Long Term Resource Monitoring Program

Technical Report

93-T003

An Aquatic Habitat Classification System for the Upper Mississippi River System

May 1993

An Aquatic Habitat Classification System for the Upper Mississippi River System

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May 1993

This report is related to the efforts of the Ecological Research and Evaluation Division, Environmental Management Technical Center. At the time of publication of this report, Robert L. Delaney was Program Manager, Barry W. Drazkowski was Deputy Program Manager, Dr. John W. Barko was Technical Director, Dr. Ken Lubinski was Manager of the Population and Community Ecology Group, and Terry D'Erchia was report editor.

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

The standard review procedure for Long Term Resource Monitoring Program Technical Reports includes internal review by selected Environmental Management Technical Center staff members, as well as review by at least three external scientists competent in the appropriate discipline(s).

Cover graphic
by Craig Nichols

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 U.S. Fish and Wildlife Service, in cooperation with the five Upper Mississippi River System states, Illinois, Iowa, Minnesota, Missouri, and Wisconsin, with guidance and program responsibility provided by the U.S. Army Corps of Engineers.

The mission of the LTRMP is to provide decision makers with information to maintain the Upper Mississippi River System (UMRS) as a viable 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.

The aquatic habitat classification system described here was initiated as part of Task PA(S)1: *Classify Upper Mississippi River System backwater areas according to geomorphological, hydrological and biotic characteristics* as described in the original Operating Plan for the LTRMP (Rasmussen and Wlosinski 1988). The classification system was meant to identify and define standard categories of aquatic habitats for establishing subsequent research and monitoring designs, and for creating selected map coverages in the LTRMP geographic information system.

Modifications to this aquatic habitat classification system, if necessary, will be based on data collected under strategies associated with monitoring floodplain elevation, aquatic and terrestrial vegetation, sediment composition, and aquatic and floodplain habitat (USFWS 1992).

This report should be cited as:

Wilcox, D. B. 1993. An aquatic habitat classification system for the Upper Mississippi River System. U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin. EMTC 93-T003. 9 pp. + Appendix A.

Abstract

A classification system for aquatic habitat in the Upper Mississippi River System (UMRS) is needed for inventory, research, impact assessment, and management purposes. The comprehensive system of aquatic habitat classification proposed here has a hierarchical structure to facilitate habitat mapping and inventory at different spatial scales and varying levels of resolution. The classification system is based on geomorphic features of large floodplain rivers, constructed features of the UMRS, and physical and chemical characteristics of aquatic habitat.

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Introduction

The Upper Mississippi River System (UMRS) includes the navigable portions of the Mississippi River above the mouth of the Ohio River, the Illinois River, and the lower reaches of the Minnesota, St. Croix, Black, and Kaskaskia Rivers (Fig. 1). The UMRS upstream of St. Louis, Missouri, has been canalized by a series of locks and dams to maintain a minimum 2.74-m (9-ft) navigation channel. The UMRS downstream of Lock and Dam 26 near St. Louis, Missouri, is unimpounded but constrained by revetments, channel-training structures, and levees. Channel-training structures, revetments, levees, headwater reservoirs, and the navigation dams have imposed a regulated flow regime and a set of anthropic aquatic habitat conditions. However, despite these alterations, aquatic habitat in the UMRS retains many characteristics of large floodplain rivers.

The UMRS, like other large river systems, contains a dynamic mosaic of aquatic habitat. Measuring, mapping, and evaluating aquatic habitat in a large river system is a challenging but necessary effort for impact assessment, research, and management purposes, and to allow stratification of sampling. There is also a need to quantify different classes of aquatic habitat in computer geographic information systems (GIS) for a variety of applications to investigate habitat distributions at various spatial scales.

Nord (1967) and Sternberg (1971) distinguished large-scale aquatic areas of the UMRS based on geomorphic and navigational features of the river: main channel, channel borders, tailwaters, side channels, river lakes and ponds, and sloughs. Archer et al. (1980) and Carter et al. (1985) devised a similar classification scheme for mapping Colorado River aquatic habitat, with more emphasis on geomorphic features. Cobb and Clark (1980) and Cobb (1989) developed an aquatic habitat classification system for the Lower Mississippi River, describing aquatic zones (areas) based on geomorphic and navigational features of the river. Leopold et al. (1964) and Hutchinson (1957) classified river floodplain waterbodies according to their geomorphic origins. Amoros et al. (1987) considered the complex nature of fluvial systems and the need for resolution at different spatial scales.

The Sternberg (1971) classification for the UMRS was designed to describe fish habitat, to orient investigators to broad areas of similar habitat, and to institute standard definitions. The classification system met these objectives and has served UMRS fisheries investigators well. This classification system is not comprehensive, however, because it does not address smaller spatial scales of aquatic habitat. For example, channel borders are spatially large areas that extend the length of the river system, containing natural banks, revetments, channel-training structures, and a variety of depth, substrate, and current velocity conditions. Also, the names of aquatic areas in the Sternberg (1971) classification are not widely used to describe floodplain waterbodies.

Aquatic habitat in large rivers can be described at a large-scale level by aquatic areas. Sternberg (1971), Archer (1980), and Cobb and Clark (1980) all used similar descriptions of aquatic areas, based primarily on large-scale geomorphic characteristics of floodplain rivers.

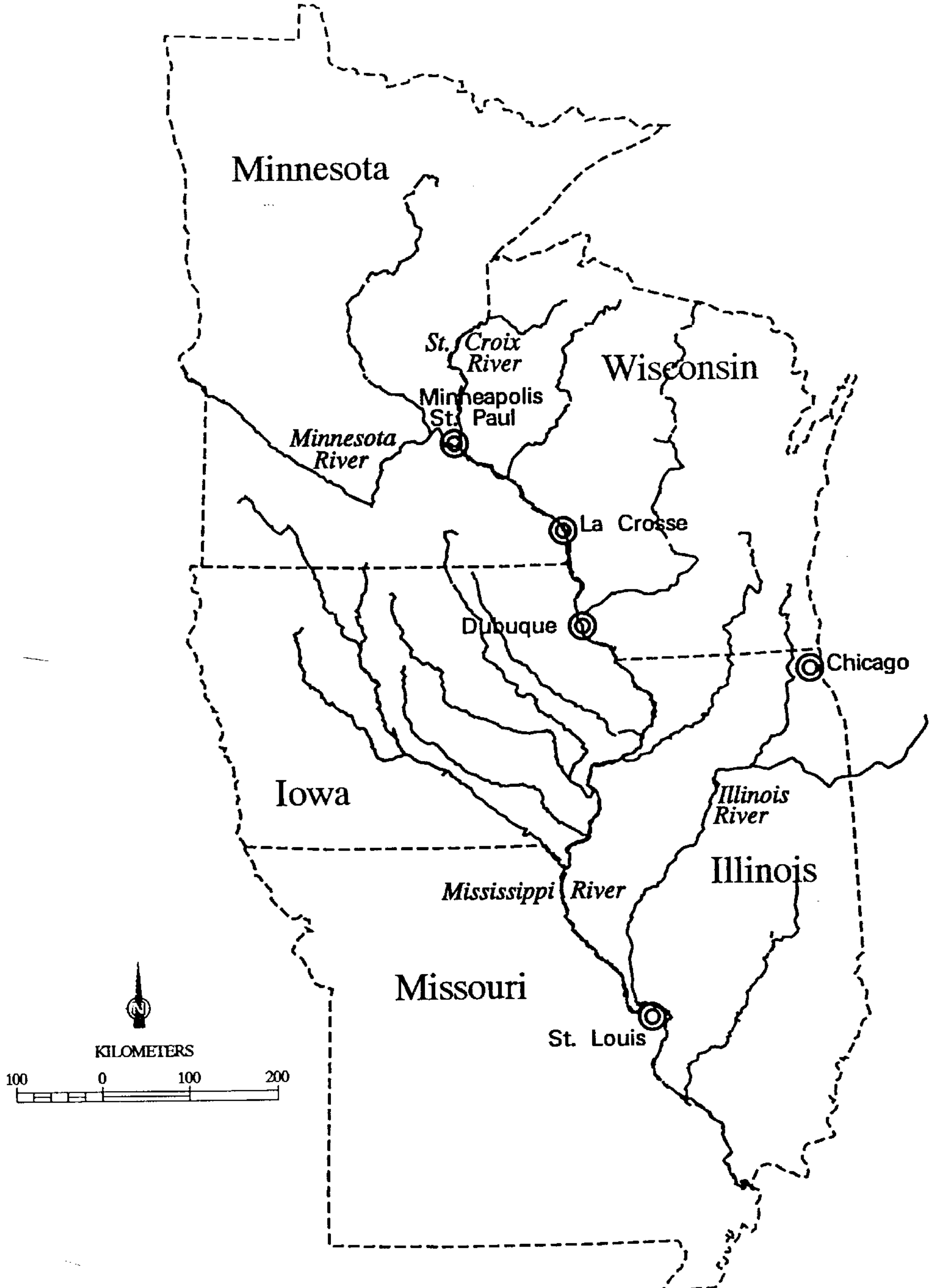

Figure 1. Upper Mississippi River System

At finer scales of spatial resolution, aquatic habitat can be further classified according to the conditions present. Habitat conditions in running water can be defined using descriptors of water temperature, dissolved gases, dissolved solids, suspended solids, current velocity, turbulence, depth, substrate type, light, and cover (Hynes 1970; Gorman and Karr 1978; Statzner et al. 1988). Habitat patches in large rivers occur in a dynamic mosaic, influenced by changes in river discharge and associated seasonal changes in physical and water quality conditions. The appropriate scales for ecological investigations of habitat patch and organism relationships depend on the organism(s) and the problem(s) in question (Pringle et al. 1988).

A Proposed Aquatic Habitat Classification for the UMRS

The classification system proposed here has a hierarchical structure to allow habitat mapping and inventory at different spatial scales and varying levels of resolution. At the first level or largest spatial scale, UMRS aquatic habitat is classified into aquatic areas (Fig. 2). Aquatic areas correspond to geomorphic and constructed features of the river. Mapping units of aquatic areas can be delineated, which remain spatially fixed until river and floodplain geometry changes. These aquatic areas cannot be considered habitat types, however, because they contain a wide range of dynamic conditions within each category and mapping unit. Definitions for aquatic areas of the UMRS (Appendix A) correspond closely to definitions of aquatic areas in the Lower Mississippi River (Cobb and Clark 1980; Cobb 1989), but the UMRS classification also includes features unique to the UMRS. The names and definitions of different types of floodplain lakes follow Hutchinson (1957).

Some of the aquatic area boundary mapping definitions (Appendix A) require information about floodplain and water surface elevation. Even without elevation data, most classes of aquatic areas can be mapped from aerial photographs of the river floodplain using provisional boundaries. When floodplain elevation and water surface data become available, the mapping unit boundaries can be refined. For example, tertiary channels without emergent banks extend into floodplain shallow aquatic areas. These smaller channels are not apparent from aerial photographs, but they can be delineated using bathymetric data.

At smaller spatial scales, aquatic habitat types can be classified using combinations of aquatic habitat conditions. Aquatic habitat conditions (Table 1) include physical and water quality variables. Aquatic habitat types are user-defined, with habitat conditions selected and ranges defined depending on the application. For example, an aquatic habitat type used by certain lotic fishes can be defined as tailwater area, sand substrate, 2 to 5 m depth, and 10 to 50 cm/s current velocity. This habitat type is quite extensive in tailwater areas of the UMRS at lower levels of river discharge, but becomes more restricted at higher levels of river discharge as current velocity and water depth increase.

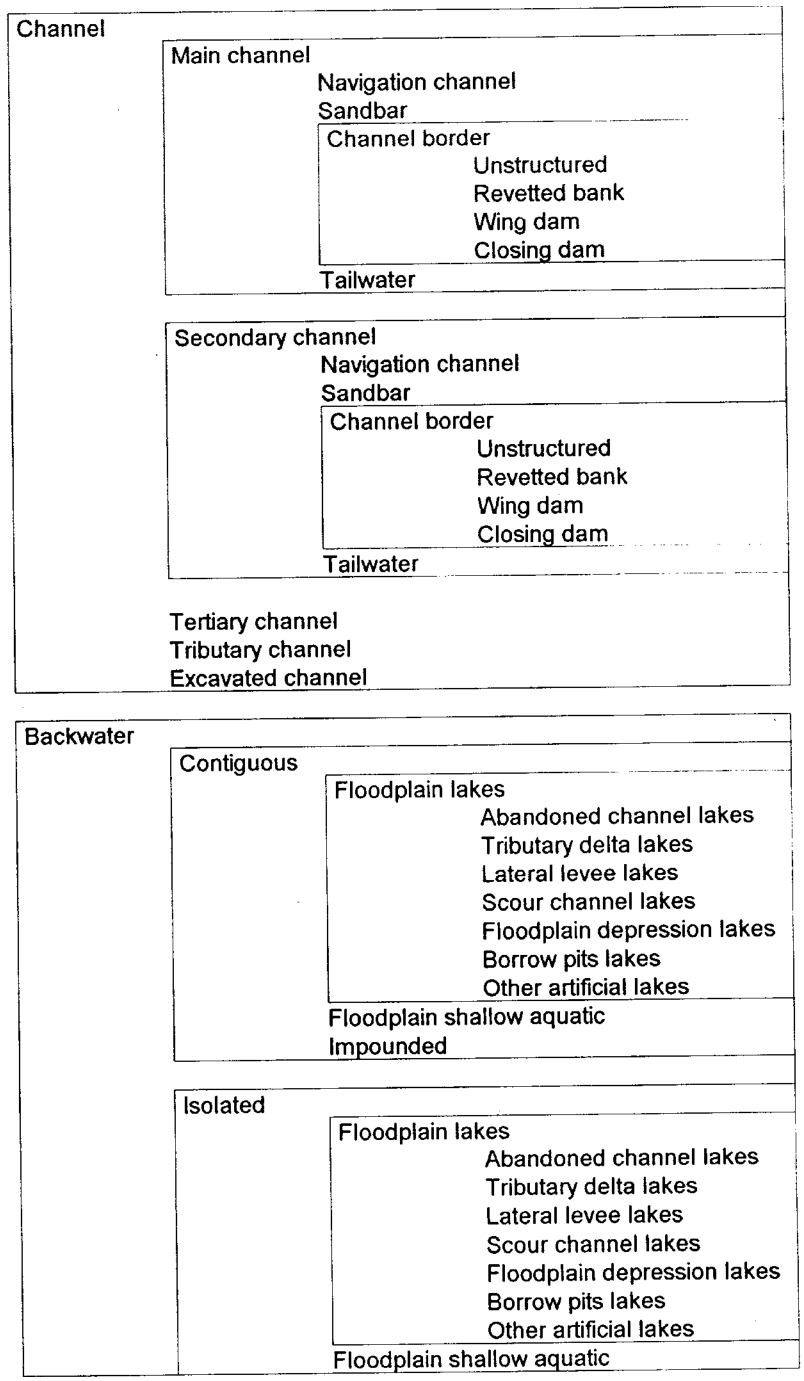

Figure 2. Aquatic areas of the Upper Mississippi River System

Table 1. Examples of conditions used to define aquatic habitat types

Habitat conditions	Condition ranges
Depth	0 - 0.5 m
	0.5 - 2.0 m
	2.0 - 5.0 m
	>5 m
Current	
Velocity	0 - 10 cm/s
	10 - 100 cm/s
	>100 cm/s
Turbulence	<500 Re (Reynold's number, laminar flow)
	500 - 2000 Re (transitional)
	>2000 Re (turbulent)
Water temperature	-1.0 - 0.0 EC (winter temperature ranges)
	0.0 - 2.0 EC
	2.0 - 5.0 EC
Dissolved oxygen	0 - 2.0 mg/L
	2.0 - 5.0 mg/L
	>5.0 mg/L
Suspended solids	0 - 10 mg/L
	10 - 25 mg/L
	25 - 100 mg/L
	100 - 300 mg/L
	>300 mg/L
Light	0 - 10 cm (1% light transmittance depth)
	10 - 50 cm
	50 - 100 cm
	100 - 200 cm
	>200 cm
Substrate type	
Rock	>100 mm (grain size)
Gravel	5 - 100 mm
Sand	0.074 - 5 mm
Silt + clay	> 0.074 mm
Organic	
Cover	
Submersed aquatic	
Emergent aquatic	
Flooded terrestrial	
Grasses/sedges	
Brush	
Forest	
Overhanging trees	
Overhanging bank	
Rock	
Built structures	

The proposed aquatic habitat classification includes consideration of the vertical dimension extending from the water surface into the substrate (Table 2). A number of specialized communities exist on the water surface, in the water column, on or in cover structures, and on and in the substrate. Using vertical dimension classification, habitat type occupied by caddisflies *Hydropsychid* could be described as channel border, rock substrate surface, 0 to 1 m depth, and 50 to 100 cm/s current velocity.

Table 2. Vertical dimension of Upper Mississippi River System aquatic habitat

Vertical dimension features
Water surface
Water column
Cover structure surface
Aquatic macrophytes
Rock
Coarse organic materials
Cover structure interior
Aquatic macrophytes
Coarse organic materials
Sediment surface
Sediment hyporheic zone
Deep sediment intertitial spaces

Application

Application of the proposed aquatic habitat classification involves mapping aquatic areas and more detailed investigations to measure and to map the spatial and temporal occurrence of habitat types. The floodplain of the UMRS covers approximately 728,000 ha, and about 178,000 ha are normally aquatic habitat. Mapping of aquatic areas can be accomplished using interpretation of aerial photography. Aquatic area boundaries can be refined as bathymetric and water surface elevation information becomes available.

Mapping and analysis of the dynamic habitat conditions in the UMRS require repeated spatial measurements of habitat conditions and realistically may be done only for special investigations covering limited areas. Given the spatial complexity and rapidly changing habitat conditions in the UMRS, these efforts will be greatly aided by remote sensing, hydraulic modeling, and computer GIS technologies.

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Appendix A

General Definitions - Proposed Aquatic Habitat Classification for the Upper Mississippi River System

Reference River Discharge

The reference river discharge is the discharge level exceeded 50% of the time at point of interest.

Reference Water Surface

The reference water surface is the water surface elevation profile associated with the reference river discharge.

Aquatic - Floodplain Terrestrial

A distinction is made between floodplain areas that are normally aquatic and areas that are normally terrestrial at the reference discharge level. At times of higher river discharge, more of the floodplain is inundated and becomes aquatic habitat. Above the reference discharge level, portions of the floodplain that are normally terrestrial can be described according to their elevation, frequency, and duration of inundation.

Channel - Backwater

A distinction is made between channel areas and off-channel or backwater areas.

Channels. Channels in the Upper Mississippi River System (UMRS) include the main channel, secondary and tertiary channels, tributary channels, and excavated channels (Fig. A-1). Within the main channel (and some secondary channels) are the designated navigation channel, sandbar, channel border, and tailwater areas. Within channel border areas are natural bank areas and areas associated with channel-training structures.

Backwaters. Backwaters are areas of the UMRS that are beyond the banks of the main and secondary channels. Backwaters include a variety of alluvial floodplain waterbodies. Tertiary and smaller tributary channels are included in backwater areas.

Contiguous, isolated. A distinction is made between contiguous (connected by surface flow with the main channel) and isolated backwaters.

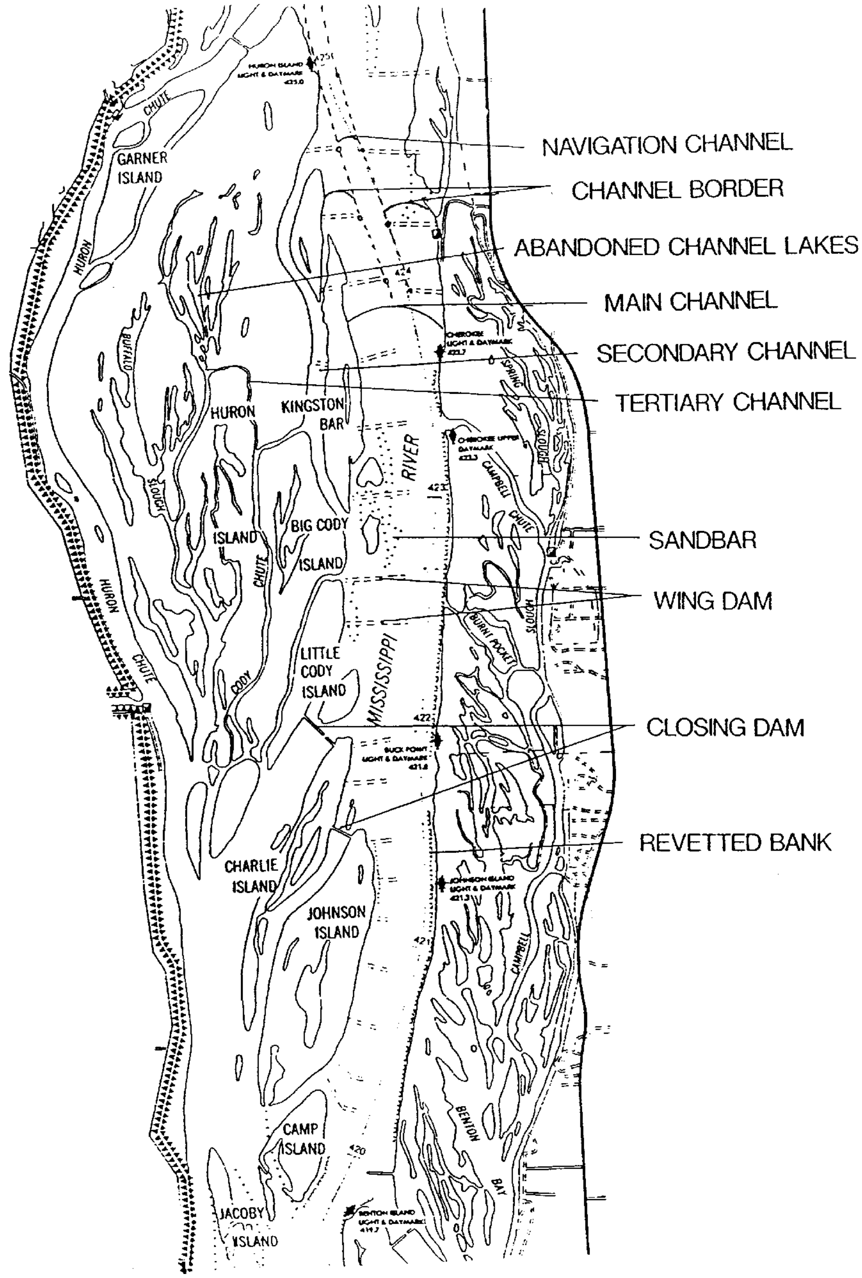

Figure A-1. Example Upper Mississippi River System aquatic areas

Vertical Dimension

Depending on study needs, aquatic habitat in the UMRS can be defined according to vertical spatial categories. Within aquatic areas are the water surface, the water column, the surfaces of cover structures such as aquatic macrophytes, rocks, and woody debris, the interior of cover structures, the sediment surface, the hyporheic zone within the sediment, and the deeper sediment.

Aquatic Areas

Aquatic areas are spatially large areas of somewhat similar aquatic habitat defined according to geomorphic and navigational features of the river (Fig. 2, p. 4).

Habitat Conditions

Habitat conditions are physical and chemical variables that occur in aquatic habitat (Table 1, p. 5).

Habitat Types

Habitat types are defined as needed for the application, using aquatic area and some combination of habitat conditions. No formal classification of aquatic habitat types is proposed. Habitat type definitions can be developed according to the needs of different investigations.

Definitions - Aquatic Areas of the UMRS

The following proposed definitions of UMRS aquatic areas are provided in conjunction with Figure 2 (p. 4) and examples shown in Figures A-1 to A-7. Boundary definitions are provided for mapping purposes.

Main Channel

The main channel conveys the majority of the river discharge and in most reaches includes the navigation channel (Fig. A-1). Boundaries of the main channel are the apparent shorelines (the land/water boundaries visible from aerial photographs taken at the reference discharge level), straight lines across the mouths of secondary, tributary, and tertiary channels, and along the top of inundated portions of the natural bank line.

Navigation Channel

The navigation channel is the designated navigation corridor marked by channel buoys (Fig. A-1). In reaches where buoys are not used, the centerline of the navigation channel is defined by lights and daymarks on shore that pilots use for navigation. The navigation channel on most of the UMRS is 91.4 m (300 ft) wide in straight reaches and 152.4 m (500 ft) wide in bends. The navigation channels in the upper pools of the UMRS and tributary waterways are narrower. The prescribed width and depth of at least 9 ft (2.6 m) are

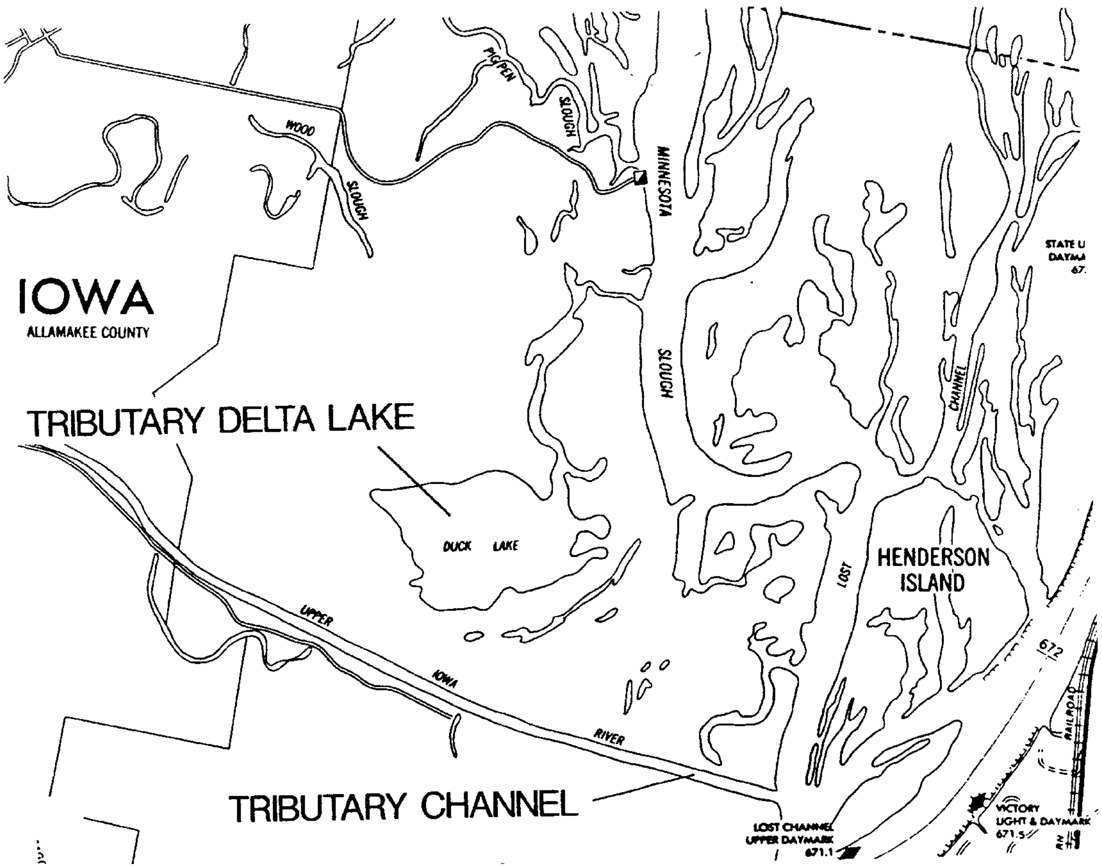

Figure A-2. Tributary delta lake and tributary channel

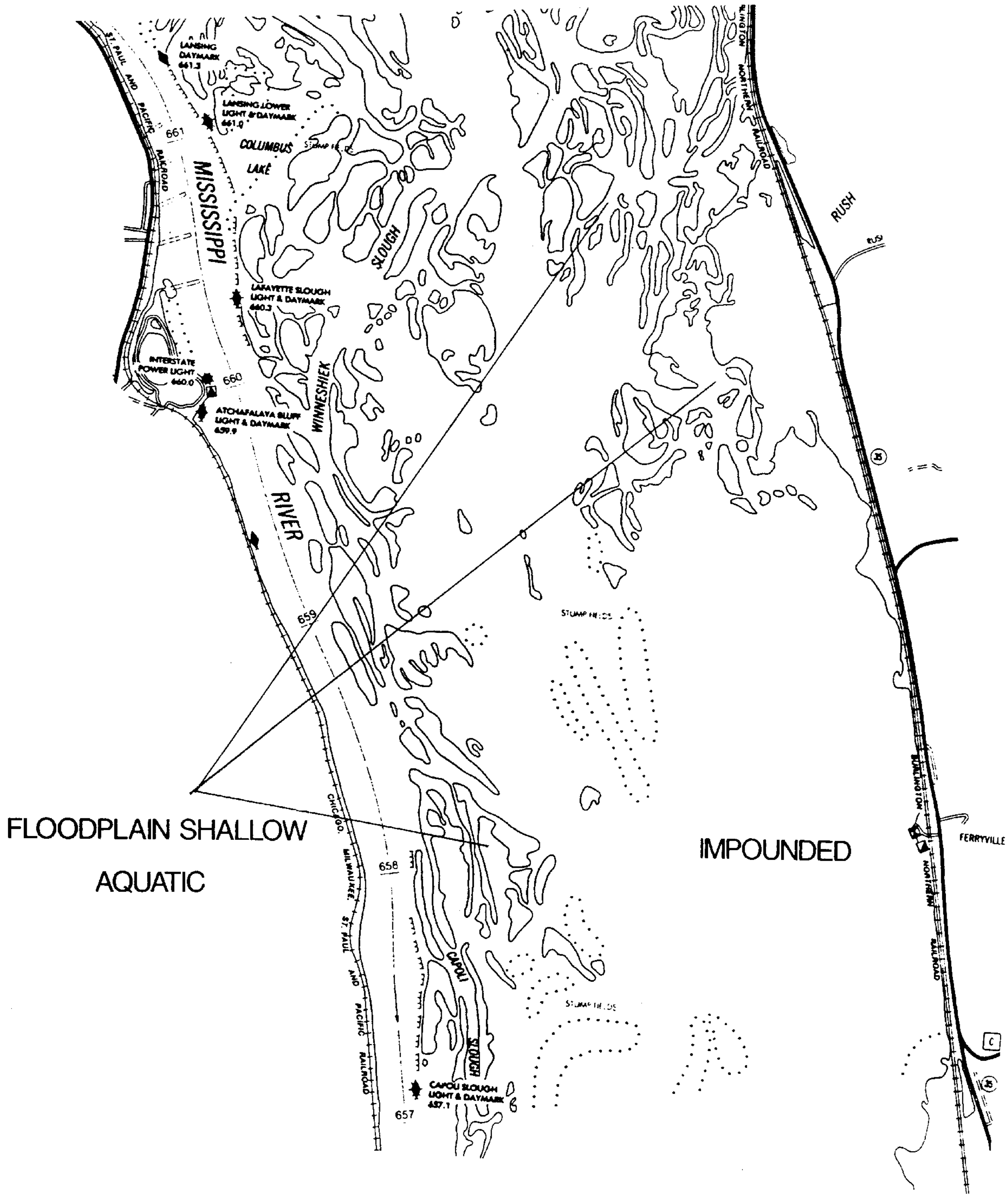

Figure A-3. Floodplain shallow aquatic areas

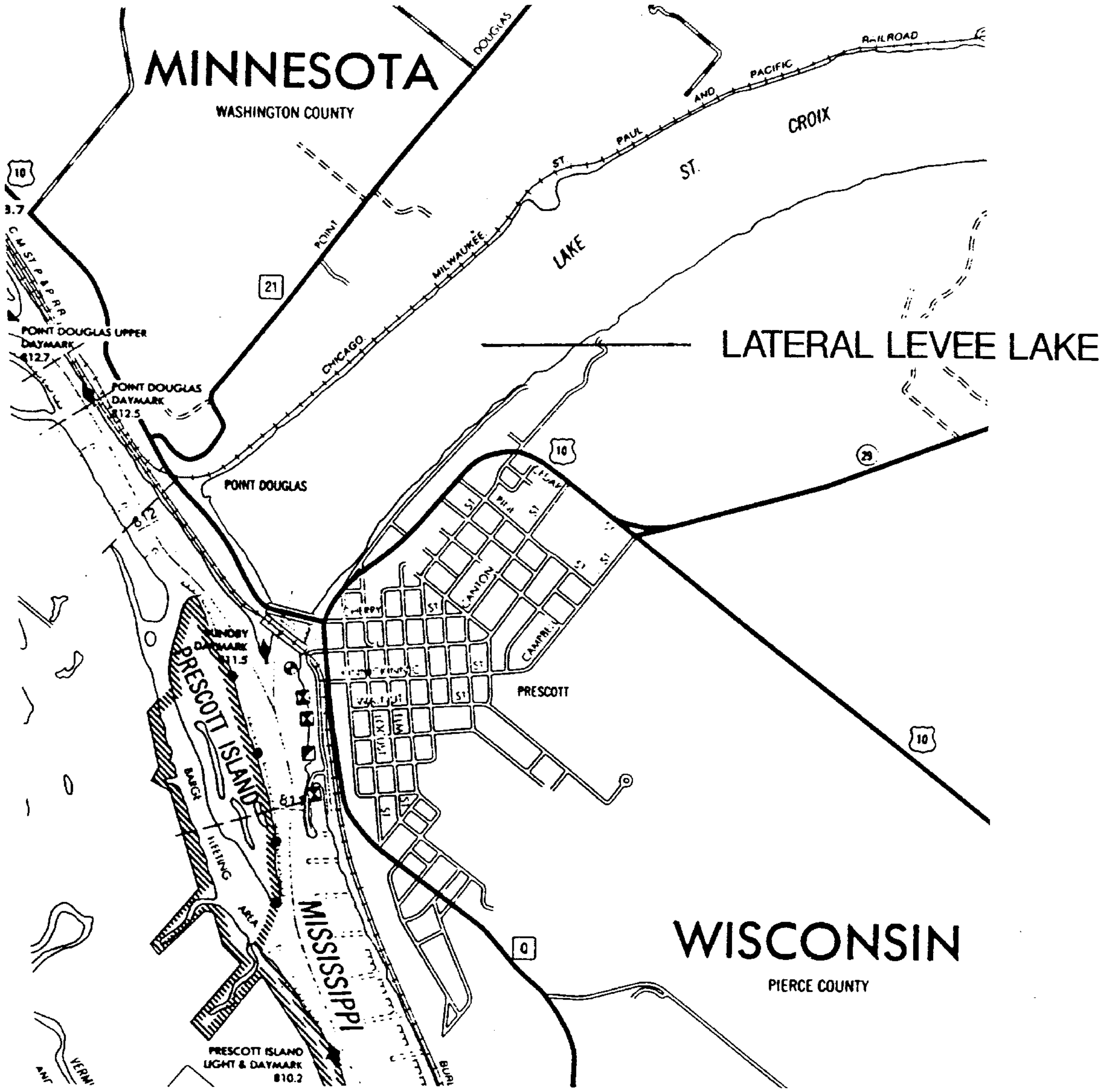

Figure A-4. Lateral levee lake

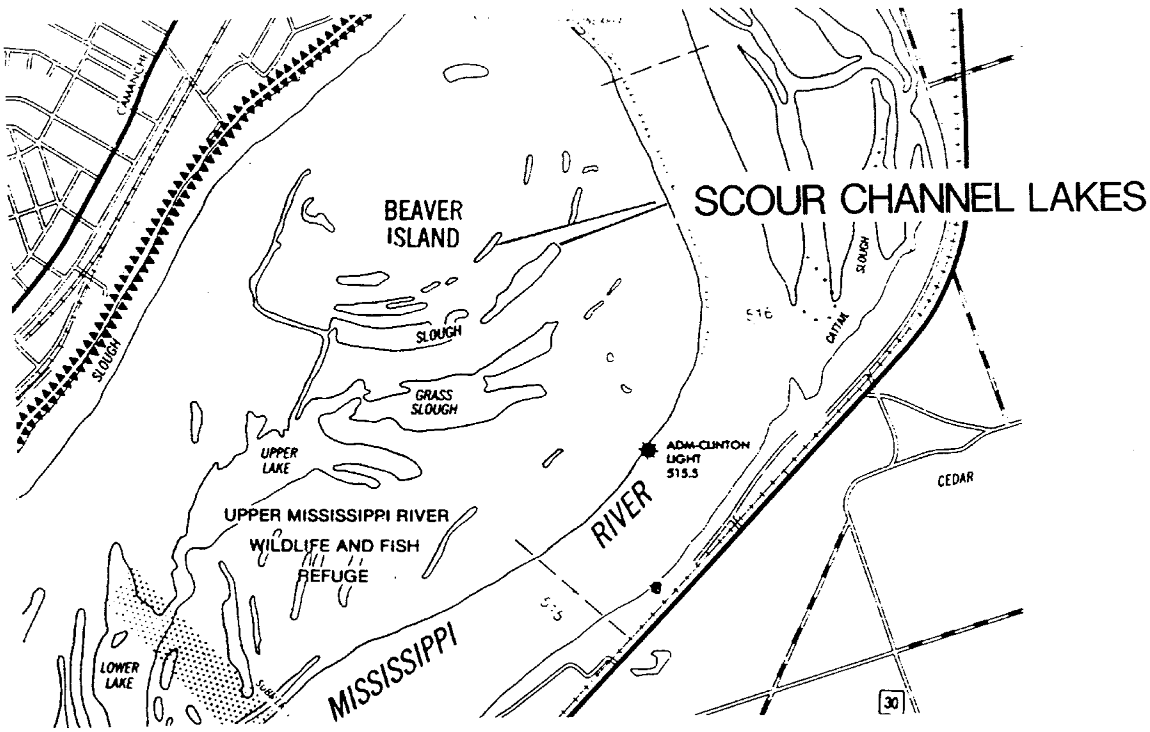

Figure A-5. Scour channel lakes

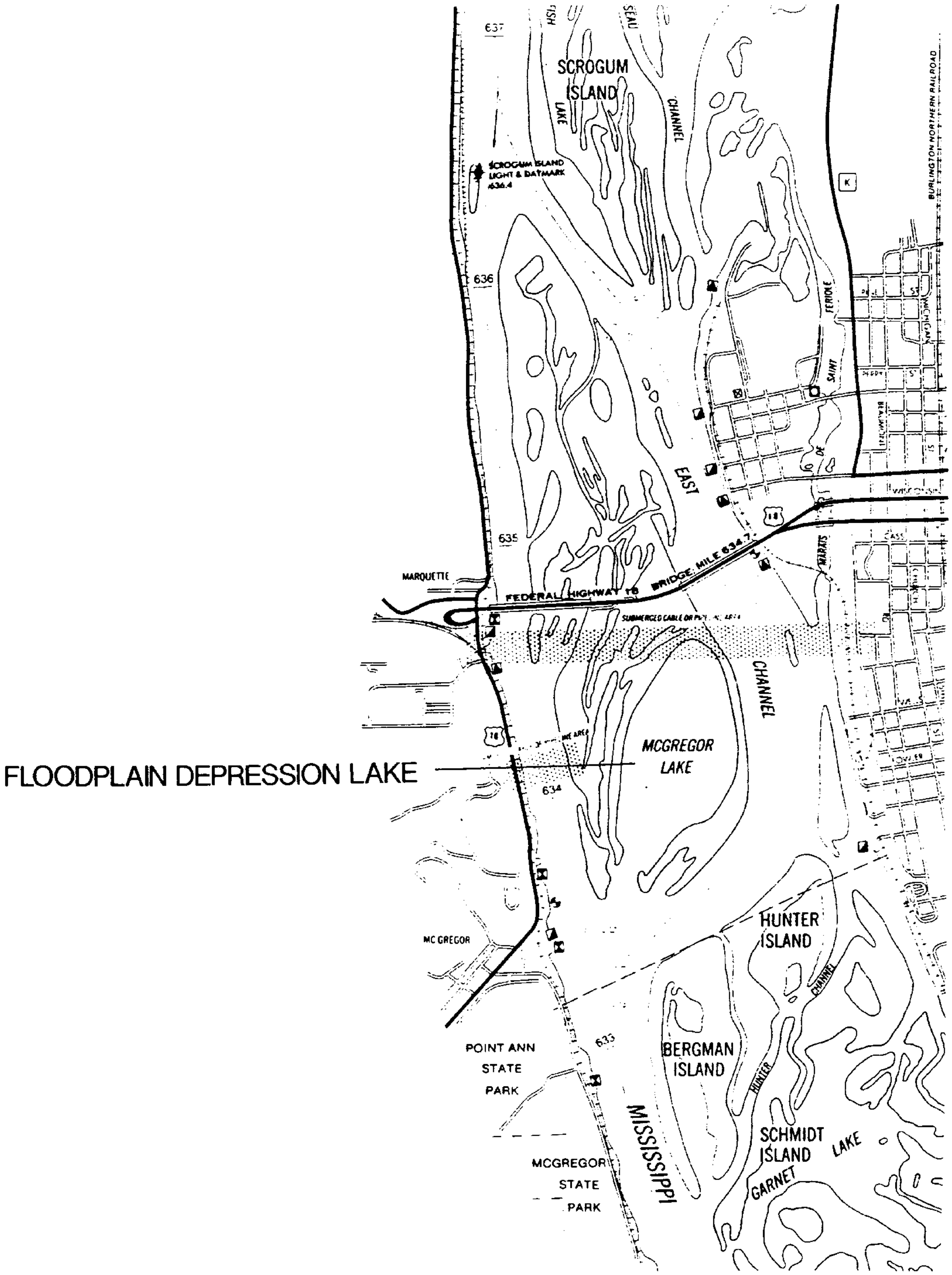

Figure A-6. Floodplain depression lake

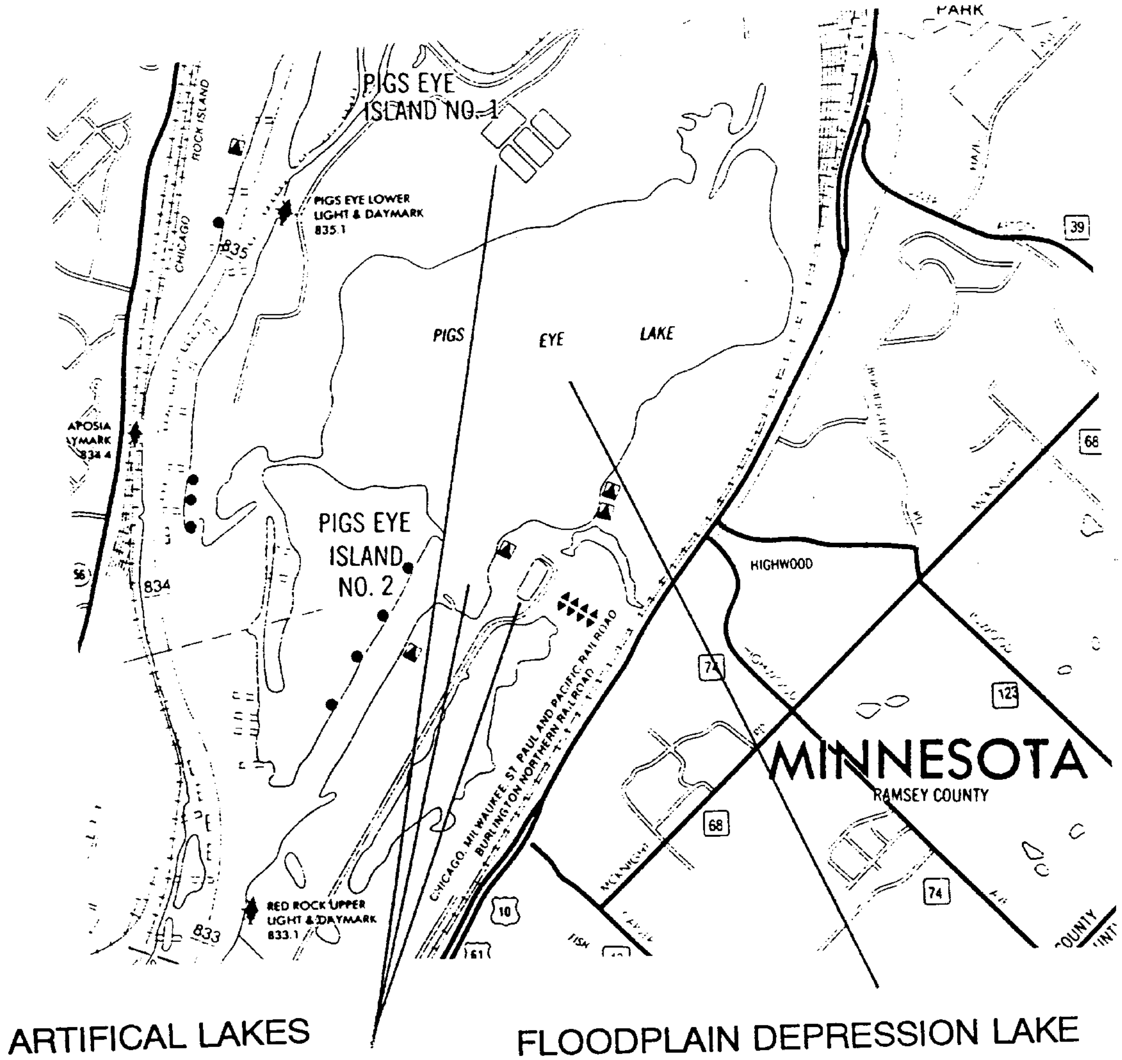

Figure A-7. Artificial lakes

maintained by the navigation dams and by dredging where necessary. The navigation channel extends through the locks at each lock and dam. The navigation channel is usually in the main channel but in some reaches, it is located in secondary channels.

Tailwaters

Tailwaters are the areas downstream of the navigation dams with deep scour holes, high velocity, and turbulent flow. Boundaries of tailwater areas are the navigation dam upstream, the apparent shorelines, and a straight line across the channel 500 m downstream of the dam.

Channel Border

Channel borders are the areas between the navigation channel and the river bank (Fig. A-1). Boundaries of channel border areas are the apparent shorelines, the navigation channel buoy line, straight lines across the mouths of secondary and tertiary channels, and the inundated portions of the natural bank line.

Wing Dam

Wing dams are stone and brush channel-training structures that extend laterally into the main and secondary channels to concentrate flow into the navigation channel (Fig. A-1). The boundaries of wing dam areas are defined by proximity to wing dam structures. The landward boundaries are the apparent shorelines and inundated portions of the natural bank line. The upstream and downstream boundaries of wing dam areas are parallel to and 50 m from the wing dam structures. The riverward boundaries are perpendicular to the riverward end of the wing dams.

Closing Dam

Closing dams are stone and brush channel-training structures that were built across channels to concentrate flow into the navigation channel (Fig. A-1). Boundaries of closing dam areas are parallel to and 50 m upstream and downstream of the structures. Where closing dams are close to the main channel border, the upstream boundary is across the mouth of the channel. The lateral boundaries are the apparent shorelines of the channel.

Revetted Bank

Revetted banks are the armored shorelines of the main and secondary channels (Fig. A-1). Revetment on the UMRS is rock riprap or articulated concrete mats. Shorelines with concrete or steel bulkheads or paved levees are included in this category. In some locations, bank revetment is no longer connected to shore. Boundaries of revetted bank areas are the apparent shoreline, the upstream and downstream limits of the revetment, and a line riverward, parallel to and 15 m from the apparent shoreline. For revetments that are no longer connected to shore, the shoreward boundary of revetted bank areas is a line parallel to and 15 m from the top of the remaining revetment material.

Unstructured Channel Border

Unstructured channel border areas are areas without revetments or other channel-training structures. Boundaries of the unstructured channel border areas are the apparent shoreline, the upstream and downstream limits of other channel border areas, the downstream limits of tailwater areas, and indundated portions of the natural bank line.

Depending on the application, unstructured channel border areas can be further classified according to depth gradient and geomorphic feature (point bar, inside bend, etc.).

Secondary Channel

Secondary channels are large channels that carry less flow than the main channel (Fig. A-1). In some reaches, the navigation channel is located in secondary channels. Boundaries of secondary channel areas are the apparent shorelines, straight lines across the mouths of tertiary channels, and straight lines at the upstream and downstream limits of the apparent shorelines where secondary channels connect with the main channel.

Sandbar

Sandbars are flat-sloped areas within the main and secondary channels that are characterized by sand substrate (Fig. A-1). Sandbars have side slopes of less than 1V:6.67H, are completely submerged at the 10% exceedence frequency discharge level, and are not connected to shore at the reference discharge level. Portions of sandbar zones emergent at the reference river discharge are unvegetated. Sandbar boundaries are the 2-m depth contours at the reference river discharge level and the apparent shoreline or boundaries of rock structure areas.

Tertiary Channel

Tertiary channels are small channels #30 m wide (Fig. A-1). The lateral boundaries of tertiary channels are the apparent shorelines or the inundated natural bank lines. The upstream and downstream limits of tertiary channels are straight lines between the upstream and downstream limits of the apparent shorelines, or where the inundated natural bank lines merge with the surrounding bottom.

Tributary Channel

Tributary channels are channels of tributary streams and rivers (Fig. A-2). The landward boundary is the line where the tributary crosses the study area boundary. The lateral boundaries are the apparent shorelines and any inundated natural bank lines. The riverward limit of a tributary channel is a line drawn across the downstream limits of the apparent shoreline or where the inundated natural bank lines of tributary channels merge with the surrounding bottom.

Excavated Channel

Excavated channels are constructed channels with flowing water.

Contiguous or Isolated

Contiguous means hydraulically connected by surface gravity flow at reference river discharge. For mapping purposes, contiguous means having apparent surface water connection with the rest of the river. Isolated means having no hydraulic connection by surface gravity flow at reference river discharge. For mapping purposes, isolated means having no apparent surface water connection with the rest of the river.

Floodplain Shallow Aquatic

Floodplain shallow aquatic areas are portions of the floodplain inundated by the navigation dams that are not part of any channels or floodplain lakes (Fig. A-3). Floodplain shallow aquatic areas contain a mosaic of open water and emergent vegetation interspersed among islands. The boundaries of these areas are defined by the apparent shorelines and by other aquatic areas. Boundaries of floodplain shallow aquatic areas are often irregular. Where floodplain shallow aquatic areas grade into impounded areas, the boundaries will be lines connecting the downstream points of islands or peninsulas across the floodplain. Tertiary and smaller tributary channels flow through floodplain shallow aquatic areas, but the boundaries (inundated bank lines) of most of these channels can be distinguished only with bathymetric information.

Impounded

Impounded areas are large, mostly open water areas located in the downstream portions of the navigation pools (Fig. A-3). The downstream boundaries of impounded areas are the navigation dam and connecting dikes. Landward boundaries are the apparent shorelines or the boundaries of other aquatic areas. Upstream boundaries are with islands and floodplain shallow aquatic zones. Riverward boundaries are channel border zones.

Floodplain Lake

Floodplain lakes are distinct lakes formed by fluvial processes or are artificial (excavated or impounded).

Abandoned Channel Lake

Abandoned channel lakes are oxbow lakes formed by meander cutoffs, lakes formed by point bar cutoffs, and lakes formed by avulsion (a major shift in channel course) (Fig. A-1). Boundaries are the apparent shorelines. The downstream boundary for contiguous abandoned channel lakes is a line that is a continuation of the apparent shoreline of the lake. Abandoned channel lakes vary greatly in size. The shape of most abandoned channel lakes reveals their origins as former channels.

Tributary Delta Lake

Tributary delta lakes are formed by the tributary deltas impounding all or part of the floodplain upstream of the mouth of the tributary (Fig. A-2). Boundaries are the apparent shorelines. For contiguous tributary delta lakes, the riverward boundary is where the (usually downstream) end of the lake joins a channel. The boundary is a line that is a continuation of the apparent shoreline of the channel.

Lateral Levee Lake

Lateral levee lakes are lakes formed by the impounding effect of natural riverbank levees (Fig. A-4). This type of lake is formed between the natural levee and the high ground that defines the edge of the floodplain of the river. Lateral levee lakes are also formed where natural levees impound tributary streams. Boundaries are the apparent shorelines and the boundaries of other more clearly delineated aquatic zones. On lakes formed at the mouth of tributary streams, the upstream boundary is the boundary of the study area.

Scour Channel Lake

Scour channel lakes are formed by the scouring of point bar swales during high flows (Fig. A-5). Scour channel lakes are generally small and crescent-shaped. Most of these aquatic areas are isolated. Boundaries are the apparent shorelines. Where contiguous, the connecting boundary is a line across the downstream limit of the apparent shorelines.

Floodplain Depression Lake

Floodplain depression lakes are generally large, shallow water bodies formed by uneven aggradation of sediment on floodplains during floods (Figs. A-6 and A-7). This type of lake has even shorelines (limited shoreline development) and a shallow basin of even depth. Most of these lakes are larger than 100 ha. Boundaries are the apparent shorelines. Where contiguous, the connecting boundary is a line across the limits of the apparent shorelines.

Borrow Pit

Borrow pits are water bodies formed where material was excavated for levee or dike construction. The boundaries are the apparent shorelines or the limits of excavation. Most borrow pits are parallel and immediately adjacent to dikes or levees.

Artificial Lake

These aquatic areas are created by dikes or levees (not the main navigation dams and dike systems) or by excavation (Fig. A-7). The boundaries of artificial lakes are the apparent shorelines, and where contiguous, the connecting boundary is a line across the limits of the apparent shorelines.

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May 1993	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

An Aquatic Habitat Classification System for the Upper Mississippi River System

5. FUNDING NUMBERS

6. AUTHOR(S)

Dan Wilcox

7. PERFORMING ORGANIZATION NAME AND ADDRESS

U.S. Fish and Wildlife Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Fish and Wildlife Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

93-T003

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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14. SUBJECT TERMS

aquatic habitat, classification, Upper Mississippi River, Illinois River, geomorphology

15. NUMBER OF PAGES

9 pp. + Appendix A

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

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