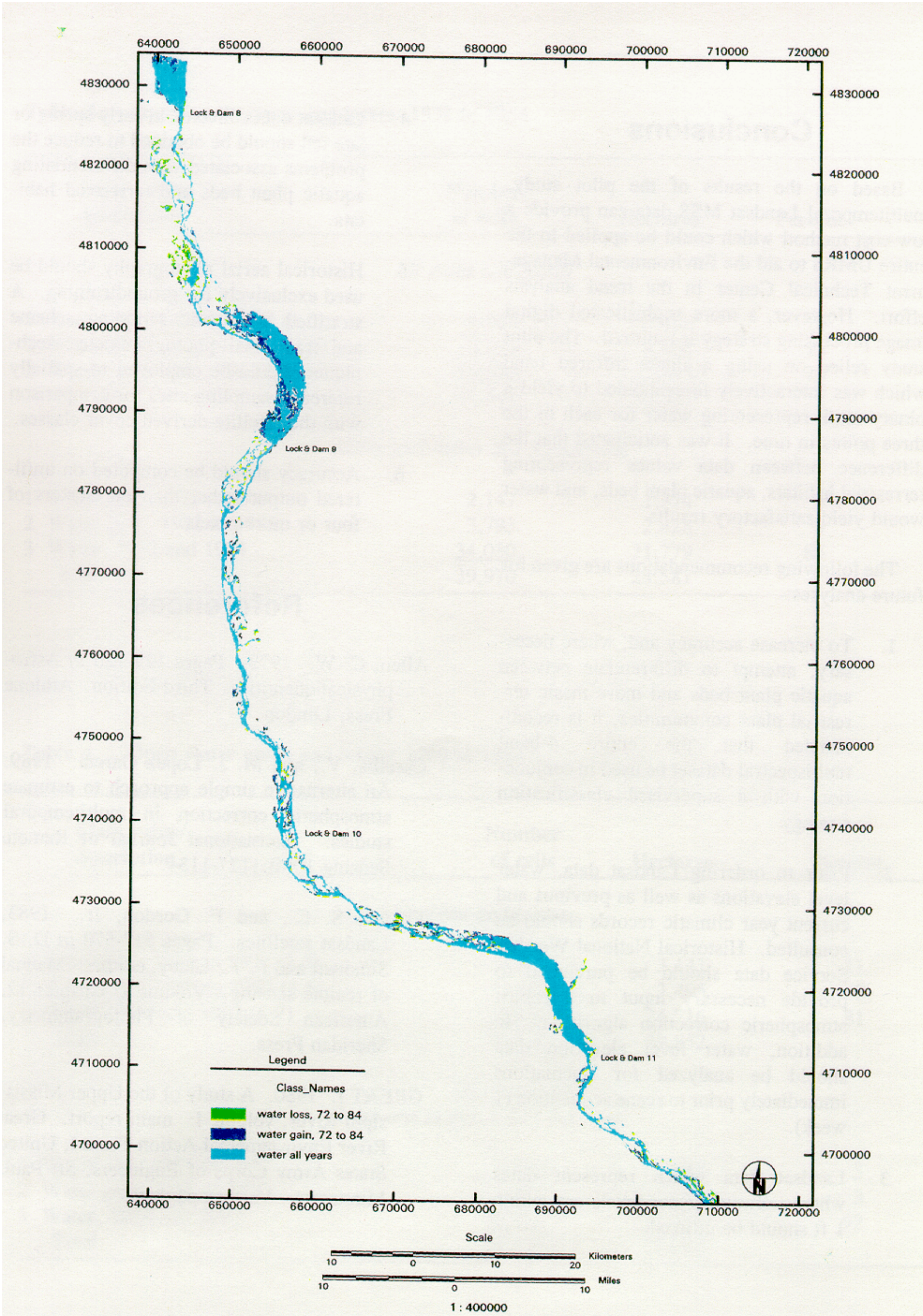

Figure 2. Open water gains and losses: 1972 to 1984

Conclusions

Based on the results of the pilot study, multitemporal Landsat MSS data can provide a low-cost method which could be applied to the entire UMRS to aid the Environmental Management Technical Center in the trend analysis effort. However, a more sophisticated digital image processing strategy is required. The pilot study relied on using a single infrared band which was interactively threshholded to yield a binary mask representing water for each of the three points in time. It was anticipated that the difference between data values representing terrestrial habitats, aquatic plant beds, and water would yield satisfactory results.

The following recommendations are given for future analyses:

1. To increase accuracy and, where necessary, attempt to differentiate between aquatic plant beds and more mesic terrestrial plant communities, it is recommended that the entire 4-band multispectral dataset be used in conjunction with a supervised classification strategy.

2. Prior to ordering Landsat data, water level elevations as well as previous and current year climatic records should be consulted. Historical National Weather Service data should be purchased to provide necessary input to a robust atmospheric correction algorithm. In addition, water level elevation data should be analyzed for fluctuations immediately prior to scene acquisition (1 week).

3. Landsat data which represent dates where tailwater water levels are within 1 ft should be utilized.

4. Landsat data collected in early spring or late fall should be obtained to reduce the problems associated with differentiating aquatic plant beds and terrestrial habitats.

5. Historical aerial photography should be used exclusively for groundtruthing. A stratified systematic sampling scheme and traditional photogrammetric techniques should be employed to spatially reference sampling sites for comparison with the satellite-derived cover classes.

6. Accuracy should be computed on unfiltered output rather than on clusters of four or more pixels.

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Appendix A

Formulae Used to Correct for Sun Angle and Atmospheric Scattering

for MSS, band 7 is as follows:

$$B_{MSS7} = 63.5 \left[1\text{-}e^{-0.0107 \csc(\alpha)}\right]$$

where α is the elevation angle of the sun.

The following formula was used for the 1972 6-bit data:

$$B_{MSS7} = 31.5 \left[1\text{-}e^{-0.0107 \csc(\alpha)}\right]$$

The scattering coefficient is derived from the following equation:

$$\sigma_s = 1.04 \times 10^5 (n-1)^2/\lambda^4$$

where n is the refractive index of air and λ is the wavelength in micrometers (midpoint of bandpass). The refractive index is based on mean atmospheric conditions where t = 0 °C, p = 760 mmHg, and water vapor pressure f = 4 mmHg (Allen 1973).

Appendix B

Great River Environmental Action Teams I, II, and III (1970s) Land Cover/Land Use Classification List

Version 2.05
21 January 1994

The Great River Environmental Action Teams (GREAT) of the late 1970s were comprised of individuals from:

Bureau of Outdoor Recreation, Ann Arbor, MI
Department of Transportation, St. Louis, MO
Environmental Protection Agency, Chicago, IL
Minnesota-Wisconsin Boundary Area Commission, Hudson, WI
Soil Conservation Service, Des Moines, IA
State of Illinois, Department of Conservation, Springfield, IL
State of Iowa, Iowa Conservation Commission, Des Moines, IA
State of Minnesota, Minnesota Department of Natural Resources, St. Paul, MN
State of Missouri, Department of Natural Resources, Jefferson City, MO
State of Wisconsin, Department of Natural Resources, Madison, WI
Upper Mississippi River Conservation Committee, Rock Island, IL
U.S. Army Corps of Engineers, Rock Island, IL
U.S. Army Corps of Engineers, St. Louis, MO
U.S. Army Corps of Engineers, St. Paul, MN
U.S. Environmental Protection Agency, Kansas City, MO
U.S. Fish and Wildlife Service, St. Paul, MN
U.S. Fish and Wildlife Service, Rock Island, IL

GREAT I (1980) studied the Upper Mississippi River System (UMRS) from St. Paul/Minneapolis, MN, to Guttenberg, IA. GREAT II (1980) studied the UMRS from Guttenberg, IA, to Saverton, MO. GREAT III (1982) studied the UMRS from Saverton, MO, to the confluence with the Ohio River.

One of the main objectives of the GREAT research teams was to evaluate current resource management practices, then develop a series of management strategies. One of the problems facing GREAT was the lack of available information on many of the river's components. One project implemented by GREAT was the creation of a land cover/use database derived from aerial photography.

In 1975, 1:9,600-scale color-infrared photography was collected for UMRS Pools 3 through 10, and 1:24,000-scale color-infrared photography from Lock and Dam 10 to the confluence with the Ohio River. In 1978, 1:24,000-scale color infrared photography was collected for Pools 1 and 2. All photographs were groundtruthed and interpreted, then data for Pools 1 through 14 were automated. During the automation process, interpreted data were transferred to 1:24,000-scale U.S. Geological Survey quad maps, then entered into a computer using the geographic information system (GIS) PIOS. As the data were transferred, they were generalized to create coverages with a minimum mapping unit of 2.5 acres. Some polygons smaller than 2.5 acres and linear features were incorporated into nearby polygons. Others were manually enlarged so that the data contained within them would be preserved. All generalizations were made in accordance with guidelines established for GREAT projects. Individuals working for the GREAT projects worked extensively with the automated data. One project converted the genus-level automated data into genus/species data. The PIOS data were then converted into ARC/INFO format by the Long Term Resource Monitoring Program (LTRMP).

The LTRMP has copies of the mylar overlays created by GREAT's photointerpreters. In 1992, the LTRMP commissioned the National Ecology Research Center (NERC) to computerize the data for Pools 19, 26, and LTRMP's Open River study reach. NERC transferred the data to 1:24,000-scale quadrangles, then automated them using the GIS program ARC/INFO.

Differences do exist between the two datasets. Coverages automated by NERC were attributed according to the classification scheme used by the photointerpreters, not the enhanced genus/species scheme developed by the GREAT project. A comparison listing of the two classification schemes appears at the end of this document.

Each land cover/use type has been assigned a numeric classification code. The codes relate the GREAT data to the LTRMP classification scheme. The LTRMP utilizes a genus-level classification scheme for its aerial photography, and has developed a 13-class generalized classification scheme for regrouping similar land cover types. An explanation of the coding system follows.

- Each LTRMP generalized vegetation group has been assigned a number that is a multiple of 100. Example: Open Water is 100, Submergents is 200.

- Each vegetation type has been assigned a numeric value relating it to the 13 vegetation groups. Example: The submergent *Myriophyllum* (Water Milfoil) is 202.

- Vegetation types unique to historical coverages have been assigned values of 50 or above. Example: *Sagittaria latifolia* (Broad Arrowhead) is 751. The 700 portion of the number signifies that *Sagittaria latifolia* is an Emergent, while the 51 signifies that this vegetation class is not in use by LTRMP photointerpreters.

- A single bold asterisk (*****) after a type description signifies a vegetation type utilized only within the enhanced GREAT coverages (Pools 1-14).

- A double bold asterisk (******) after a type description signifies a vegetation type utilized only within the GREAT coverages automated by NERC (Pools 19, 26, and the Open River study reach).

****

100 Open Water - Any unvegetated body of water. All 100-numbered water types within the 13-class land cover/land use coverages are grouped into Open Water. Note: Industrial ponds are classified under Urban/Developed (1200's).

101 Lemnaceae - Duckweed (floating) - Duckweed has been assigned an Open Water classification because of its mobile tendencies; Duckweed goes wherever the wind takes it.

150 Lake** - Note: Some artificial ponds have been grouped with the Urban classes (1200's).

****

200 Submergents** - Used to classify any area with submergent vegetation whose species composition is unknown. All 200-numbered submergents within the 13-class land cover/land use coverages are grouped into Submergents. Note: The order in which plant combinations are listed does not reflect plant dominance.

201 Lemnaceae/submergents** - Duckweed/submergent vegetation mixture

250 Vallisneria/Potamoget/Heteran* - Wild Celery/Pondweed/Water Stargrass mixture

251 Ceratophyllum* - Coontail

252 Lemnaceae/Ceratophyllum* - Duckweed/Coontail mixture

253 Lemna/Ceratophyll/Potamogeton* - Duckweed/Coontail/Pondweed mixture

254 Potamogeton* - Pondweed

255 Vallisneria - **Wild Celery** - This vegetation class, while contained in the classification list for the enhanced coverages, has not been located in any of the automated coverages.

****

300 Submerg-Rooted Floating Aqua

- This class is used only to regroup 300-numbered Submergent-Rooted Floating Aquatics for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages. <u>Note:</u> The order in which plant combinations are listed does not reflect plant dominance.

350 Nelumbo/Lemna/Ceratophyllum* - American Lotus/Duckweed/Coontail mixture

351 Nymphaea/Ceratophy/Potamogeton* - White Water Lily/Coontail/Pondweed mixture

352 Nymph/Ceratophy/Potamog/Lemna* - White Water Lily/Coontail/Pondweed/Duckweed mixture

****

400 Submerg-Rooted Floating-Emerg

- This class is used only to regroup all 400-numbered Submergent-Rooted Floating Aquatic-Emergents for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages. <u>Note:</u> The order in which plant combinations are listed does not reflect plant dominance.

450 Sag latif/Lemna/Ceratophyllum* - Broad Arrowhead/Duckweed/Coontail mixture

****

500 Rooted Floating Aquatics

- This class is used only to regroup all 500-numbered Rooted/Floating Aquatics for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages. <u>Note:</u> The order in which plant combinations are listed does not reflect plant dominance.

502 Jussiaea** - Water Primrose

503 Nelumbo - American Lotus

504 Nelumbo/Lemnaceae** - American Lotus/Duckweed mixture

507 Nymphaea* - White Water Lily

****

700 Emergents

- This class is used only to regroup all 700-numbered Emergents for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages. <u>Note:</u> The order in which plant combinations are listed does not reflect plant dominance.

703 Cyperus* - Flat Sedge

709 Sagittaria** - Arrowhead

714 Scirpus - Bulrush

717 Sedge meadow* - A very wet meadow dominated by sedges. Other emergents may be mixed within.

718 Sparganium* - Bur Reed

719 Typha - Cattail

722 Typha/Scirpus/Sparganium* - Cattail/Bullrush/Bur Reed mixture

724 Zizania* - Wild Rice

751 Sagittaria latifolia* - Broad Arrowhead or Duck Potato

752 Sagittaria rigida* - Stiff Arrowhead

753 Sag latifolia/Sag rigida* - Broad Arrowhead/Stiff Arrowhead

754 Scirpus/Sagittaria latifolia* - Bulrush/Broad Arrowhead

****

800 Emergents-Grasses/Forbs - This class is used only to regroup all 800-numbered Emergents-Grasses/Forbs for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages. Note: The order in which plant combinations are listed does not reflect plant dominance.

811 Scirpus/Phragmites* - Bulrush/Common Reed mixture

812 Scirpus/Polygonum* - Bulrush/Smartweed mixture

850 Sagittaria latifolia/Phalaris* - Broad Arrowhead/Reed Canary Grass mixture

851 Leers/Carex/Sag latifolia/Poly* - Cutgrass/Sedges/Broad Arrowhead/Smartweed mixture

852 Scirp/Echinocyst/Xanthium/Poly* - Bulrush/Cucumber family/Cocklebur/Smartweed mixture

****

900 Grasses/Forbs - Non-woody plants. This class is used only to regroup all 900-numbered Grasses/Forbs for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages. Note: The order in which plant combinations are listed does not reflect plant dominance.

901 Ambrosia - Ragweed - This vegetation class, while contained in the classification list for the enhanced coverages, has not been located in any of the automated coverages.

902 Grass* - Used to delineate areas of mixed grasses. Abandoned/set-aside fields are also placed within this class.

904 Pasture (heavily grazed areas)* - "Hay fields" regularly pastured with cattle or similar livestock.

905 Leersia - Cutgrass

907 Meadow* - Upland areas regularly cut and baled for hay.

908 Mixed forbs and/or grasses** - Class used to describe a mixture of many different Grasses and Forbs.

910 Phalaris* - Reed Canary Grass

912 Phragmites* - Common Reed

914 Polygonum - Smartweed

916 Rdside-levee/grass/forbs/shrub - Any roadside ditch or levee. Example of a roadside: Delineation of a north/south roadway would begin on the far west side of the western ditch and go to the far eastern side of the eastern ditch. Both ditches and the road are included within the same polygon.

918 Spartina* - Cord Grass

919 Vines as dense overgrowth - Any live stem vine growing as a dense covering. Within LMIC's coverages, *Echinocystis* (Wild Cucumber) and Brush covered with *Echinocystis* were grouped into 919. The class is utilized "as is" in the coverages automated by NERC.

****

1000 Woody Terrestrial - All trees and shrubs. This class is used only for regrouping all the Woody Terrestrial vegetation for the 13-class land cover/land use coverages. This class does not appear in any GREAT coverages. <u>Note:</u> The order in which plant combinations are listed does not reflect plant dominance.

1005 Brush - Any small shrubby species

1007 Cephalanthus** - Button Bush

1011 Plantation - Any group of planted, cultivated trees. Examples include apple orchards, Christmas tree farms, and stands of planted pines.

1014 Salix* - Willows

1055 >50% Cottonwd &/or Willow <20' - This class is used to classify stands of *Populus* and/or *Salix* trees under 20 feet tall which cover at least 50% of the polygon.

1056 >50% Cottonwd &/or Willow >20' - This class is used to classify stands of *Populus* and/or *Salix* trees over 20 feet tall which cover at least 50% of the polygon.

1057 >50% Lowland Hardwoods <20' - This class is used to classify stands of Mesic hardwood under 20 feet tall which cover at least 50% of the polygon.

1058 >50% Lowlnd Hardwds >20'-grass - This class is used to classify stands of Mesic hardwood over 20 feet tall which cover at least 50% of the polygon and have an understory of grasses.

1059 >50% Lowland Hardwoods >20' - This class is used to classify stands of Mesic hardwood over 20 feet tall which cover at least 50% of the polygon.

1060 Sagittaria latifolia/Salix* - Broad Arrowhead/Willow mixture

****

1100 Agriculture - Any cultivated field that is either turned with a plow or worked with a disk. Crops include corn, soybeans, and oats. LMIC's class Cropland-Farmstand has been assigned to Agriculture.

****

1200 Urban/Developed - Any area "developed" by humans. This class is used only to regroup all 1200-numbered Urban classes for use in the 13-class generalized land cover/land use coverages. This class does not appear in any GREAT coverages.

1201 Developed** - Shopping malls, industrial parks, military depots, farmsteads, storage facilities, and isolated industrial sites (built in the middle of a rural area) are considered Developed.

1202 Developed parks** - City and state parks are included in this category but only those areas actively used by humans. Examples are picnic areas, campgrounds, administrative buildings, and interpretive complexes.

1203 Industrial pond - Examples of industrial ponds are water coolant ponds and fish ponds actively managed for industrial or research use (i.e., fish farms and hatcheries).

1204 Urban* - Residential areas, including schools.

1250 Farm Pond

1251 Residential**

****

1300 Sand/Mud - This class is used only to regroup all 1300-numbered Sand/Mud classes for use in the 13-class generalized land cover/land use coverages. This class does not appear in any of the GREAT coverages.

1301 Mud - Mud

1303 Sand - Sand

****

1450 Unknown - Polygons whose attributes were either lost or indecipherable.

Land Cover/Land Use - Pools 1 through 14

- Created from interpreted photos, then modified by the GREAT program -

Descriptions appear as listed within the coverages

Brush
Ceratophyllum (Coontail)
Cottonwood and/or Tree Willow (ave. ht. > 20 ft.)
Cottonwood and/or Willow (ave. ht. < 20 ft.)
Cropland-Farmsteads
Cyperus (Nut Grass)
Echinocystis (Wild Cucumber)
Farm Pond
Grassland
Improved-Pasture
Industrial Pond
Leersia (Rice Cutgrass)
Leersia-Carex-Sagittaria latifolia-Polygonum
Lemnaceae (Duckweed)
Lemnaceae-Ceratophyllum
Lemnaceae-Ceratophyllum-Potamogeton
Mixed Lowland Hardwood (ave. ht. > 20 ft.)
Mixed Lowland Hardwoods (ave. ht. < 20 ft.)
Mud
Nelumbo (American Lotus)
Nelumbo-Lemnaceae-Ceratophyllum
Nymphaea (Waterlily)
Nymphaea-Ceratophyllum-Potamogeton
Nymphaea-Ceratophyllum-Potamogeton-Lemnaceae
Open Water
Open stand of Mixed Hardwoods with Grass Understory
Phalaris (Reed Canary Grass)
Phragmites (Reed Grass)
Polygonum (Smartweed)
Potamogeton (Pondweed)
Roadside Levee Grass and Brush
Sagittaria latifolia (Broadleaf Arrohead)
Sagittaria latifolia - Phalaris
Sagittaria latifolia - S. rigida
Sagittaria latifolia - Salix
Sagittaria latifolia-Lemnaceae-Ceratophyllum
Sagittaria rigida (Bur Arrowhead)
Salix Willow
Sand (> 90% bare sand)
Scirpus (Bulrush)
Scirpus-Echinocystis-Xanthium-Polygonum
Scirpus-Phragmites
Scirpus-Polygonum
Scirpus-Sagittaria-latifolia
Sedge Meadow
Sparganium (Bur-reed)
Spartina (Cord Grass)
Tree Farm
Type 35 covered by Echinocystis
Typha (Cattail)
Typha - Scirpus - Sparganium
Unknown
Upland Meadow
Urban
Vallisnaria-Potamogeton-Heteranthra
Zizania (Wild Rice)

Land Cover/Land Use - Pools 19, 26, and Open River Study Reach

- Created from interpreted photos -

Descriptions appear as listed within the coverages

>50% Cottonwd &/or Willow <20'
>50% Cottonwd &/or Willow >20'
>50% Lowland Hardwoods <20'
>50% Lowland Hardwoods >20'
Agriculture
Brush
Cephalanthus
Developed
Developed park
Farm Pond
Grasses/Forbs
Industrial pond
Jussiaea
Lake
Leersia
Lemnaceae
Lemnaceae/Submergents
Lemnaceae/submergents
Mixed forbs and/or grasses
Mud
Nelumbo
Nelumbo/Lemnaceae
Plantation
Polygonum
Potamogeton
Rdside-levee/grass/forbs/shrub
Residential
Sagittaria
Sand
Scirpus
Submergents
Typha
Unknown
Vines as dense overgrowth
Water

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13. ABSTRACT (Maximum 200 words)

Landsat Multispectral Scanner data representing conditions in 1972, 1984, and 1992 were processed to identify open water conditions. The study area included the Upper Mississippi River floodplain between Genoa, Wisconsin, and south of Dubuque, Iowa. Data were analyzed to identify changes which occurred over the 20-yr period and these changes have been combined to represent gains and losses. Gains generally equate to a loss of aquatic plant beds and islands in the lower pools (erosion), while losses are generally restricted to off-channel habitats and represent the effects of sedimentation. Between 1972 and 1992, gains totaled 6,959 hectares; losses totaled 6,321 hectares.

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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information to maintain the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the National Biological Service, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.