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MORPHOLOGIC EFFECTS OF LOWER MISSISSIPPI RIVER DIKE FIELDS

by

Nelson R. Nunnally

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

Linda B. Beverly

University of North Carolina at Charlotte
Charlotte, North Carolina 28213

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Dikes are used extensively on large, meandering rivers to help maintain navigation channels. Dike fields alter flow velocities and sedimentation patterns, thereby affecting river morphology and the amount and quality of aquatic habitat. Some investigators have theorized that sedimentation induced by the dike fields constructed on the lower Mississippi, largely since 1960, is altering river morphology and aquatic habitat in a manner similar to the changes that have been observed in the lower Missouri. Others are of the opinion that dike

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fields on the lower Mississippi do not typically fill completely with sediment, and the pools they contain have increased the amount of slack-water habitat.

Low-water photographs taken in 1962 and 1976 and comprehensive hydrographic surveys done in 1962-64 and 1974-75 were used to measure morphologic changes in diked and undiked reaches. River surface area between river miles 320 and 954 was classified as main channel, secondary channel, slough, chute, or pool. The 1962 and 1976 areas in each category were measured from the photographs. River stage at time of photography averaged about 2 ft (0.6 m) lower in 1976, so 1976 measurements were adjusted for stage differential, based on width measurements taken from the hydrographic surveys. Results were summarized for diked and undiked reaches.

Total river area remained relatively constant. Secondary channel area decreased by 16.28 square miles (42.2 sq km) (-38.6 percent), but this was offset by increases in sloughs, chutes, and pools. Sloughs increased by 7.13 square miles (18.5 sq km) (+53.2 percent), chutes by 6.92 square miles (17.9 sq km) (+44.8 percent), and pools by 5.09 square miles (13.2 sq km) (+2,357.1 percent). Practically all of the loss occurred in secondary channel area, and all of the increase in sloughs, chutes, and pools occurred in diked reaches. Analysis of changes by age of dike field revealed no noticeable trends or patterns.

PREFACE

The study described in this report was conducted as part of the Environmental and Water Quality Operational Studies (EWQOS) Program, Task VIB, Design and Construction Techniques for Waterways Projects. The EWQOS Program is sponsored by the Office, Chief of Engineers (OCE), US Army, and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman.

The study was conducted primarily during the period March 1983 through June 1984 by Dr. Nelson R. Nunnally and Ms. Linda B. Beverly. Dr. Nunnally was on temporary assignment with the Water Resources Engineering Group (WREG), Environmental Engineering Division (EED), EL, under the terms of an Intergovernmental Personnel Agreement between WES and the University of North Carolina at Charlotte (UNCC). Ms. Beverly was a graduate student in geography at UNCC and performed some of the work under Contract No. DACW83-M-1287 with WES.

Technical reviews of the report were performed by Mr. Ed Glover and Mr. Charles Elliott of the WES Hydraulics Laboratory; Drs. C. H. Pennington and D. C. Beckett of the Aquatic Habitat Group, EL; and Mr. F. D. Shields of WREG. Mr. Shields was also responsible for several revisions and corrections of the draft report. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division.

The study was performed under the direct supervision of Dr. Michael R. Palermo, Chief, WREG, and under the general supervision of the late Mr. A. J. Green, Chief, EED; Dr. Raymond L. Montgomery, Acting Chief, EED; and Dr. John Harrison, Chief, EL. Dr. J. L. Mahloch was EWQOS Program Manager.

At the time of publication, COL Allen F. Grum, USA, was Director of WES and Dr. Robert W. Whalin was Technical Director.

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CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
square miles	2.589998	square kilometres

MORPHOLOGIC EFFECTS OF LOWER MISSISSIPPI RIVER DIKE FIELDS

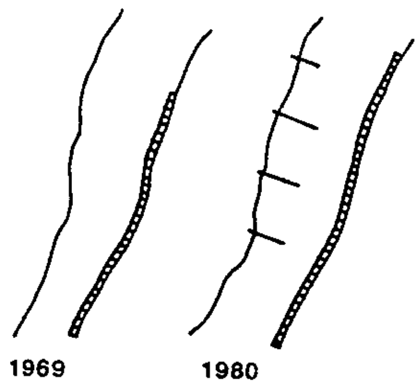
PART I: INTRODUCTION

Background

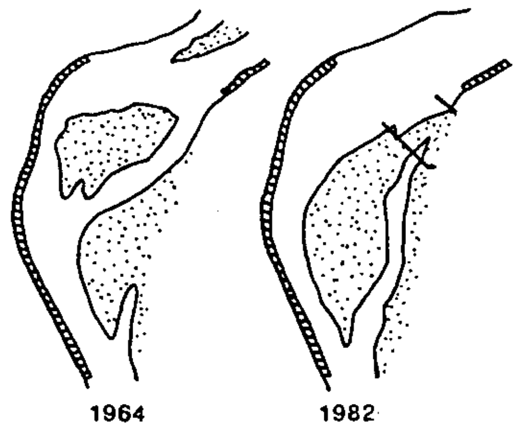
1. Dikes and revetments are widely used on large rivers to stabilize navigation channels. Most dikes constructed on the Missouri and Mississippi Rivers since the 1950s are spur, or transverse, rock dikes that project perpendicular from the bank or are angled upstream or downstream. Other designs, such as rootless vane dikes that more or less parallel the bank and L-head dikes, which are transverse dikes with vanes attached, are used occasionally.

2. The purpose of dikes is to develop a channel with dimensions and alignments suitable for navigation and/or flood control purposes. Dikes accomplish this by stabilizing bar locations, controlling flow through secondary channels, and reducing channel width and increasing flow depth over some range of discharges. Dikes are normally used in conjunction with revetments to develop and stabilize the channel. Although single dikes are used occasionally to close chutes and small secondary channels, single dikes generally are not effective in inducing general scour (Simons et al. 1974). Therefore, dikes are usually placed in groups and are called dike fields (Figure 1).

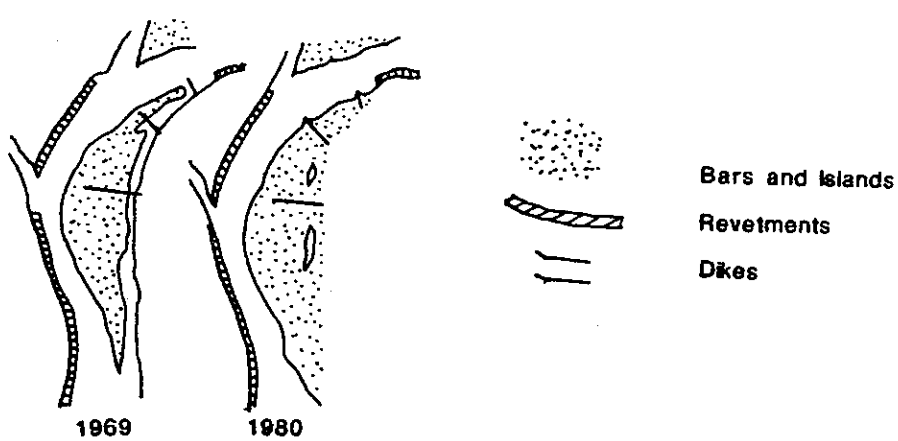
3. Because of their effects on flow patterns and sediment transport, dike fields may have a profound effect on river morphology and associated aquatic habitats. Precise effects vary considerably, however, depending on dike field placement; type, number, length, height, spacing, angle, and slope of dikes; river hydrology; and sediment supply (Franco 1967). Dike fields placed at point bars or other natural sedimentary environments induce rapid sedimentation, whereas dike fields used to force crossings or placed in other nonsedimentary environments may not. Burch et al. (1984) provide a review of existing



a. Donaldson Point Dikes - forced crossing



b. Commerce Dikes - secondary channel closure



c. Leota Dikes - point bar chute closure

Figure 1. Dike field types

information on dike field design and effects on river morphology and river biota.

4. Uncontrolled meandering rivers support a mixture of habitat types that are associated with different velocity regimes and substrate conditions. Slack-water areas along main channel borders, side channels, and old chutes and sloughs are recognized as environmentally and economically valuable habitats. These areas are primary feeding, resting, and spawning areas and are important for species diversity

(Kallemeyn and Novotny 1977). Although abandoned meanders and chutes may fill with sediment over time, new ones are continually created by the meandering process.

5. Large numbers of revetments and dike fields are locking the Mississippi River channel into a permanent alignment and will severely limit channel migration. A concern exists that the mixture of habitats will shift increasingly toward higher percentages of main channel at the expense of productive slack-water environments as existing chutes and sloughs fill with sediment, and that dike field sedimentation will accelerate the process.

6. The purpose of this paper is to investigate quantitative and qualitative changes in aquatic habitat on the lower Mississippi River and the association of such changes with construction of dike fields by the US Army Engineer Districts (USAED), Vicksburg and Memphis. It is difficult to definitely relate morphologic change to dike field construction because rivers are dynamic systems that respond to changes in water or sediment discharge. Water and sediment discharge may be affected by climatic variation and any natural or human disturbances which influence rainfall-runoff relationships and sediment yield (Nunnally 1985, Schumm 1968, Schumm and Lichty 1963). In order to develop appropriate working hypotheses and to aid in formulating the research design, similar studies of morphologic effects of training structures on the Missouri River are reviewed below.

Effects of Dikes on the Lower Missouri River

Morphologic effects

7. Much of the concern about the effects of river-training structures on river morphology and aquatic habitat is based on what has been written about the lower Missouri River. The Iowa Geological Survey has produced perhaps the best documented study of morphological changes on the lower Missouri, although it is concerned only with that portion of the river adjacent to Iowa (Hallberg et al. 1979). Table 1

summarizes changes in water surface area between 1879 and 1976 reported by Hallberg et al. for the Iowa portion of the river. During the period from 1923 to 1976, water surface area decreased by 30,228 acres* or 66 percent and the river pattern changed from a multichannel, semi-braided stream to a single channel without bars or islands. These results are in substantial agreement with those of Funk and Robinson (1974), who concluded that river regulation efforts on the same river in the state of Missouri between 1879 and 1974 produced a stable navigation channel but reduced water surface areas by 50 percent.

Table 1

Changes in Morphology of the Lower Missouri River (Iowa Portion), 1879-1976 (from Hallberg et al. 1979)

Period	River Miles miles(%)	Water Area acres (%)	Rate of Change acres/year (%/year)	Island Area acres (%)	Bar Area acres (%)
1879-1890	+3.7 (+2)	-21,140 (-37)	-1,762 (-3.0)	-3,986 (-41)	+14,671 (+99)
1890-1923	-14.3 (-7)	+9,013 (+25)	+265 (+0.7)	+5,705 (+98)	-9,496 (-32)
1923-1947	-3.0 (-1)	-22,353 (-49)	-894 (-1.9)	-881 (-8)	-4,412 (-22)
1947-1976	-15.0 (-8)	-7,875 (-34)	-262 (-1.1)	-10,632(-100)	-15,499(-100)

8. The changes in water surface area reported in Table 1 were measured from maps surveyed by the Corps over periods of 3 months in 1879, 12 months in 1890, and 5 months in 1923 and from photographs taken over a period of 3 months in 1944 and 1945 and on 11 November 1976. Mean monthly discharges at Sioux City varied substantially during and between mapping periods, from a high of 141,900 cfs in June 1879 to a low of 14,020 cfs in December 1944 (Hallberg et al. 1979). Discharge variations of this magnitude could easily account for much of

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

the variation in water surface area measured by Hallberg et al. (1979) and Funk and Robinson (1974), who used the same data sources. In fact, when mean discharges at Sioux City for the mapping and photography periods (except for 1979 when mean daily discharge is used) are plotted against water surface area (Table 2) on a log-log scale (Figure 2), no systematic changes in water surface area are evident during this period (1879-1947). Changes between 1947 and 1976, on the other hand, may be of greater magnitude than indicated by Hallberg et al. (1979).

Table 2

Mean Discharge During Mapping and Photography Periods and Water Surface Area

Year	Mean Discharge at Sioux City During Mapping Period, cfs	Water Surface Area acres
1879	99,270	57,760
1890	44,960	36,620
1923	60,600	45,650
1944-45	17,590	23,300
1976	37,300*	15,420

NOTE: computed from data in Hallberg et al. (1979).
* Mean daily discharge on 11 November.

9. Hallberg et al. (1979) concluded that the changes they measured in water surface area and bar and island area between 1923 and 1976 are directly attributable to the construction of dike fields and revetments. Approximately 500* permeable pile dikes were constructed along the Iowa reach between 1923 and January 1945, the date of last photography. During the period 1945 to 1976 the pile dikes were converted to stone fill dikes** and approximately 400* additional stone

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* Counted from maps contained in Hallberg et al. (1979).
** Burch et al. (1984).

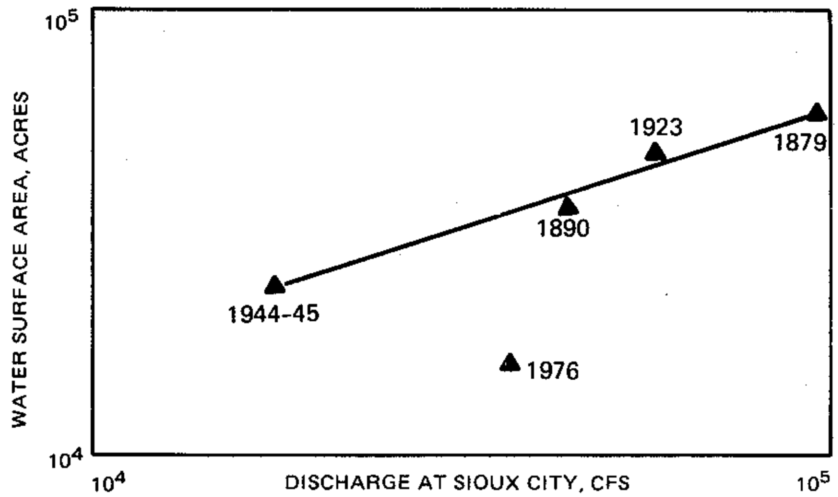

Figure 2. Mean discharge at Sioux City, Iowa, versus water surface area (log-log scale)

fill dikes were added. In addition, five of the six major dams on the Missouri River were closed after 1945 (Fort Peck was closed in 1940). Figure 2 suggests that the changes measured between 1923 and 1947 were the result of variation in discharge and that the pile dikes constructed prior to 1945 had little overall effect on water surface area.

10. The amount of water surface area lost between 1945 and 1976 is difficult to estimate, although Figure 2 suggests that it may have been more than the 7,875 acres reported by Hallberg et al. (1979). It is clear that by 1976 the combined effects of dike, revetments, and dam closures had altered the entire Iowa reach into a single channel with a sinuous alignment. In such a channel, the effects of stage variation on water surface area are much less than for the multibranch channel that existed prior to 1945. Apparently 45 percent of the loss in water surface area reported by Hallberg et al. (1979) occurred in Fremont County, and another 15 percent occurred immediately upstream in Mills County. The Platte River confluence is located in Mills County, and

the reach below this confluence has historically been braided. It would appear that the combined effects of river engineering on water surface area have had their greatest impacts on this braided reach. Although the upper 92 miles in Harrison, Monona, and Woodbury Counties have as many or more dikes per mile as the lower 50 miles (Table 3), the loss in water surface area per dike per river mile is several times as large in the lower section. This and the change in river miles (column 2, Table 3) imply that the water surface area loss in the traditionally braided section is due largely to dike field sedimentation, but that the loss in water surface area in the upper reaches is more a product of river shortening. The large number of dikes in the upper reach apparently is needed to counteract a tendency toward channel widening and instability caused by channel cutoffs. Although it may not be possible to estimate the magnitude of the reduction in water surface area along the downstream portion of the Missouri River, it is clear

Table 3

Effect of Dikes on Water Surface Area, 1945-1976

Reach (County)	River Miles 1976 (1)	Change in Miles 1879-1946 (2)	Number of Dikes 1976* (3)	Dikes per Mile (4)	Loss of of Water Surface Area 1945-1976 (5)	Loss in Water Surface Area per Dike per River Mile (Col 5/ Col 3)/Col 1) (6)
Fremont	29.1	-2.5	168	5.77	-3,535	0.72
Mills	21.1	-2.3	91	4.31	-1,298	0.68
Pottawattamie	40.5	-0.7	116	2.86	-45	0.01
Harrison	32.9	-9.6	175	5.32	-1,154	0.20
Monona	33.5	-2.9	199	5.94	-642	0.10
Woodbury	25.3	-1.6	166	6.56	-1,211	0.29
Total	182.4	-19.6	915	5.02	-7,885	0.05

SOURCE: Hallberg et al. (1979).
* Counted from maps in Hallberg et al. (1979).

that water surface area has declined, especially since 1945, and that the bulk of the decline occurred in the reach bordering Mills and Fremont Counties. The present river is clearly deeper, narrower, shorter, and has a greatly reduced surface area.

Aquatic habitat changes

11. A number of investigators have concluded that diking of the Missouri has caused reductions in habitat quality and habitat diversity due to reduced water surface area and disproportionate loss of slack-water environments. Morris et al. (1968) found that small backwater channels accounted for 15.8 percent of river area in undiked reaches but only 2 percent in diked reaches. Funk and Robinson (1974) concluded that aquatic habitat quality declined drastically between 1879 and 1976 due to backwater area losses. Groen and Schmulbach (1978) attributed decreased habitat diversity in the channelized reaches of the Missouri largely to loss of backwater aquatic habitat.

12. The almost complete loss of backwater areas on the diked portions of the Missouri River can be confirmed by even a cursory examination of the sequential maps available in Hallberg et al. (1979). There seems to be little doubt that the loss of backwater has been caused by construction of dikes, revetments, levees, and dams. Dikes and revetments eliminated channel migration and its associated slack-water environments, and dams have reduced flow variability (Figure 3). Elimination of high discharges may have hastened sedimentation and stabilization of dike fields by reducing the magnitude and frequencies of floods that could periodically scour sediment from them. Even if the Missouri had been evolving toward a single-channel system, its eventual form would have been far different from that which now exists. More than likely it would have evolved into a wider, longer, migrating stream with associated backwater environments.

Effects of Dikes on the Mississippi River

13. The Missouri River experience with river regulation and

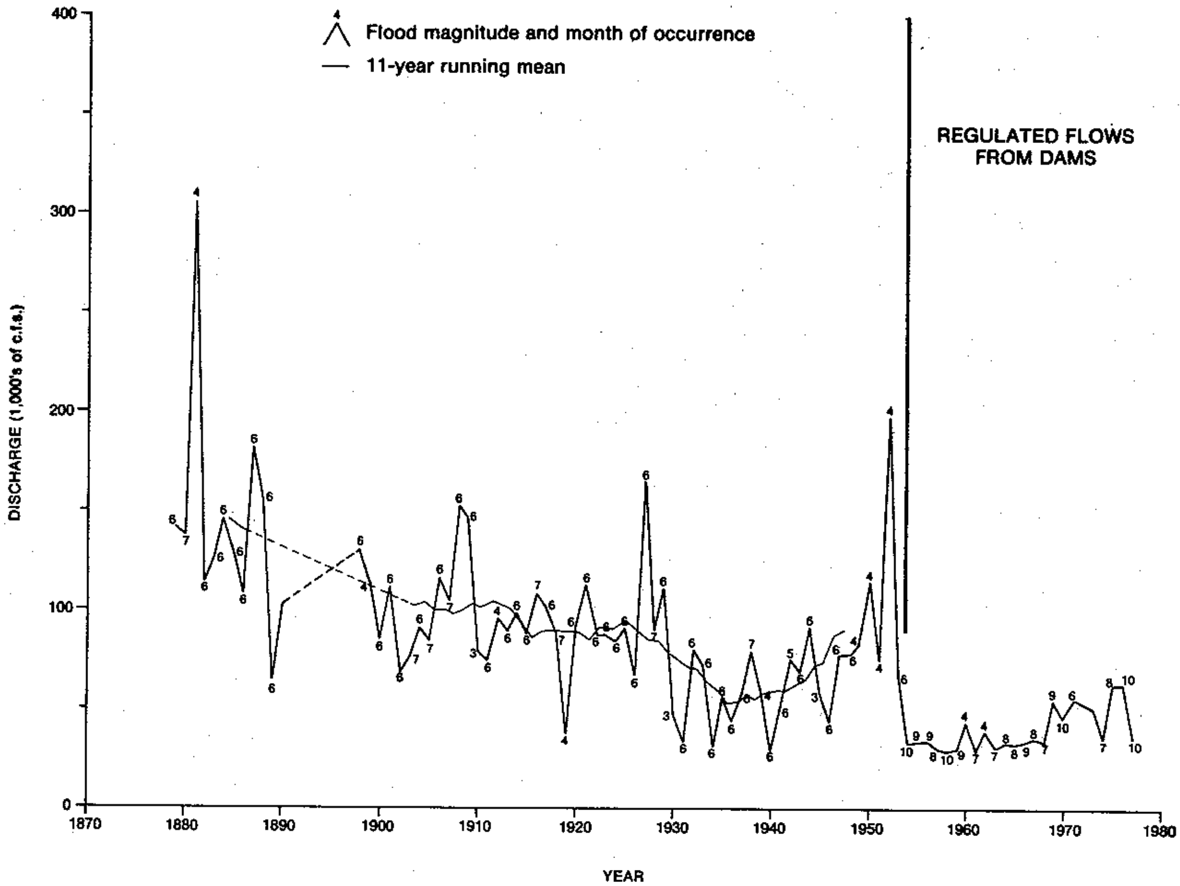

Figure 3. Recurrence characteristics of floods (highest mean monthly discharge per year) on the Missouri River at Sioux City, Iowa. The 11-year running mean is not continued into recent years because the discharge was regulated by dams (Hallberg et al. 1979)

stabilization cannot be directly extended to the lower Mississippi River due to fundamental hydrologic and morphologic differences. The Mississippi River has larger and more variable discharge, lower slope, and lower sediment concentration. High discharges that overflow dike fields tend to hinder establishment of permanent vegetation on bars and to flush out some sediments. Low slopes cause the effects of dike fields to extend further upstream and downstream than they do on steeper streams such as the Missouri River. Nevertheless, there is concern that sedimentation induced by dike fields on the lower Mississippi has adversely affected aquatic slack-water habitats.

14. Simons et al. (1981) concluded that the dike fields constructed on the upper Mississippi River prior to impoundment were responsible for reducing river width and water surface area and for forming new bars and islands by inducing sedimentation during the predam period. Likewise, Westphal and Clemence (1978) noted a considerable decrease in surface width on the middle Mississippi since the construction of dikes. This is supported by Simons et al. (1974), who concluded that depths were greater for all discharges on the middle Mississippi after modification by dikes.

15. Dike field effects on the lower Mississippi are less evident. Although case studies (Burch et al. 1984, Wells 1982) reveal scouring and increased thalweg depths adjacent to dike fields, studies of effects on river width are not conclusive. Evaluating the effects of dike construction is difficult because of the complexity of cross-sectional shape changes and the possible overriding effects of changes due to factors other than dike construction. Westphal et al. (1976) noted a decrease in mean width between first vegetation* of about 4 percent in the Memphis reach from 1961 to 1972 and a decrease of about 20 percent in the Vicksburg reach from 1962 to 1974, but cautioned that these changes could not be attributed to dike construction. Tuttle and Pinner (1982) found that mean top bank width increased by about 12 percent in the Vicksburg reach between 1962 and 1975, and width at low water increased by about 10 percent during the same period.** The lack of conclusive information about dike field effects on the lower Mississippi River habitats prompted this study.

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* Width measured as distance between first vegetation by scaling distances on hydrographic surveys and aerial photographs at 2-mile intervals. Of course, vegetation often occurs between top banks and low water, so these measurements are hard to compare with those done by others.

** Method of width measurement not specified, but was most likely based on distances scaled from hydrographic surveys at regular intervals.

PART II: STUDY PROCEDURE

Study Area

16. The study area consisted of a continuous 634-mile reach of the lower Mississippi River between miles 320.0 and 954.0 above Head of Passes (AHP). All of the river within the USAED, Vicksburg and Memphis, is included. There are no dikes in the USAED, New Orleans (miles 0.0-320.0 AHP).

Data Source

17. Low-water aerial photographs of the lower Mississippi River are taken annually by the Corps. These photos provide an economical source of water surface area data. Most of the river in the study area is surveyed at least every year or two by hydrographic methods. Many of these surveys are made during high water and contain details of dike field bottom topography. However, low-water photos are better sources than hydrographic charts for comparing biologically significant water surface areas. Hydrographic surveys do not provide a true synoptic view because they take from 2 to 3 years to complete. During this time, significant changes in flow usually occur, along with associated changes in dike field topography. From an aquatic biology perspective, low-water conditions are much more meaningful because slack-water habitats are critical to some fry and juvenile fish.

18. Low-water aerial photos used in the analysis were taken in 1962 and 1976. These dates were chosen for comparison because: (a) most dike fields in the USAED, Vicksburg and Memphis, have been constructed since 1962, and (b) examination of stage and discharge data on the dates of photography during the early 1960s and the period from 1975-1982 revealed that the most comparable low-water stages occurred in 1962 and 1976 (Table 4).

19. The 1976 photos were used to delineate diked and undiked

Table 4

Stages and Discharges on Dates of Photography, Lower Mississippi River, 1962 and 1976

Gage	1962 Stage Discharge, ft (1,000 cfs)	1976 Stage Discharge, ft (1,000 cfs)	Difference (1962 less 1976) Stage Discharge ft (1,000 cfs)
Memphis District			
Cairo	12.8	8.7	+4.1
Columbus	10.8	7.8	+3.0
Hickmon	7.5	4.5*	+3.0
New Madrid	6.6	7.1	-0.5
Cottonwood Point	5.9	5.8	+0.1
Fulton	0.4	-2.5	+2.9
Memphis	3.3 (209)	-1.2 (199)	+4.5 (+10)
Moon Landing	-0.4	-1.1	+0.7
Helena**	9.5 (200)	3.9 (184)	+5.6 (+16)
Fair Landing†	3.5	4.5	-1.0
Vicksburg District			
Rosedale	7.4	6.1	+1.3
Arkansas City	4.8 (246)	4.0 (276)	+0.4 (-30)
Greenville	16.4	13.2	+3.2
Lake Providence	-0.4	-3.0	+2.5
Vicksburg	4.9 (253)	3.5 (251)	+1.4 (+2)
St. Joseph	4.8	2.4	+2.4
Natchez	11.0 (276)	8.2 (218)	+2.8 (+58)

* Estimated record.
** Gage moved 3.4 miles between 1962 and 1976.
† Multiple photographic dates. Figure shown is mean for those dates.

reaches of the river. Reach boundaries and habitat types were traced onto clear mylar overlays. Photos for the USAED, Vicksburg, reaches were available in mosaics at a scale of 1:62,500 for both years. High contrast on the USAED, Memphis, mosaics obscured detail, so larger scale contact prints were used. The scales of individual photos were checked, and identifiable landmarks were used to carefully register them prior to preparing overlays. All tracings were digitized, and areas were calculated for each habitat type by reach using a microprocessor-based program called Stereometric Measurement and Analysis Program. Summary statistics were generated with the SPSS (Statistical Package for the Social Sciences). The tracings were used to prepare 1962 and 1976 habitat maps at a common scale. These maps (Appendix A) also show diked and undiked reach boundaries and river mileages.

Delineation of Habitat Types

20. The area between lines of permanent vegetation on the aerial photos was subdivided and categorized according to habitat type. Five aquatic habitat types were delineated for each year, and the river was subdivided into diked and undiked subreaches based on dike fields shown on the 1976 photographs. The habitat types are illustrated in Figure 4, and their definitions are as follows:

- a. Main channel. The main navigation channel in which large commercial vessels operate at low flow.
- b. Secondary channel. A subchannel that is separated from the main channel by a bar or island and carries flow all year.
- c. Chute. A narrow, shallow channel connected to the main or secondary channel by an inlet and outlet. Throughflow was occurring at the time of photography, but flow might not occur at lower stages.
- d. Slough. A slack-water area connected to a main or secondary channel by a single inlet or outlet and having no throughflow at the time of photography. Some sloughs would be classified as chutes at higher stages.
- e. Pool. An isolated body of water located within the riverbanks (between lines of permanent vegetation) and not connected to flow at the time of photography. Most pools are associated with dike fields, but some are found on large sandbars not associated with dike fields.

Although the habitat types selected are not identical to those used by Cobb and Clark (1981), they are very similar to the habitat types they identified as main channel, permanent secondary channel, temporary secondary channel, abandoned river channel 1, and dike field pool. The habitat types used in this study were selected because they were easy

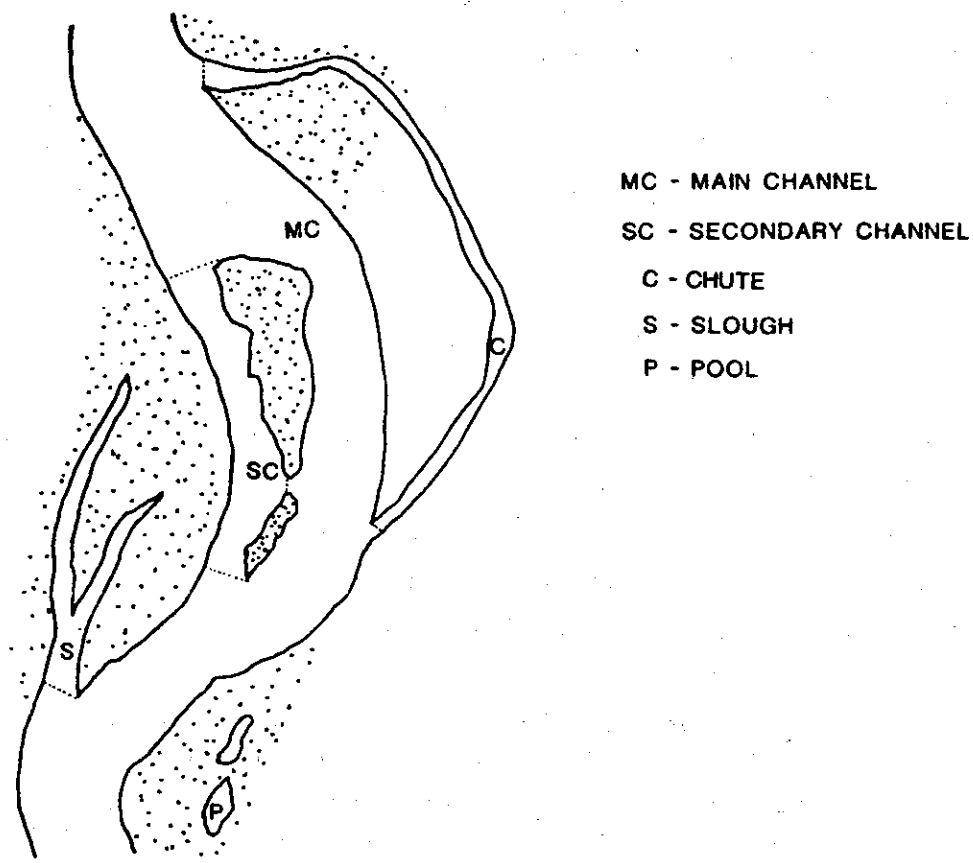

Figure 4. Aquatic habitat types

to identify on low-water photographs and because they could be more easily related to dike field purpose and effectiveness, such as to close secondary channels or point bar chutes. Midchannel bars and islands were also identified and measured.

PART III: RESULTS

Initial Findings

21. Initial results (Table 5) indicated an overall reduction in low-water surface area of about 50 square miles (11.4 percent)--34.7 square miles in the USAED, Memphis, and 15.8 square miles in the USAED, Vicksburg. Assuming constant river length between 1962 and 1976, the loss of 15.8 square miles in the USAED, Vicksburg, would have been equivalent to a reduction in mean low water width (MLWW)* of 8 percent, or about 365 ft.

22. These initial results were not consistent with those reported by Tuttle and Pinner (1982), who indicated increases in both top bank and low-water widths for the USAED, Vicksburg, since 1962. According to Tuttle and Pinner, width increased by 280 ft (10.4 percent) between 1962 and 1975 at the elevation of the Low Water Reference Plane (LWRP). To resolve the discrepancy, measurements of channel width at the LWRP elevation were made from detailed hydrographic surveys done in 1962-64 and 1974-75. Widths were measured along the entire study reach at approximately 1-mile intervals. The MLWW was found to be 2,970 ft in 1975, a figure almost identical to that reported by Tuttle and Pinner. However, the MLWW for 1962 was not in agreement with the figure reported by Tuttle and Pinner. They reported a value of 2,684 ft compared to the 2,940-ft width measured from the hydrographic surveys of this study. Further investigation revealed that Tuttle and Pinner's 1962 measurements were made at the elevation of the Average Low Water Plane (ALWP), the reference elevation in use in 1962, and not the LWRP as they indicated. The ALWP was 2 to 3 ft lower, on the average, than the LWRP.

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* Mean low water width was determined by dividing the total low-water surface area by the channel length. Low-water width based on only main channel area would be 15 to 20 percent less.

Table 5
Unadjusted Morphologic-Habitat Type Changes, 1962 to 1976

Reach and Habitat Type	1962 Area square miles (1)	1976 Area square miles (2)	Change square miles (3)	Percent Change (4)
Main channel	370.00	326.41	-44.58	-12.1
Memphis	201.69	169.50	-32.19	-16.0
Undiked	119.83	99.36	-20.47	-17.1
Diked	81.86	70.14	-11.72	-14.3
Vicksburg	169.31	156.91	-12.40	-7.3
Undiked	99.65	91.79	-7.86	-7.9
Diked	69.66	65.12	-4.54	-6.5
Secondary channel	42.14	22.80	-19.35	-45.9
Memphis	21.91	8.42	-13.49	-61.6
Undiked	9.03	6.28	-2.75	-30.4
Diked	12.88	2.14	-10.74	-97.7
Vicksburg	20.23	14.37	-5.86	-29.0
Undiked	7.26	8.46	+1.20	+16.5
Diked	12.97	5.91	-7.06	-62.6
Chute	15.44	19.70	+4.26	+27.6
Memphis	8.62	11.15	+2.53	+29.4
Undiked	2.37	3.53	+1.16	+48.8
Diked	6.25	7.62	+1.37	+21.9
Vicksburg	6.82	8.55	+1.73	+25.4
Undiked	1.15	1.25	+0.10	+8.5
Diked	5.67	7.30	+1.63	+28.9
Slough	13.40	18.09	+4.69	+35.0
Memphis	4.94	10.55	+5.61	+113.6
Undiked	2.89	4.25	+1.36	+47.0
Diked	2.05	6.30	+4.25	+207.0
Vicksburg	8.46	7.54	-0.92	-10.9
Undiked	3.75	1.79	-1.96	-35.8
Diked	4.71	5.75	+1.04	+22.0
Pool	0.21	4.67	+4.46	+2,123.8
Memphis	0.06	2.92	+2.86	+4,766.7
Undiked	0.00	0.00	0.00	0.0
Diked	0.06	2.92	+2.86	+4,766.7
Vicksburg	0.15	1.75	+1.60	+1,066.7
Undiked	0.00	0.12	+0.12	--
Diked	0.15	1.63	+1.48	+986.7
Total	442.19	391.67	-50.52	-11.4
Memphis	237.23	202.55	-34.68	-14.6
Undiked	134.13	113.42	-20.71	-15.4
Diked	103.10	89.13	-13.97	-13.6
Vicksburg	204.96	189.12	-15.84	-7.7
Undiked	111.81	103.41	-8.40	-7.5
Diked	93.15	85.71	-7.44	-8.5
Total undiked	245.94	216.83	-29.11	-11.8
Total diked	196.25	174.84	-21.41	-10.9
Bars and islands	89.76	65.04	-24.72	-27.5
Memphis	53.30	28.95	-24.35	-45.7
Undiked	27.69	17.92	-9.77	-35.3
Diked	25.61	11.03	-14.58	-57.0
Vicksburg	36.46	36.09	-0.37	-1.0
Undiked	13.91	17.98	+4.07	+29.3
Diked	22.55	18.11	-4.44	-19.7

Stage Adjustment

23. Based on the measured 260-ft difference in low-water width caused by the 2- to 3-ft difference in elevation, it seemed likely that the reduction in water surface area between 1962 and 1976 shown in Table 5 could have been the result of lower water stages at the time of photography in 1976. In the USAED, Memphis, the weighted average stage* was about 4.5 ft lower in 1976 than in 1962, and in the USAED, Vicksburg, the weighted average stage was about 2 ft lower. Based on the measured effect of stage difference on low-water width, the average widths computed from 1976 measurements were adjusted for the stage difference between 1962 and 1976 (Table 6). The results indicate little change in low-water width between 1962 and 1976.

24. Since river length did not change in the study reach between 1962 and 1976, stage-adjusted 1976 low-water surface areas were computed for the USAED, Vicksburg and Memphis, by multiplying their 1976 surface areas (column 2, Table 5) by an adjustment factor based on width (column 4, Table 6). Areas of bars and islands were divided, rather than multiplied, by this factor. The stage-adjusted surface area measurements are shown in Tables 7, 8, and 9 for the total reach, Memphis reach, and Vicksburg reach, respectively. Since the adjustment factor was deemed accurate to only three significant figures, adjusted areas are expressed in three significant figures. Adjusting the 1976 water surface areas in this manner may tend to overestimate area of main channel, secondary channel, sandbars, and islands and to underestimate chute, slough, and pool area because of differences in border slope. The bed, bank, and bar slopes associated with slack-water habitats during low water are much less steep than those associated with the riverbanks that border channels. Although this would not affect the substance of the conclusions discussed in the following section, it

* Weighted average stage was calculated by multiplying the stage at each gage by the distance from one-half way to the next upstream gage to one-half the way to the next downstream gage, summing the results, and dividing by the total river mileage involved.

Table 6

Mean Low-Water Widths, 1962 and 1976

Reach	1962 Photo Width ft (1)	1976 Photo Width ft (2)	Stage Adjustment* for 1976 Width ft (3)	Habitat Area Adjustment Factor $1 + \frac{\text{Col 3}}{\text{Col 2}}$ (4)	1976 Stage-Adjusted Width ft (5)	Change, 1962 to 1976 ft (6)	Percent Change 1962-1976 (7)
Memphis	3,720	3,170	590	1.19	3,760	+40	+1.0
Vicksburg	3,640	3,360	260	1.08	3,620	-20	-0.5
Total reach	3,680	3,260	440	**	3,700	+20	+0.5

* Stage adjustment for mean widths calculated as follows:

Based on 1974 hydrographic chart measurements, river width 5 ft above LWRP was 660 ft greater than LWRP width. Stages at the times of photography in 1976 were 4.5 ft lower in the USAED, Memphis, and 2.0 ft lower in the USAED, Vicksburg. An adjustment for mean width for the total reach was computed as the length-weighted average of the two subreaches.

$$\text{Memphis width adjustment} = \frac{4.5(660)}{5} = 590 \text{ ft}$$

$$\text{Vicksburg width adjustment} = \frac{2(660)}{5} = 260 \text{ ft}$$

$$\text{Total stage adjustment} = \frac{(4.5)(337) + (2)(297)}{(337 + 297)} \times \frac{660}{5} = 440 \text{ ft}$$

** An area adjustment factor was not computed for the total reach. The figures shown in Table 7 are the sums of corresponding entries in Tables 8 and 9.

Table 7

Stage-Adjusted Morphologic-Habitat Type Changes, 1962-1976, Total Reach (Mile 320 AHP to Mile 954 AHP)

Habitat Type	1962 Area square miles (1)	1976 Area square miles (2)	Change square miles (3)	Percent Change (4)
Main channel	371.00	371.	0.	0.
Undiked	219.48	217.	-2.4	-1.1
Diked	151.52	153.8	+2.3	+1.5
Secondary channel	42.14	25.54	-16.7	-39.5
Undiked	16.29	16.61	0.32	+2.0
Diked	25.85	8.93	-16.92	-65.45
Chute	15.44	22.50	+7.1	+46.
Undiked	3.52	5.55	+2.03	+57.7
Diked	11.92	16.95	+5.03	+42.2
Slough	13.40	20.70	+7.2	+54.
Undiked	6.64	6.99	+0.35	+5.3
Diked	6.76	13.71	+6.95	+103.
Pools	0.21	5.37	+5.16	+2,500.
Undiked	0.00	0.13	+0.13	--
Diked	0.21	5.24	+5.03	+2,400.
Total	442.19	446.	+3.	+1.
Undiked	245.94	247.	+1.	0.
Diked	196.25	199.	+3.	+1.
Bars and islands	89.76	57.8	-32.0	-35.7
Undiked	41.60	31.7	-9.9	-24.
Diked	48.16	26.1	-22.1	-45.8

Table 8

Stage-Adjusted Morphologic-Habitat Type Changes, 1962-1976, USAED, Memphis (Mile 617-Mile 954)

Habitat Type	1962 Area square miles (1)	1976 Area square miles (2)	Change square miles (3)	Percent Change (4)
Main channel	201.69	202.	0.	0.
Undiked	119.83	118.	-2.	-2.
Diked	81.86	83.5	+1.6	+2.0
Secondary channel	21.91	10.02	-11.89	-54.27
Undiked	9.03	7.47	-1.56	-17.3
Diked	12.88	2.55	-10.33	-80.20
Chute	8.62	13.27	+4.65	+53.9
Undiked	2.37	4.20	+1.83	+77.2
Diked	6.25	9.07	+2.82	+45.1
Slough	4.94	12.56	+7.62	+154.
Undiked	2.89	5.06	+2.17	+75.1
Diked	2.05	7.50	+5.45	+2.66
Pools	0.06	3.48	+3.42	+5,700.
Undiked	0.00	0.00	0.00	0.00
Diked	0.06	3.48	+3.42	+5,700.
Total	237.23	241.	+4.	+2.
Undiked	134.13	135.	+1.	0.
Diked	103.10	106.	+3.	+3.
Bars and islands	53.30	24.4	-28.9	-54.2
Undiked	27.69	15.1	-12.6	-45.5
Diked	25.61	9.3	-16.3	-63.7

Table 9

Stage-Adjusted Morphologic-Habitat Type Changes, 1962-1976, USAED, Vicksburg (Mile 320 to Mile 617)

Habitat Type	1962 Area square miles (1)	1976 Area square miles (2)	Change square miles (3)	Percent Change (4)
Main channel	169.31	169.4	0.1	0.06
Undiked	99.65	99.1	-0.6	-0.6
Diked	69.66	70.3	+0.6	+0.9
Secondary channel	20.23	15.52	-4.7	-23.3
Undiked	7.26	9.14	+1.88	+25.9
Diked	12.97	6.38	-6.59	-50.8
Chute	6.82	9.23	+2.41	+35.3
Undiked	1.15	1.35	+0.20	+17.
Diked	5.67	7.88	+2.21	+39.0
Slough	8.46	8.14	-0.32	-3.8
Undiked	3.75	1.93	-1.82	-48.5
Diked	4.71	6.21	+1.50	+31.9
Pools	0.15	1.89	+1.74	+1,200.
Undiked	0.00	0.13	+0.13	--
Diked	0.15	1.76	+1.61	+1,100.
Total	204.96	205.	-1.	-0.5
Undiked	111.81	112.	0.	0.
Diked	93.15	92.6	-0.6	-0.6
Bars and islands	36.46	33.4	-3.1	-8.4
Undiked	13.91	16.6	+2.7	+19.
Diked	22.55	16.8	-5.8	-26.

would make them somewhat conservative, because actual increases in slack-water habitat may have been somewhat larger than the results indicate. Had the 1976 stages been identical to 1962, pool, slough, and chute habitat classifications would have changed to some extent, but presumably the changes would not have been significant.

Stage-Adjusted Results

25. The use of dikes to close secondary channels and chutes is clearly reflected in the data of Tables 7-9. Roughly 45 percent of the low-water surface area was in diked reaches in 1976, but 61 percent of the 1962 secondary channel area and 77 percent of the 1962 chute area were located in reaches that had been diked by 1976. A number of conclusions can be readily drawn from the results shown in Tables 7-9.

- a. Total low-water surface area and main channel area remained relatively unchanged between 1962 and 1976.
- b. There was a significant reduction in secondary channel area, nearly all of which occurred in diked reaches. In fact, a slight increase occurred in the undiked reaches of the USAED, Vicksburg. Thus, dikes were effective in reducing secondary channel area.
- c. Total chute area increased between 1962 and 1976, despite the common use of dikes to close chutes. Nearly all of the increase in chute areas occurred in diked reaches. This would imply that many of the dike fields constructed in secondary channels did not completely eliminate flow. Even at low water, shallow throughflow still occurred.
- d. Slough area increased dramatically in diked reaches, presumably as a result of chute and secondary channel closure. Slough area also increased in undiked reaches of the USAED, Memphis, but decreased to a comparable degree in undiked reaches in the USAED, Vicksburg.
- e. Nearly all pool area developed since 1962, and practically all of this area is associated with dike fields.
- f. There was an overall decrease in area of midchannel bars and islands, most of which occurred in diked reaches.

26. In summary, diked reaches exhibited significant increases in low-water surface area of pools, sloughs, and chutes, which are

considered to be valuable types of aquatic habitat (Beckett et al. 1983; Pennington, Baker, and Bond 1983). Secondary channel area decreased accordingly.

PART IV: DISCUSSION

27. The foregoing results suggest that dike fields on the lower Mississippi have not completely filled with sediment. In fact, dikes on the lower Mississippi appear to be responsible for transforming secondary channel areas into shallow-water and slack-water habitats at low flow.

28. Whether the chutes, sloughs, and pools will persist through time and become permanent features depends on whether the sedimentation patterns responsible for the changes observed are transient features, or whether they represent a condition of dynamic equilibrium that will be maintained for the foreseeable future. Analysis of changes by age of dike field revealed no noticeable trend or pattern. This would suggest that the changes observed between 1962 and 1976 are not transient and do not represent a gradual evolution toward eventual sedimentation that will eliminate slack-water environments. Rather, it suggests that sedimentation patterns develop rapidly following dike field construction and quickly attain a dynamic equilibrium that persists for a number of years.

29. A number of diked reaches containing large areas of shallow-water habitats seem to fit this description. Figure 5 shows one of the troublesome navigation reaches in the USAED, Vicksburg. It contains several dike fields with a variety of designs and locations, some of which were constructed in the mid- to late-1960s. The figure was compiled from navigation charts which are produced from low-water photographs taken annually. Even though there was variability in stage at the time of photography, the sequence clearly shows that the dike fields in this reach have developed basic sedimentation patterns that have persisted over a period of 10-15 years.

30. Because of the short time period covered by this study, it is not possible to specify whether the slack-water environments associated with dike fields are transitory or permanent features. A hypothesis dealing with the behavior of a large dynamic river based on two

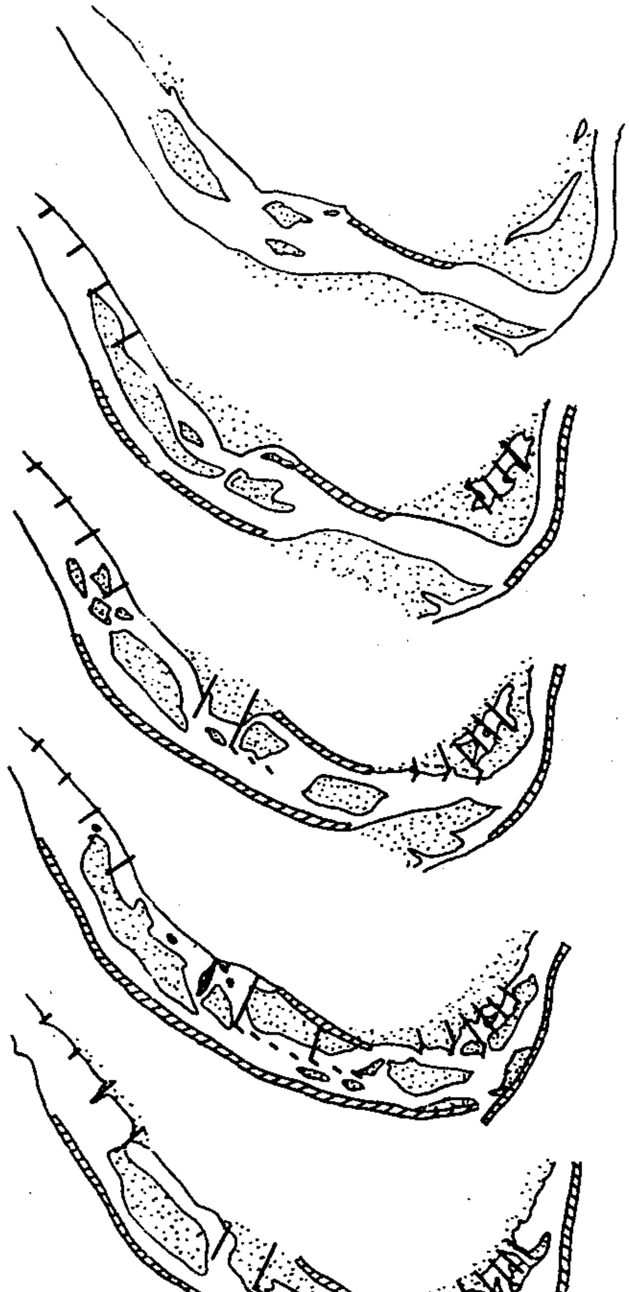

Figure 5. Habitat changes in a typical diked reach

points in time separated by 14 years remains tenuous until reexamined in the light of additional data. The effect on dike field sedimentation patterns of the major Mississippi River flood that occurred in

1973 is unknown. A better understanding of the mechanics of dike field sedimentation and its relation to dike location, dike field design, flow hydrology, and sediment flow is needed to resolve the issue. Burch et al. (1984) noted that two important gaps exist in studies of dikes and dike fields. "First, studies of processes within the dike fields have received little attention. Thus, little is known about how dike field placement, river hydrology, and dike design parameters influence patterns of sediment accretion within dike fields. Second, laboratory and theoretical work has failed to simulate the complex dynamics of field situations." Such an understanding can be gained only by studying dike field sedimentation processes in detail, either by well-designed model studies that do simulate field conditions or by extensive monitoring of dike field morphology using data collected over long periods. In light of recent findings (Beckett and Pennington 1985) regarding the ecological value of dike fields, such an effort would seem to be extremely worthwhile.

PART V: SUMMARY AND CONCLUSIONS

31. Dike field sedimentation processes appear to be different on the lower Mississippi River than on the lower Missouri. Although some of the reduction in low-water surface area on the lower Missouri since 1947 may have been due to natural trends that have been occurring since 1890, the almost total loss of slack water in diked reaches clearly seems to be the result of river-training structures and dam construction. During the 14-year period from 1962 to 1976 total low-water surface area on the Mississippi changed very little, but in diked reaches significant loss occurred in secondary channel area and significant offsetting gains were observed for chutes, sloughs, and pools, all of which are valuable slack-water habitats.

32. It cannot be determined whether the slack-water habitats measured on the lower Mississippi are temporary features that will eventually fill with sediment or whether they represent some sort of dynamic equilibrium that will be maintained. It is conceivable that the highly variable discharge, lower slope, and relatively low sediment load of the Mississippi River enable it to periodically scour sediments from dike fields during high flood discharges, thereby rejuvenating low-water slack-water environments provided by dike field pools.

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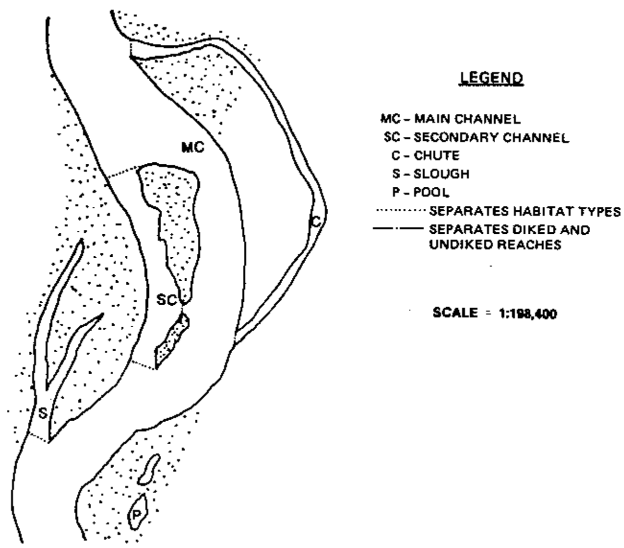
APPENDIX A: MAPS OF WATER SURFACE AREA AND AQUATIC HABITAT TYPES, 1962 AND 1976

The maps in this appendix were prepared from low-water aerial photographs as described in Part II of the main text. A legend for the maps is shown below. Each of the maps in this appendix is drawn to a scale of 1:198,400 or 1 in. = 3.13 miles.



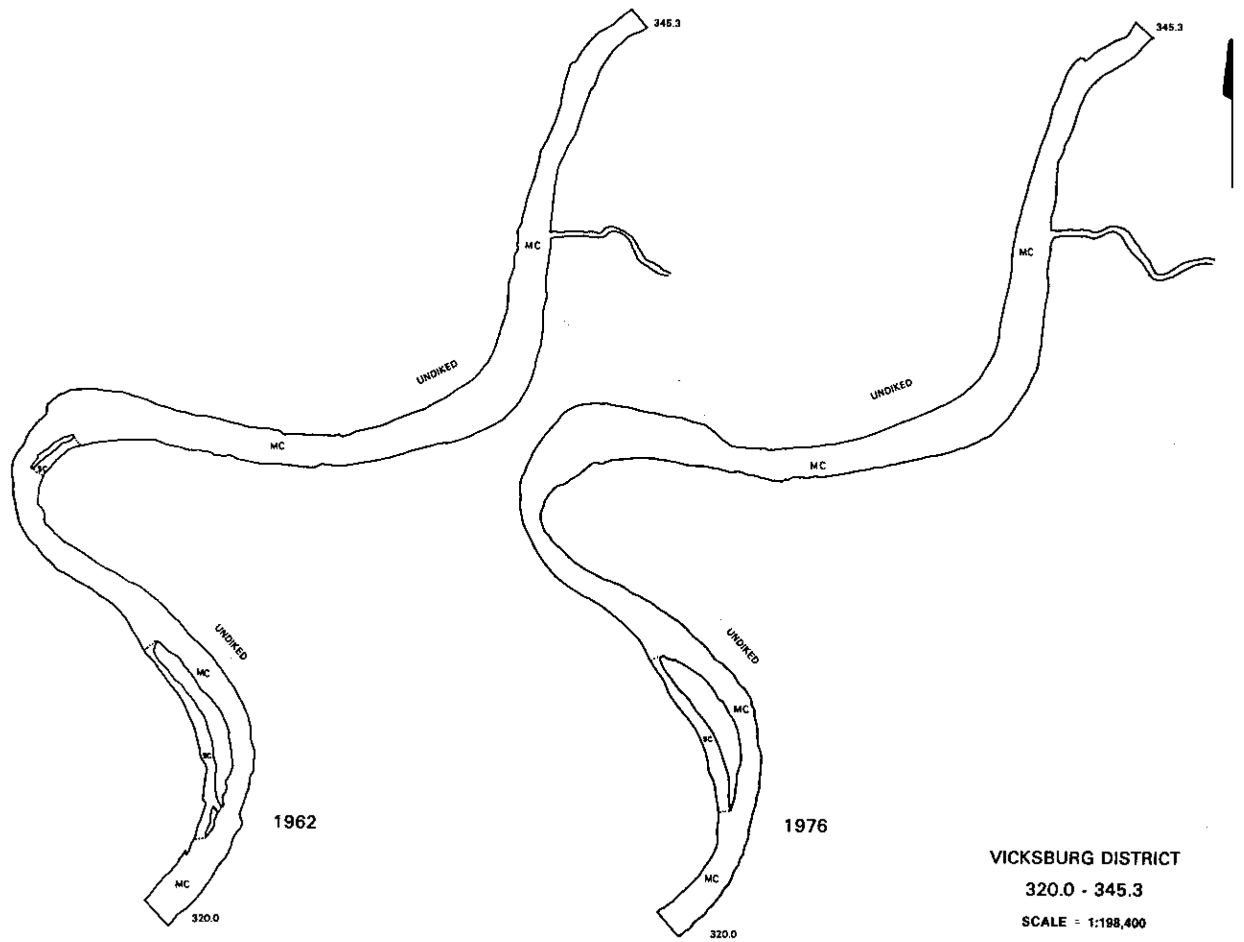


Figure A1. Water surface area and aquatic habitat types in the Mississippi from mile 320.0 to 345.3 AHP (Vicksburg District) in 1962 and 1976

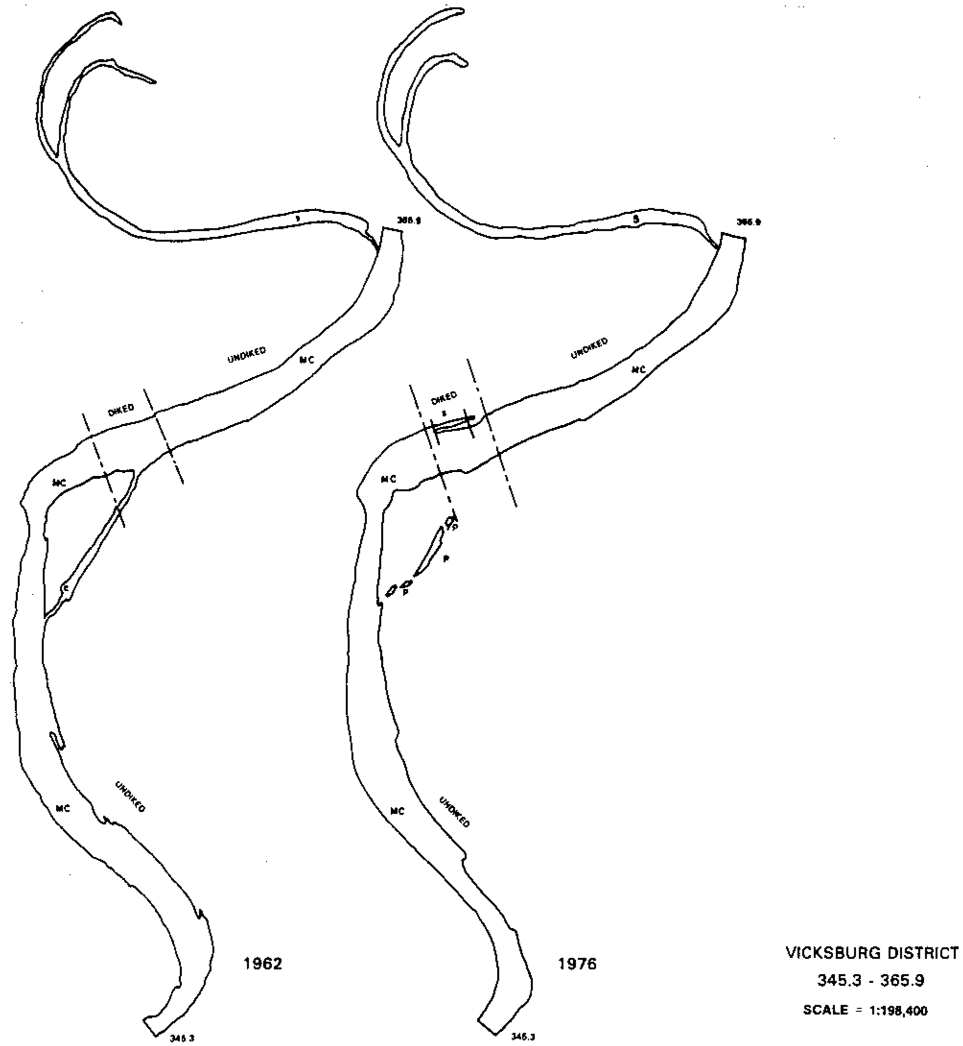


Figure A2. Water surface area and aquatic habitat types in the Mississippi from mile 345.3 to 365.9 AHP (Vicksburg District) in 1962 and 1976

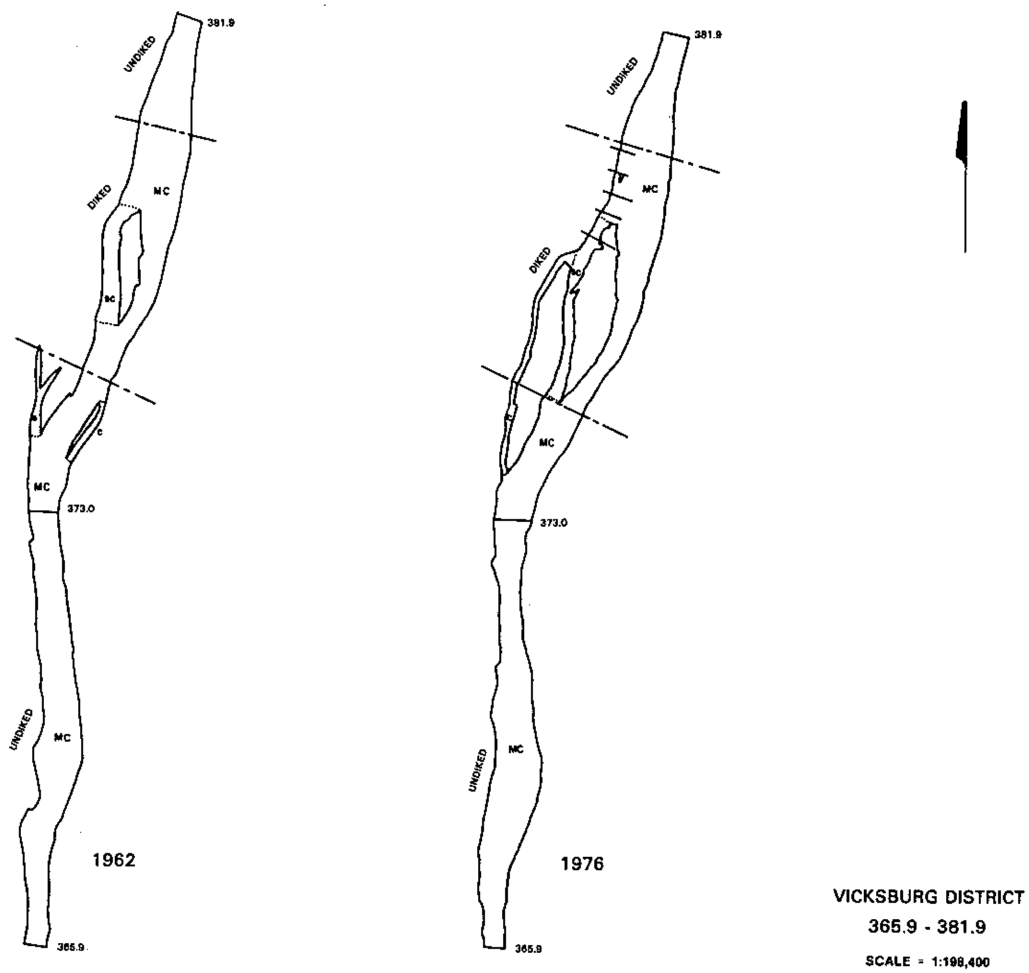


Figure A3. Water surface area and aquatic habitat types in the Mississippi from mile 365.9 to 381.9 AHP (Vicksburg District) in 1962 and 1976

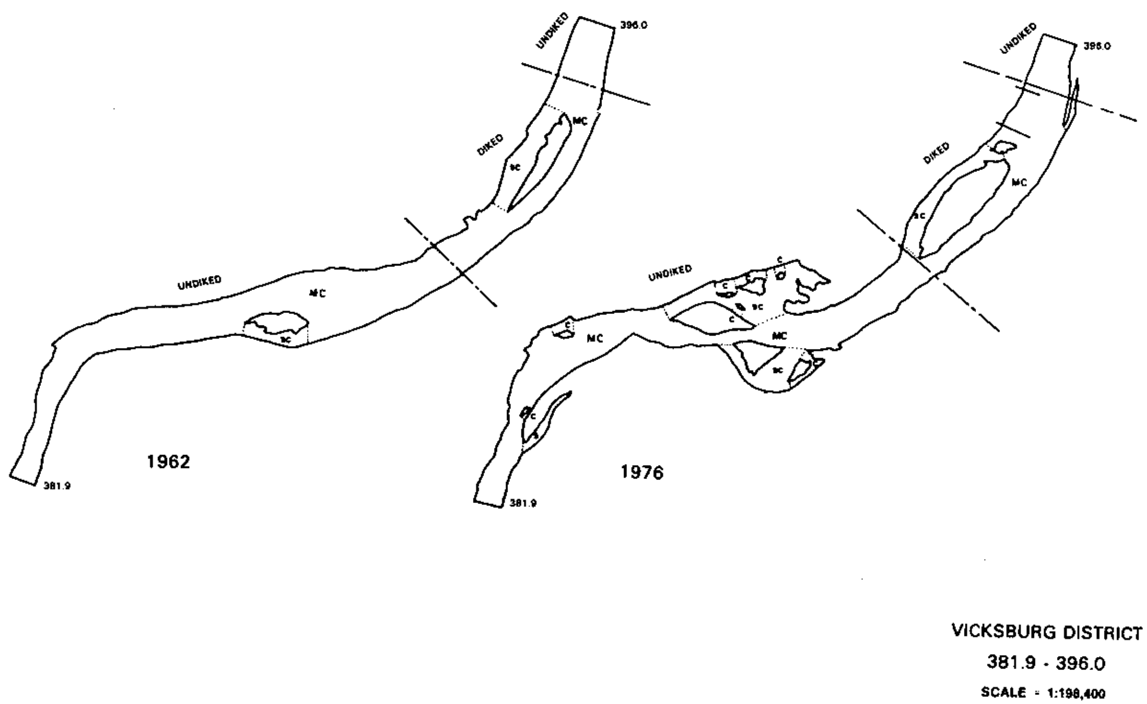


Figure A4. Water surface area and aquatic habitat types in the Mississippi from mile 381.9 to 396.0 AHP (Vicksburg District) in 1962 and 1976

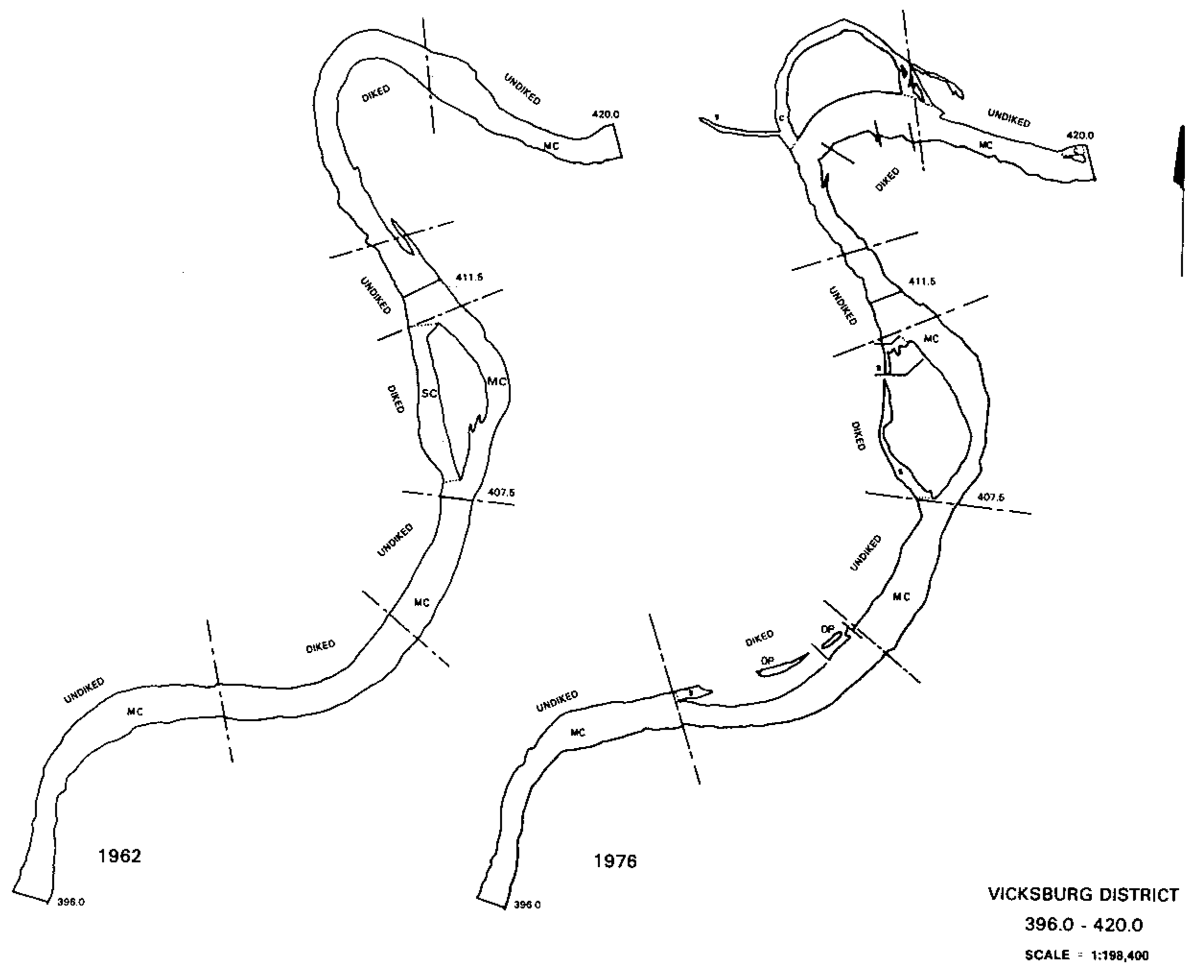


Figure A5. Water surface area and aquatic habitat types in the Mississippi from mile 396.0 to 420.0 AHP (Vicksburg District) in 1962 and 1976

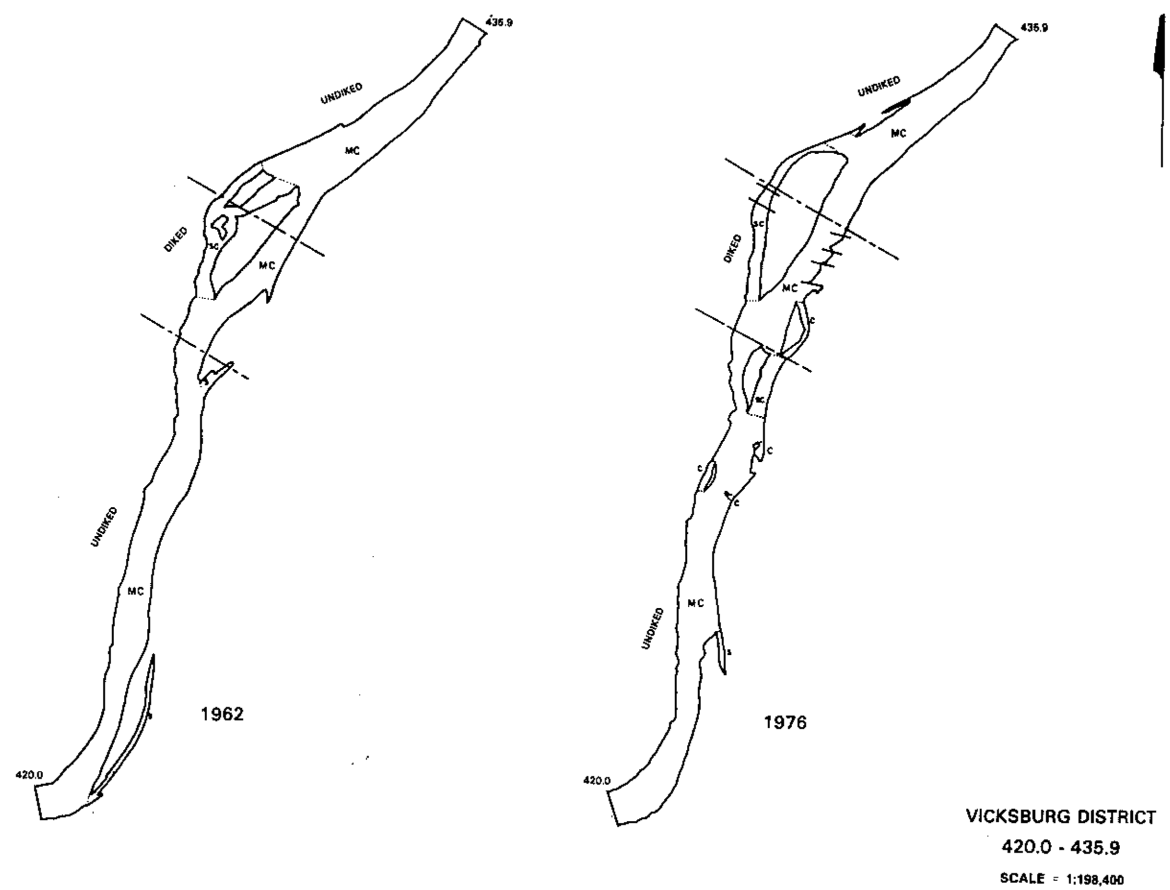


Figure A6. Water surface area and aquatic habitat types in the Mississippi from mile 420.0 to 435.9 AHP (Vicksburg District) in 1962 and 1976

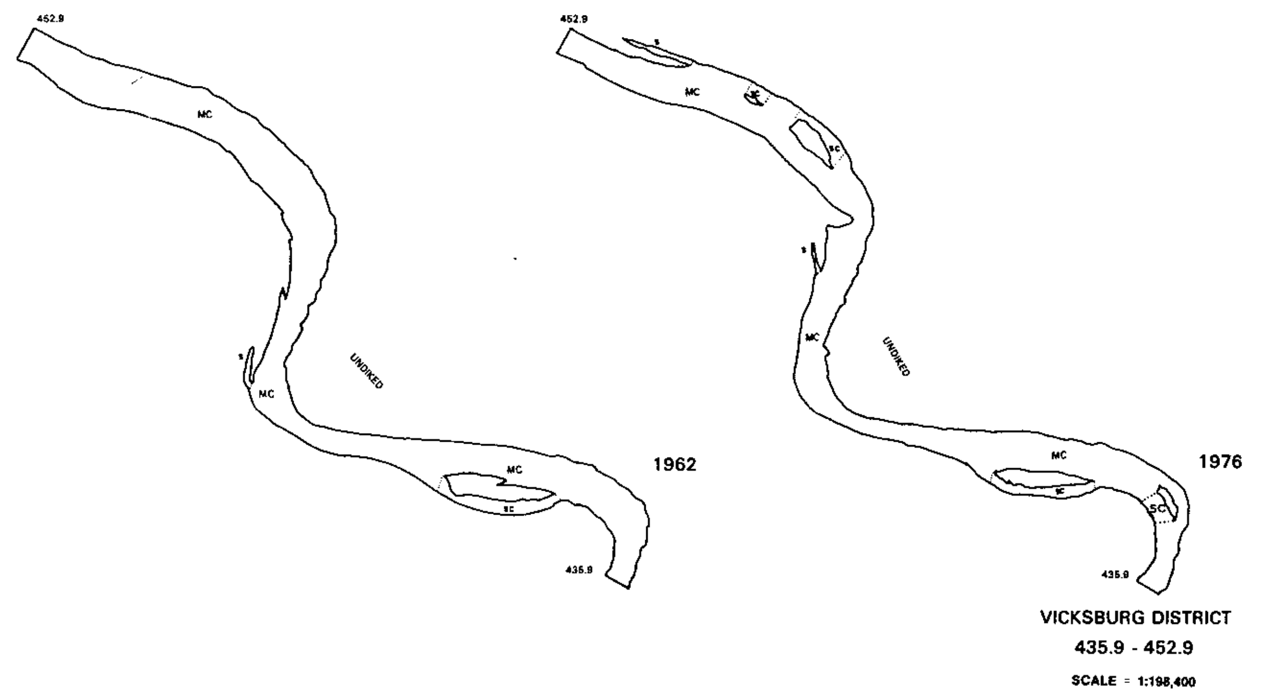


Figure A7. Water surface area and aquatic habitat types in the Mississippi from mile 435.9 to 452.9 AHP (Vicksburg District) in 1962 and 1976

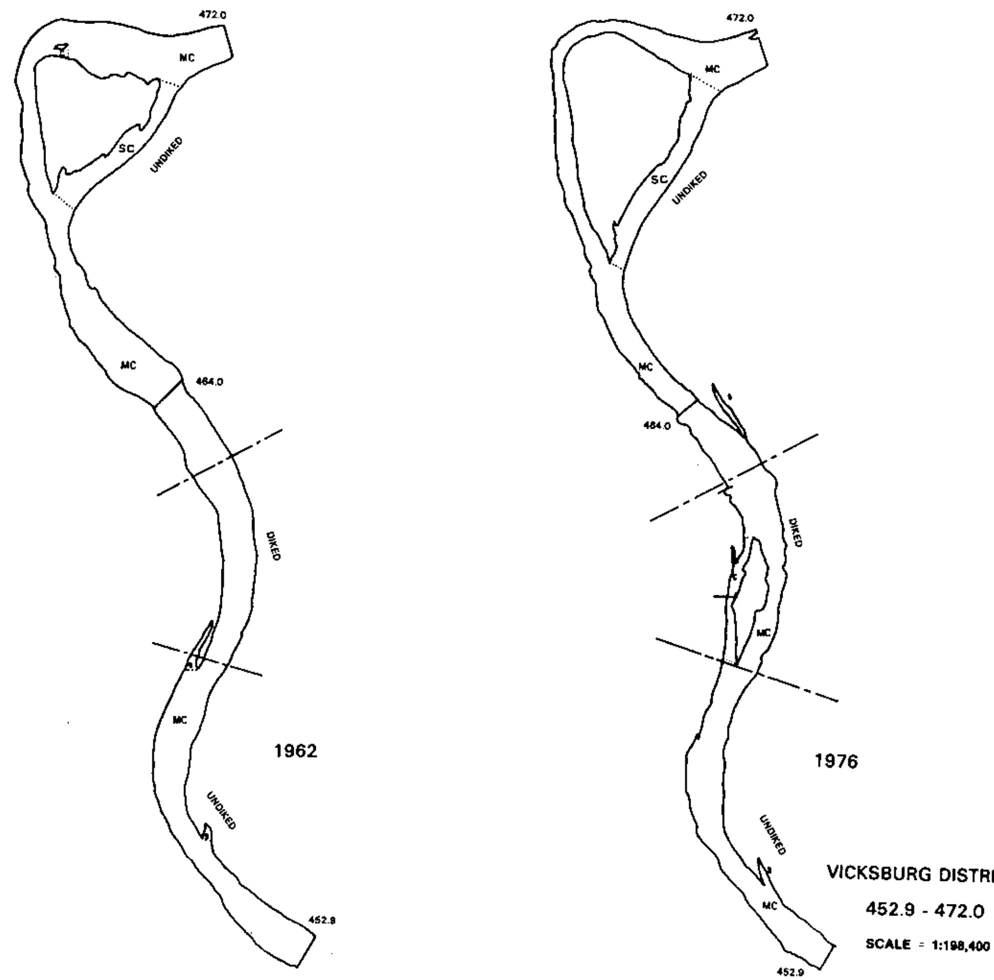


Figure A8. Water surface area and aquatic habitat types in the Mississippi from mile 452.9 to 472.0 AHP (Vicksburg District) in 1962 and 1976

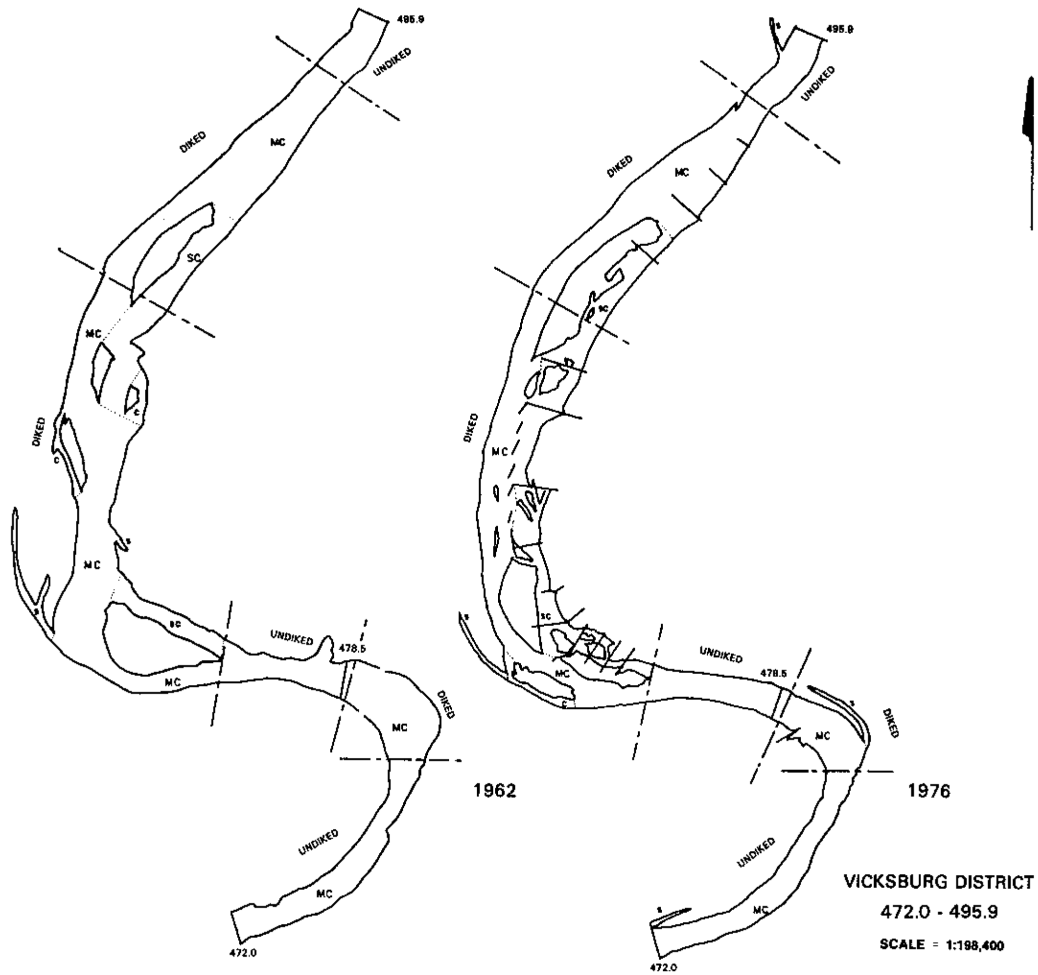


Figure A9. Water surface area and aquatic habitat types in the Mississippi from mile 472.0 to 495.9 AHP (Vicksburg District) in 1962 and 1976

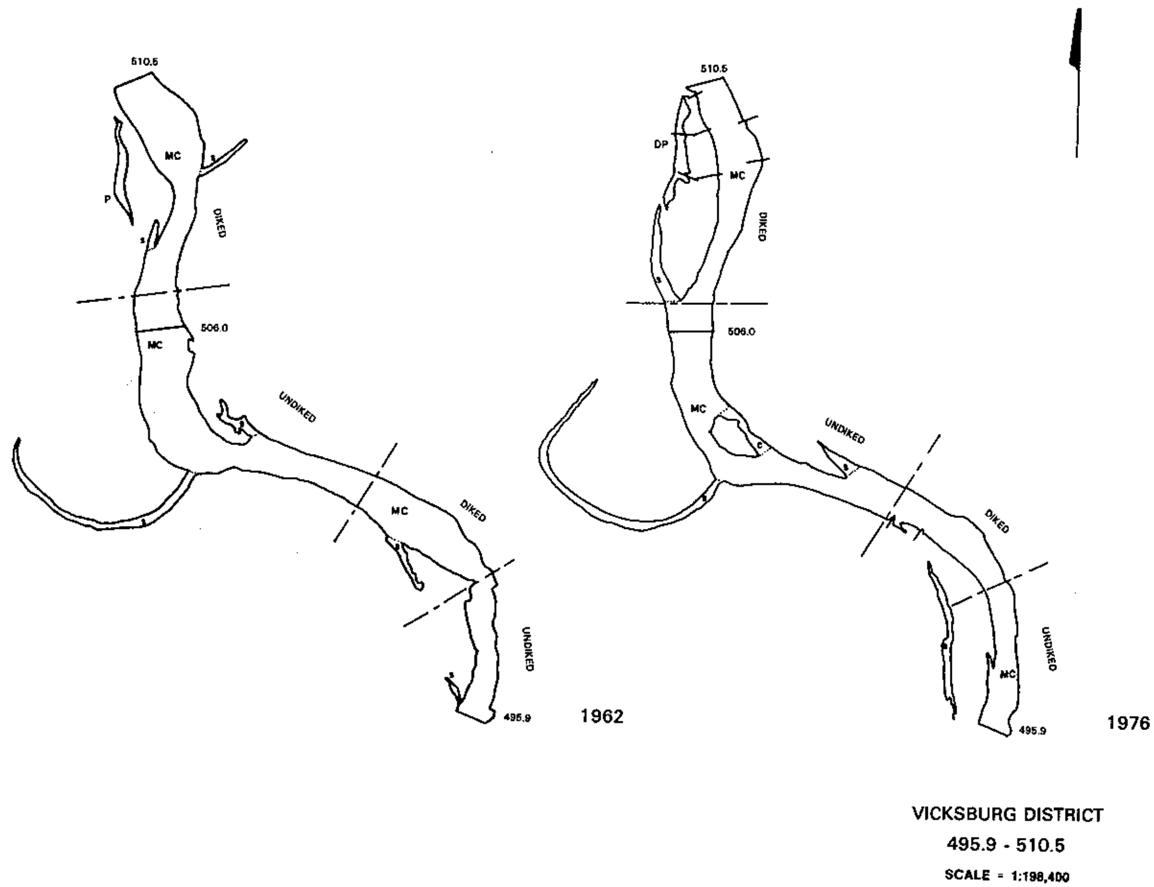


Figure A10. Water surface area and aquatic habitat types in the Mississippi from mile 495.9 to 510.5 AHP (Vicksburg District) in 1962 and 1976

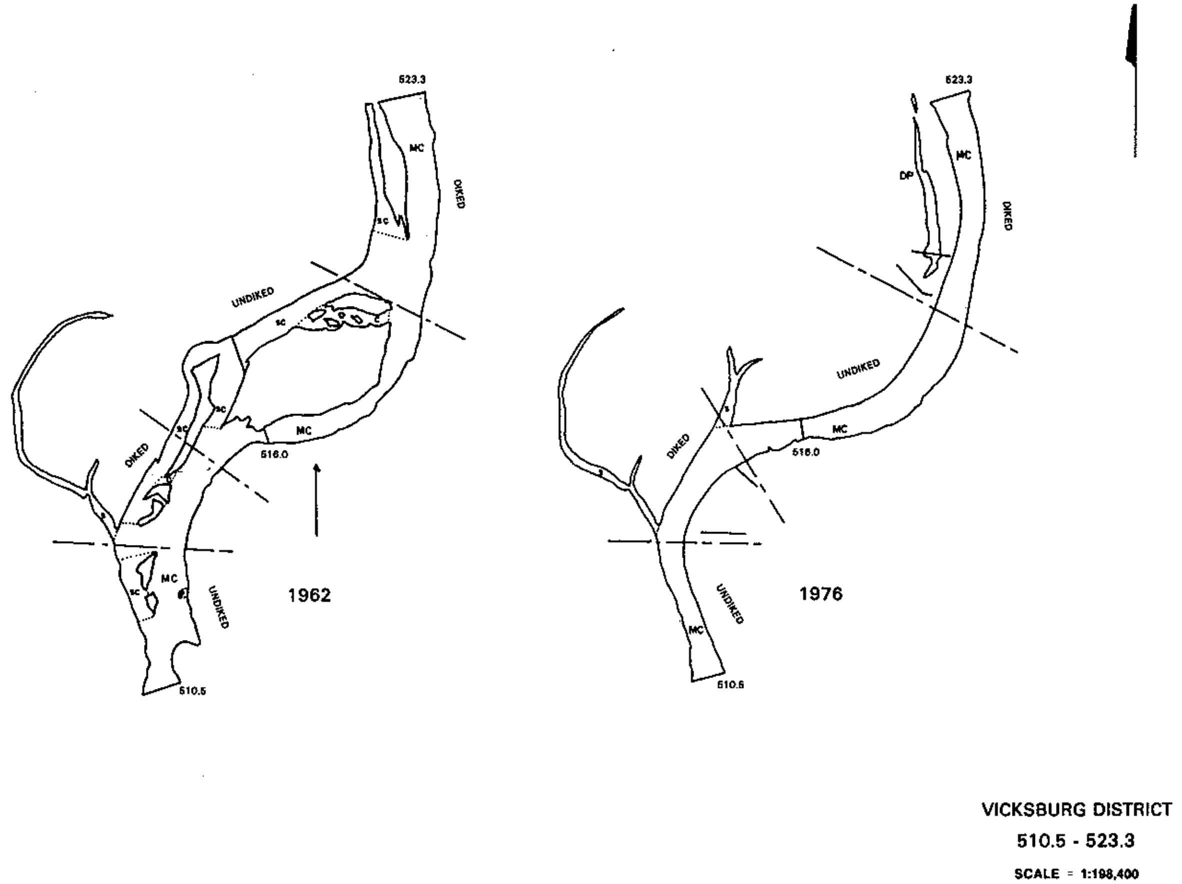


Figure A11. Water surface area and aquatic habitat types in the Mississippi from mile 510.5 to 523.3 AHP (Vicksburg District) in 1962 and 1976

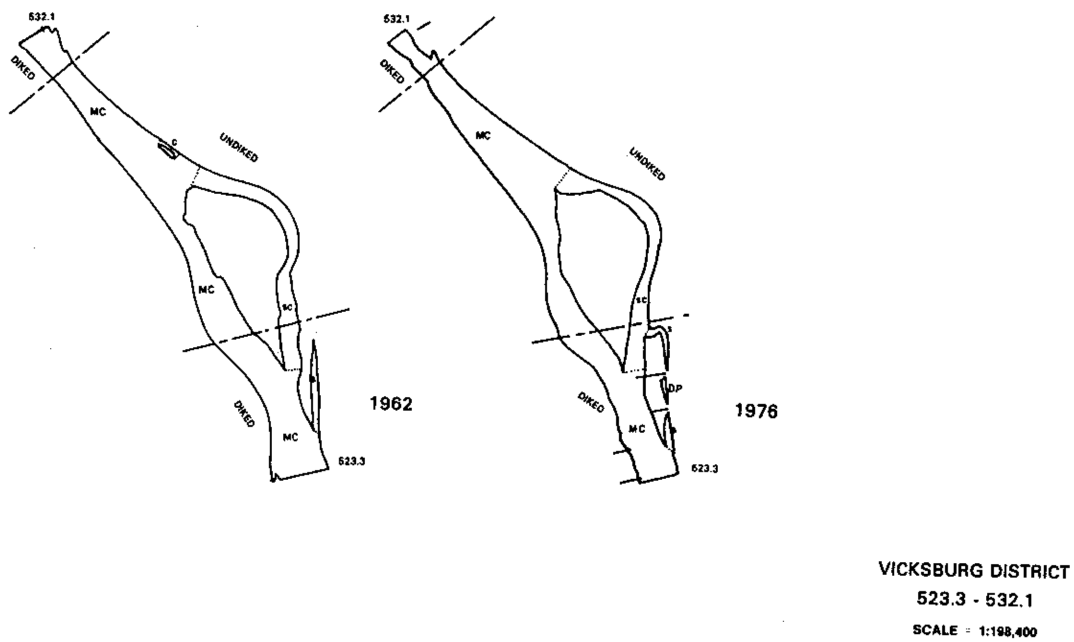


Figure A12. Water surface area and aquatic habitat types in the Mississippi from mile 523.3 to 532.1 AHP (Vicksburg District) in 1962 and 1976

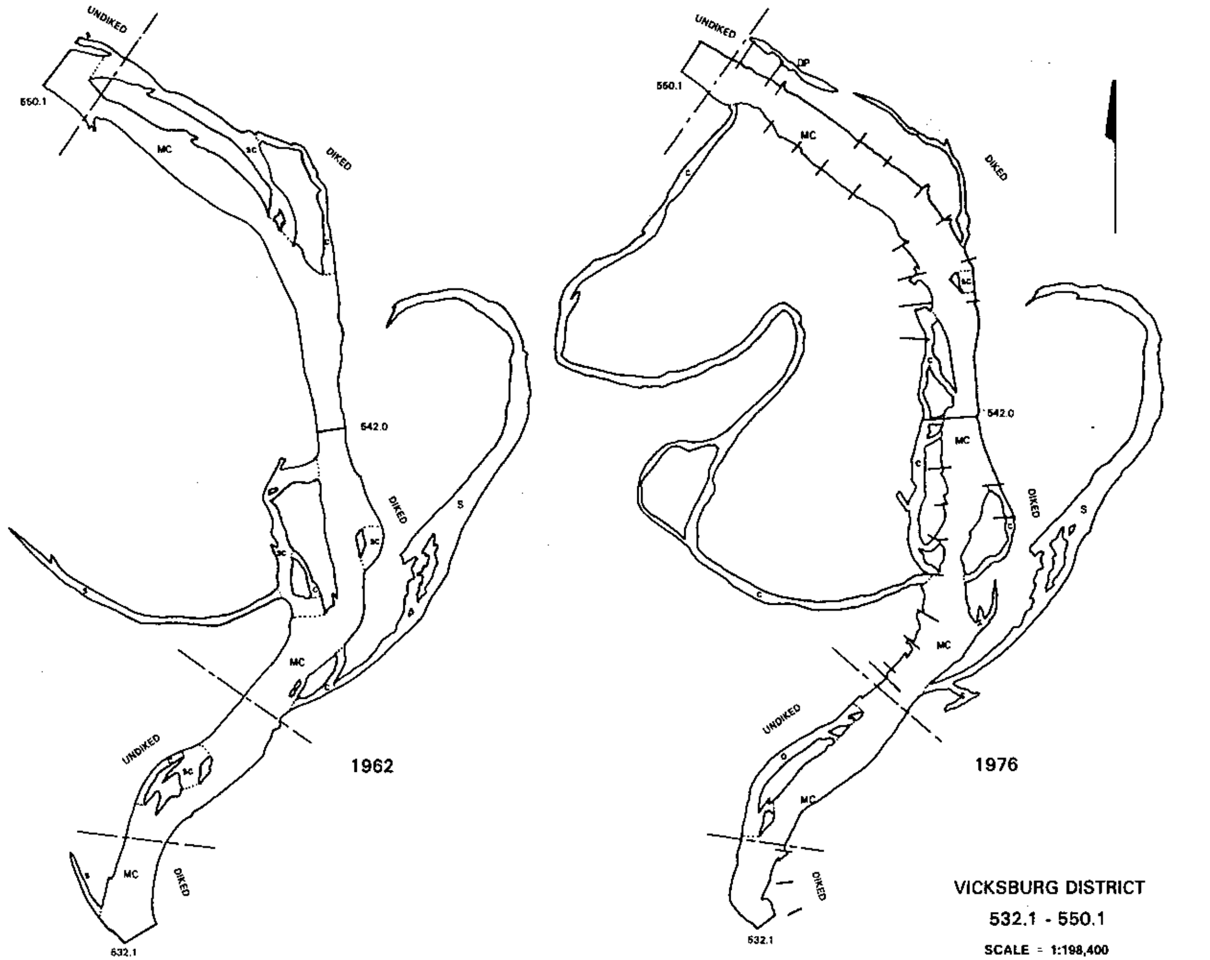


Figure A13. Water surface area and aquatic habitat types in the Mississippi from mile 532.1 to 550.1 AHP (Vicksburg District) in 1962 and 1976

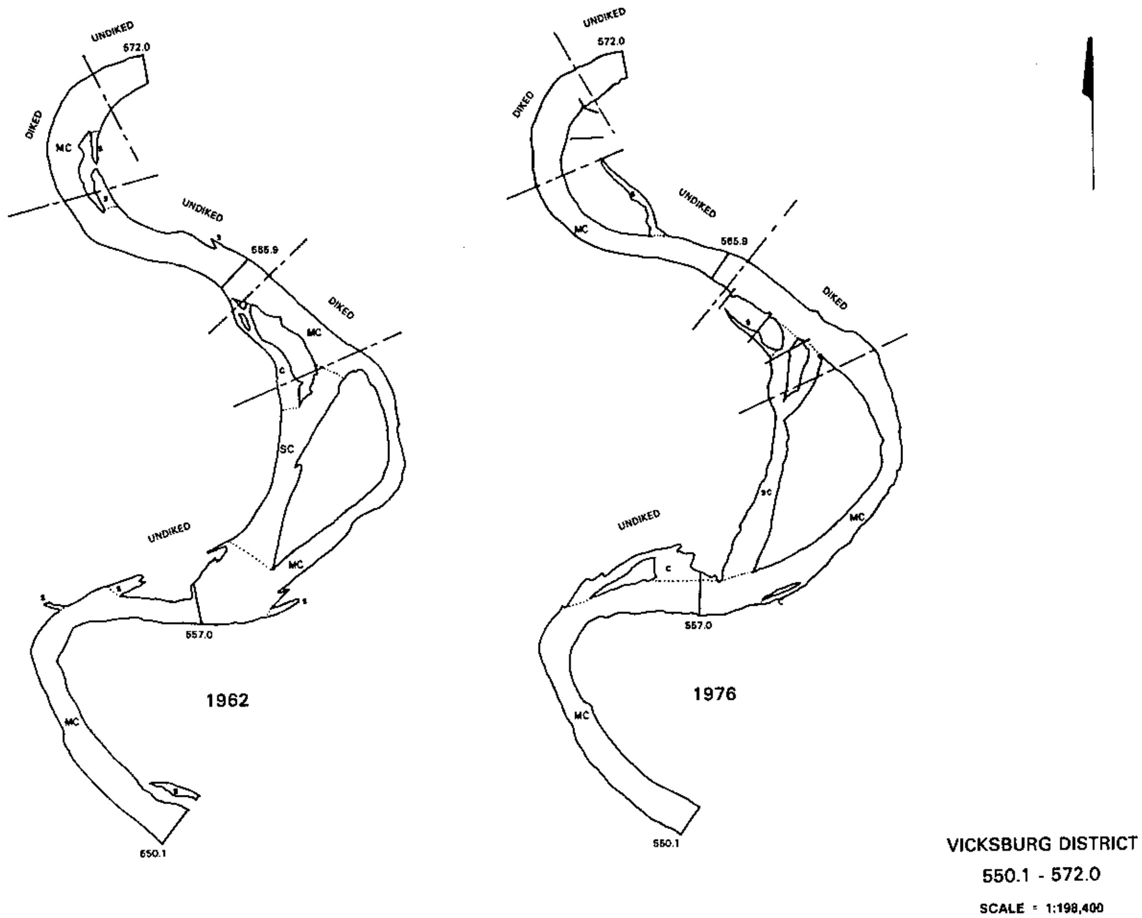


Figure A14. Water surface area and aquatic habitat types in the Mississippi from mile 550.1 to 572.0 AHP (Vicksburg District) in 1962 and 1976

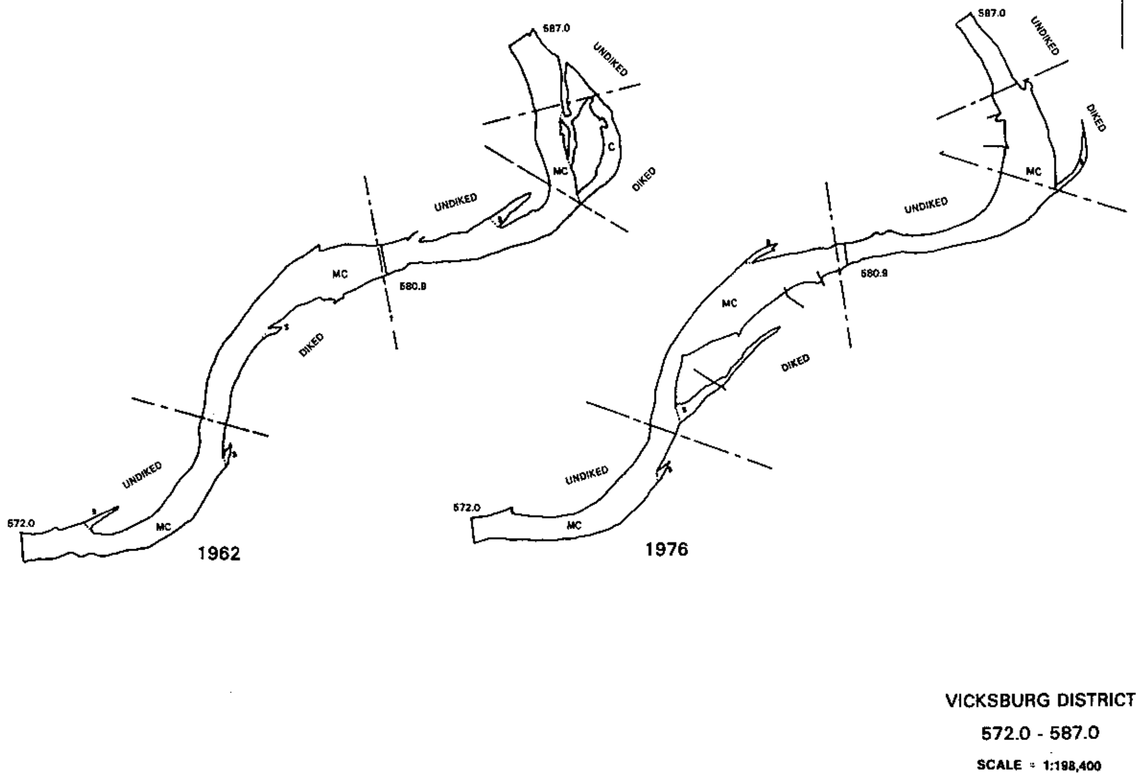


Figure A15. Water surface area and aquatic habitat types in the Mississippi from mile 572.0 to 587.0 AHP (Vicksburg District) in 1962 and 1976

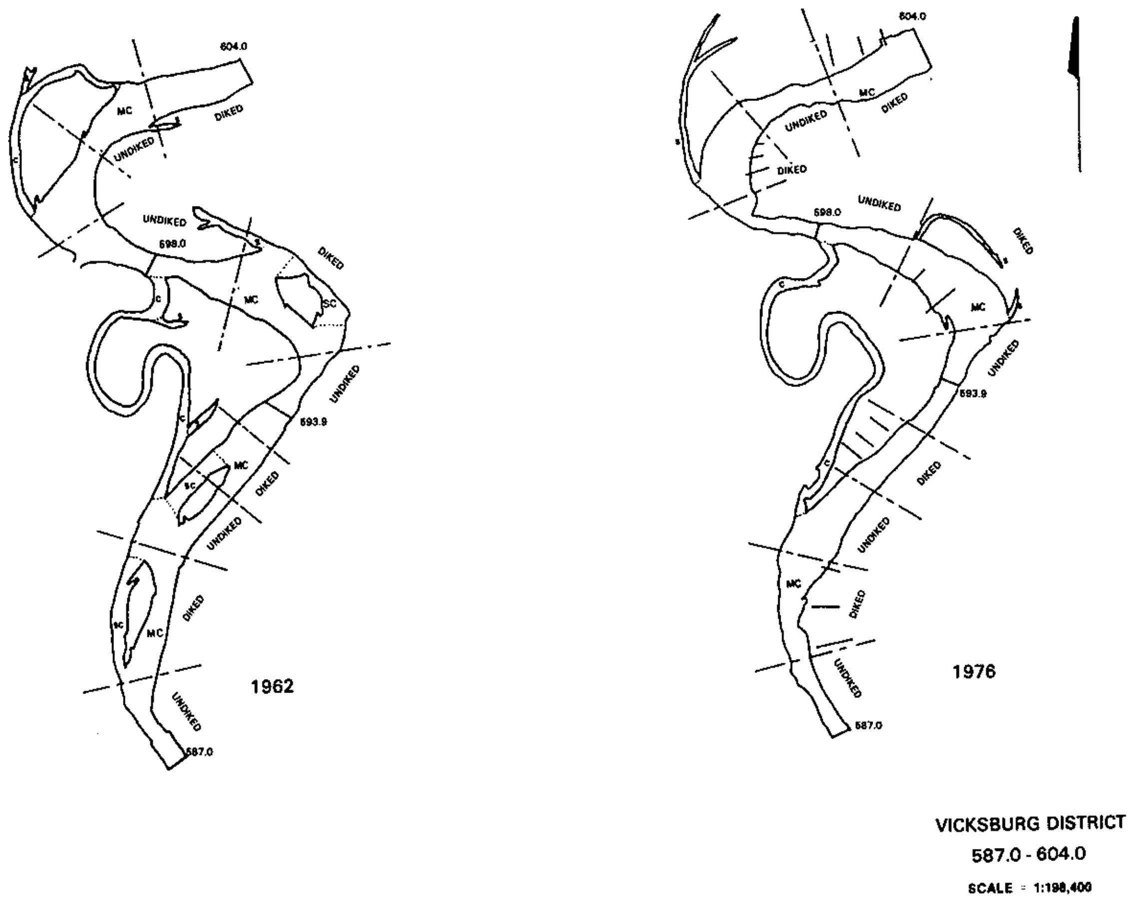


Figure A16. Water surface area and aquatic habitat types in the Mississippi from mile 587.0 to 604.0 AHP (Vicksburg District) in 1962 and 1976

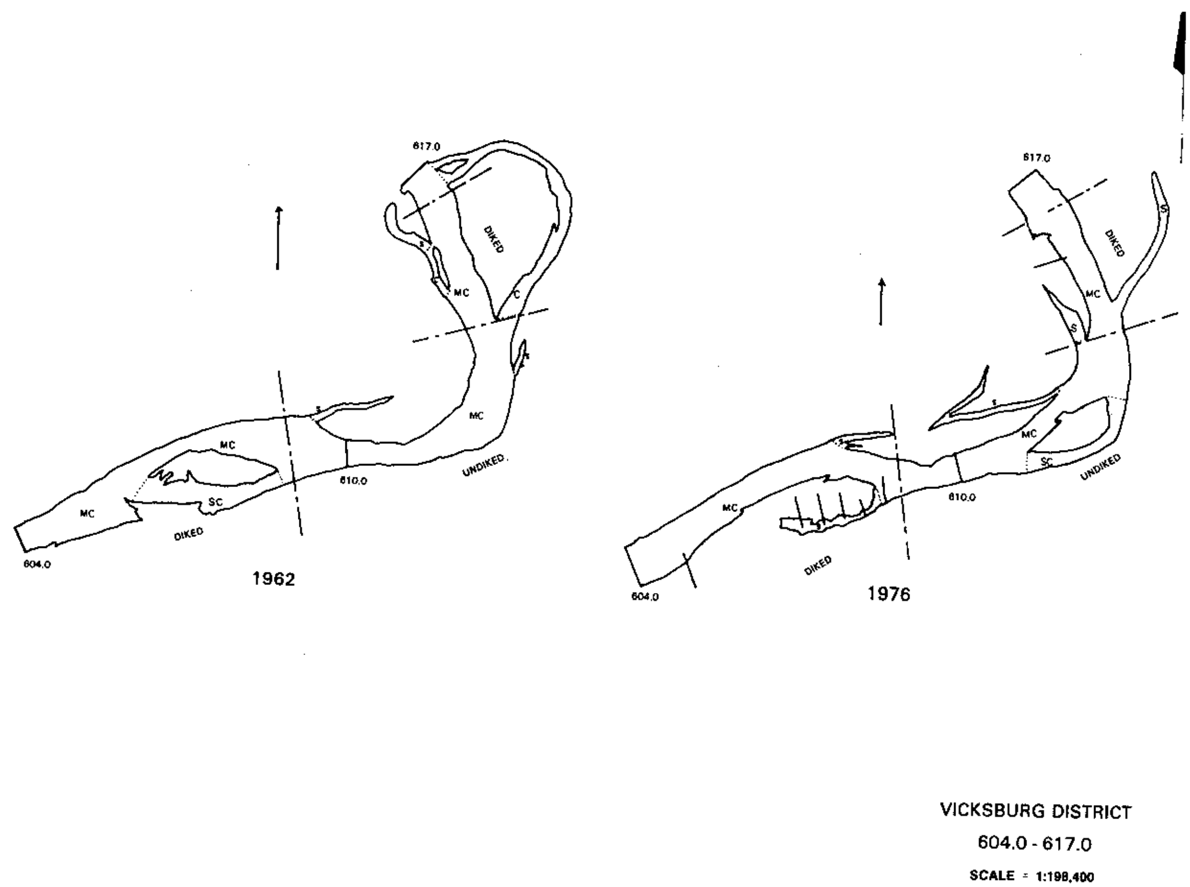


Figure A17. Water surface area and aquatic habitat types in the Mississippi from mile 604.0 to 617.0 AHP (Vicksburg District) in 1962 and 1976

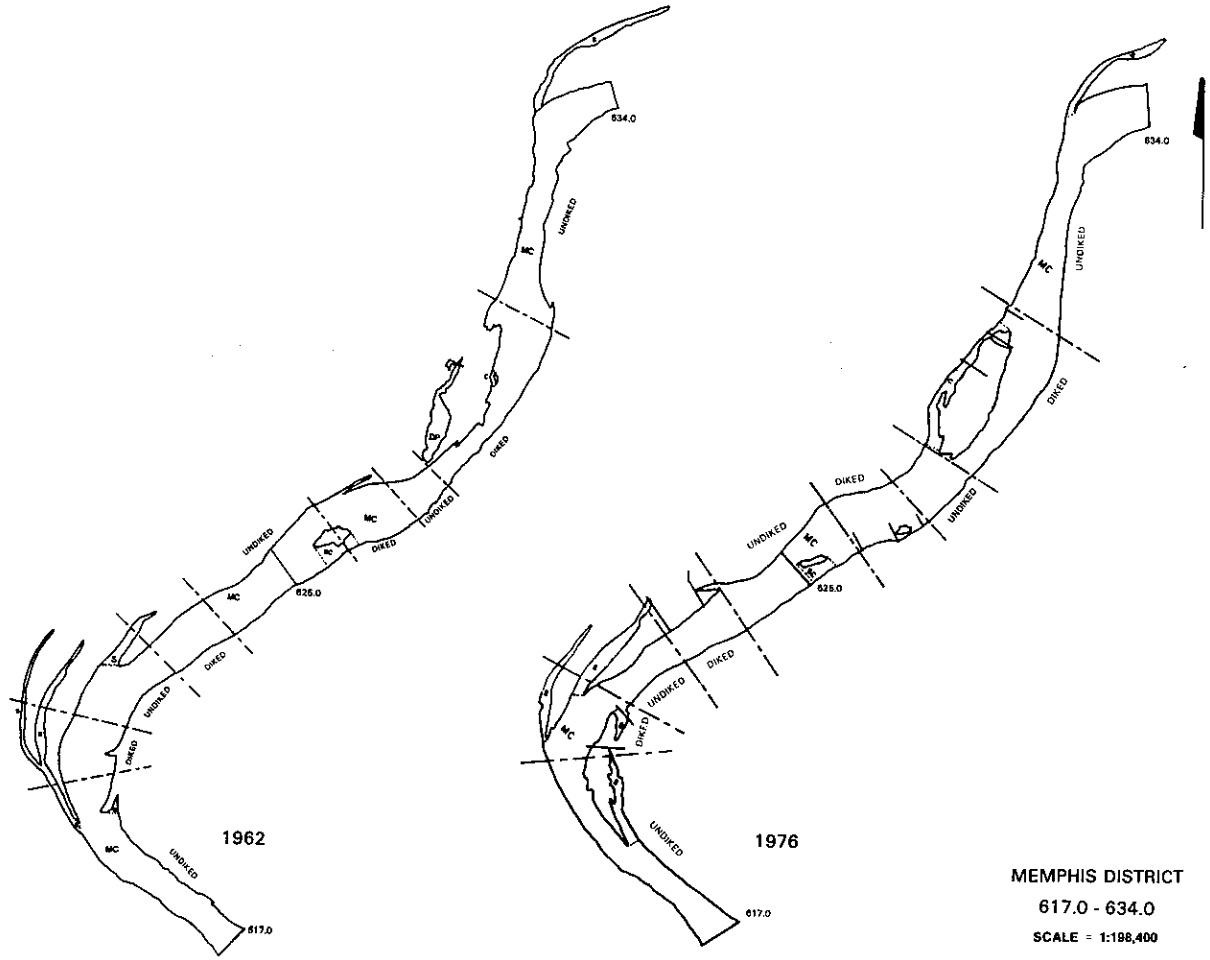


Figure A18. Water surface area and aquatic habitat types in the Mississippi from mile 617.0 to 634.0 AHP (Memphis District) in 1962 and 1976

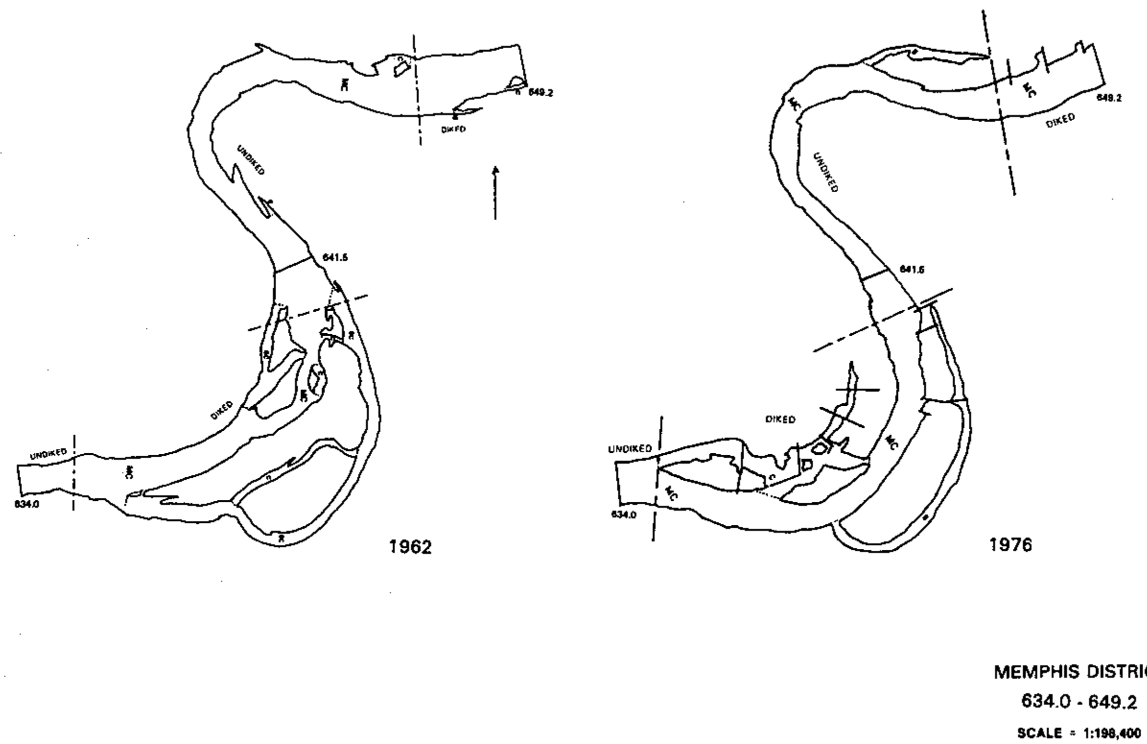


Figure A19. Water surface area and aquatic habitat types in the Mississippi from mile 634.0 to 649.2 AHP (Memphis District) in 1962 and 1976

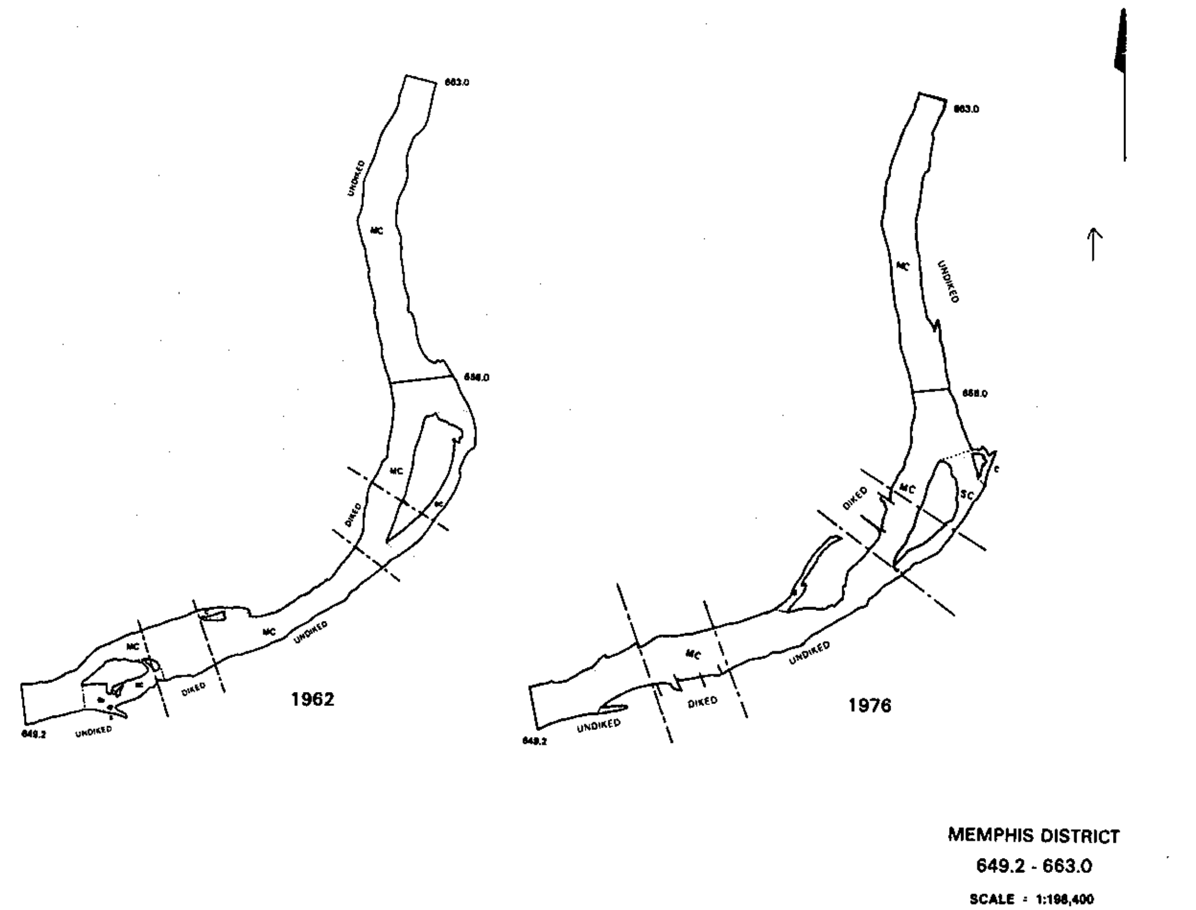


Figure A20. Water surface area and aquatic habitat types in the Mississippi from mile 649.2 to 663.0 AHP (Memphis District) in 1962 and 1976

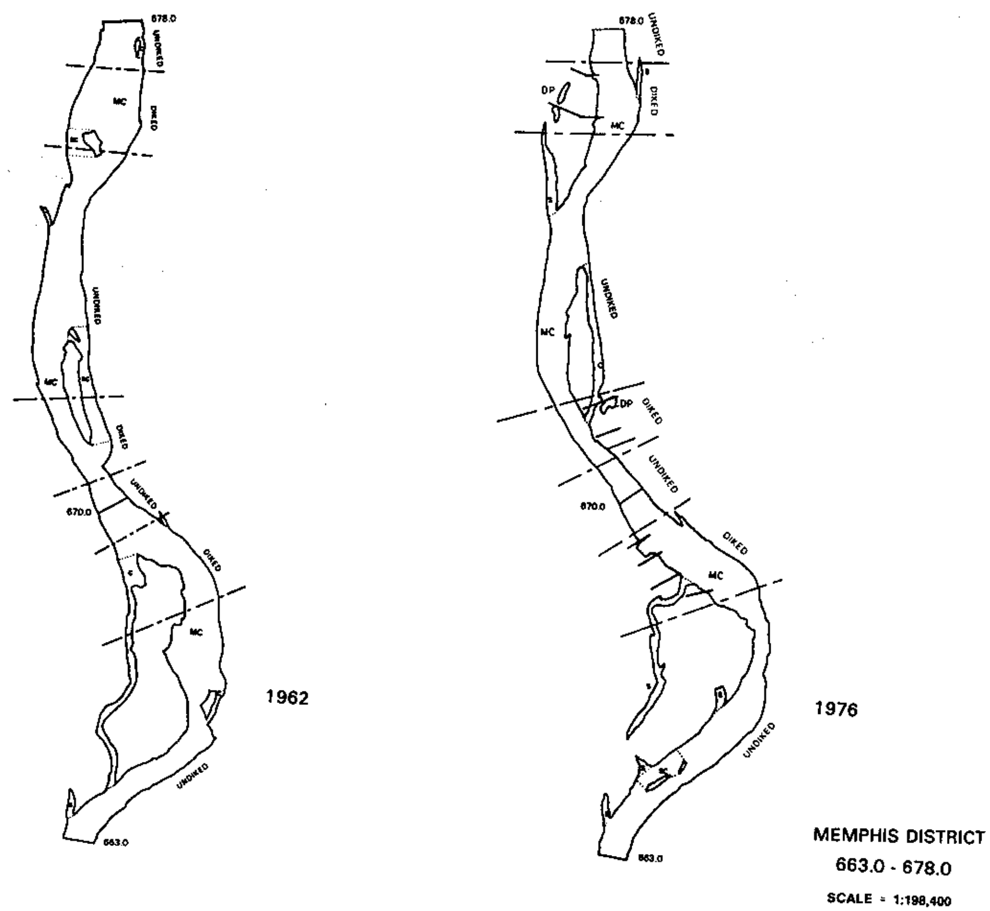


Figure A21. Water surface area and aquatic habitat types in the Mississippi from mile 663.0 to 678.0 AHP (Memphis District) in 1962 and 1976

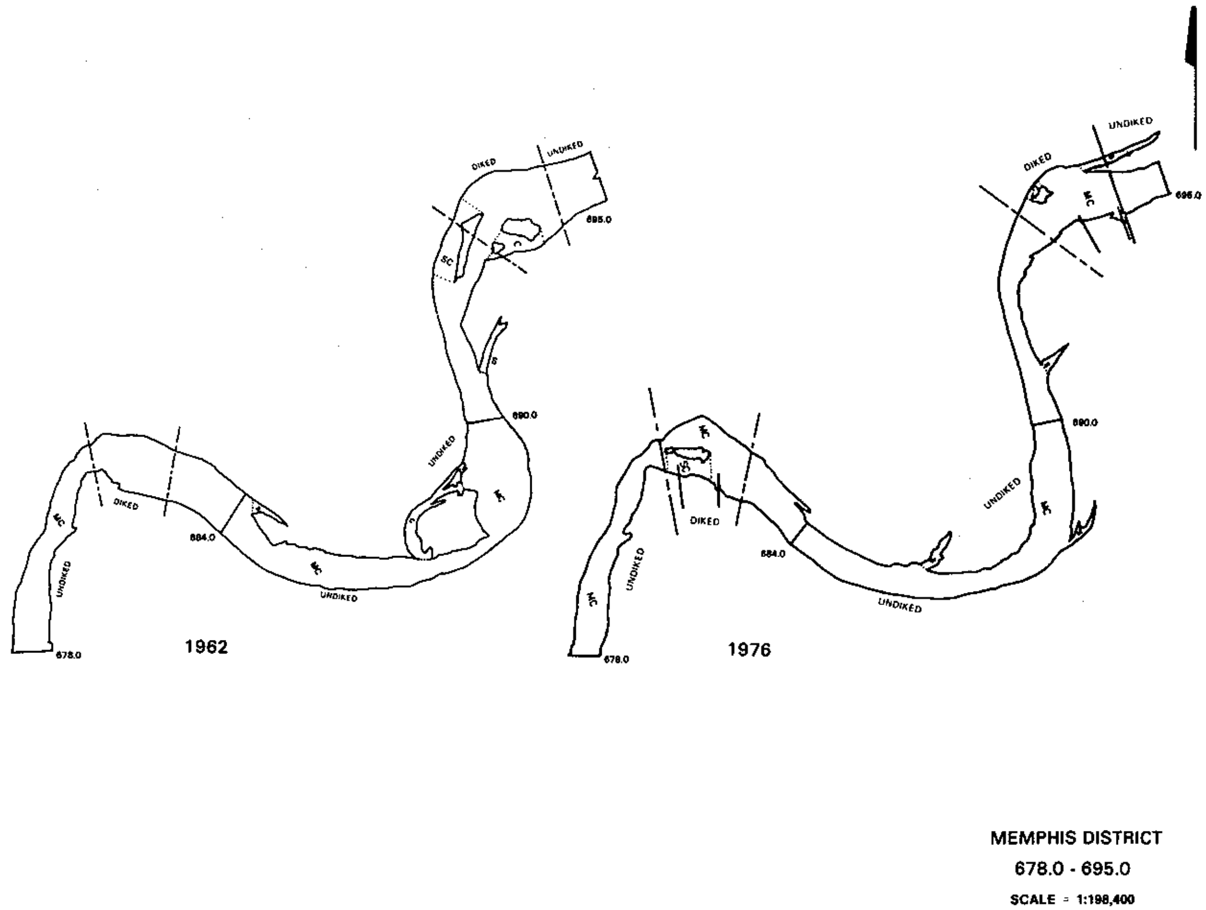


Figure A22. Water surface area and aquatic habitat types in the Mississippi from mile 678.0 to 695.0 AHP (Memphis District) in 1962 and 1976

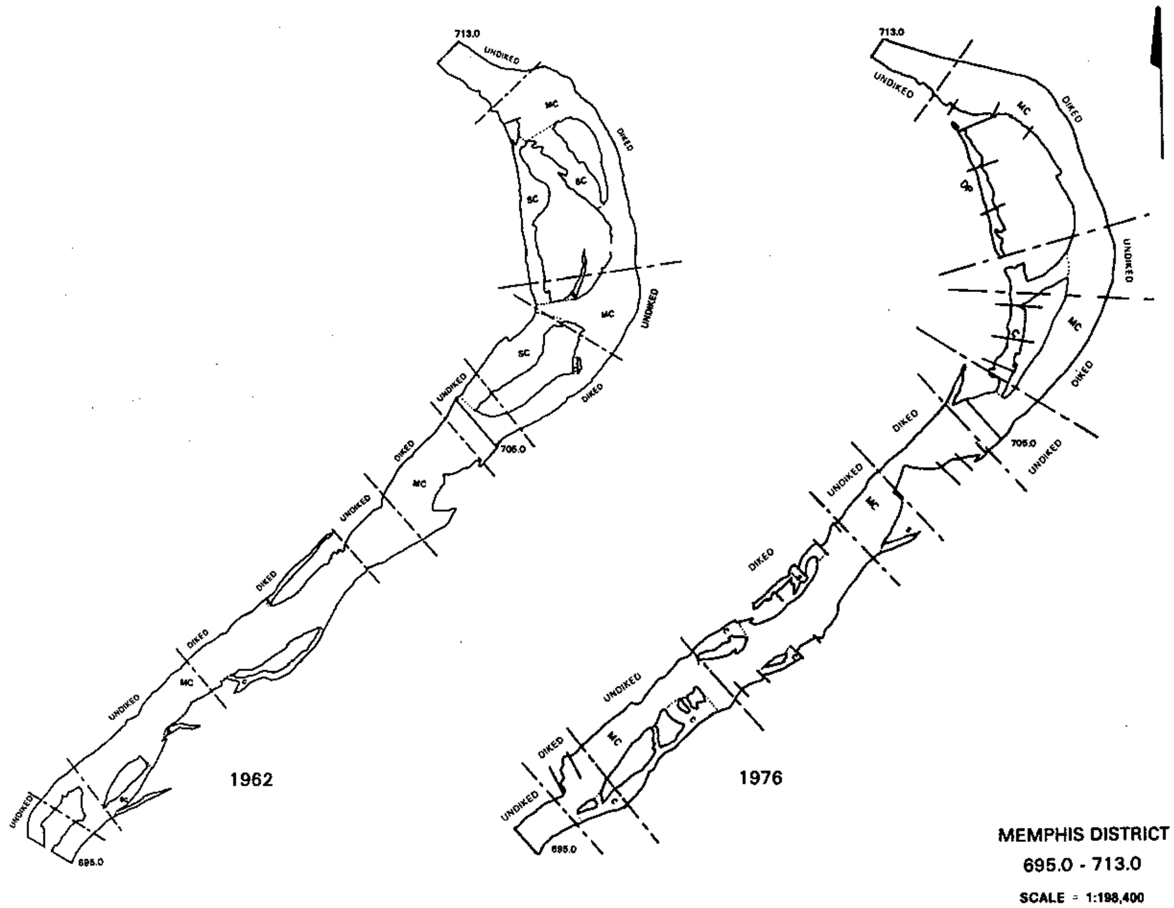


Figure A23. Water surface area and aquatic habitat types in the Mississippi from mile 695.0 to 713.0 AHP (Memphis District) in 1962 and 1976

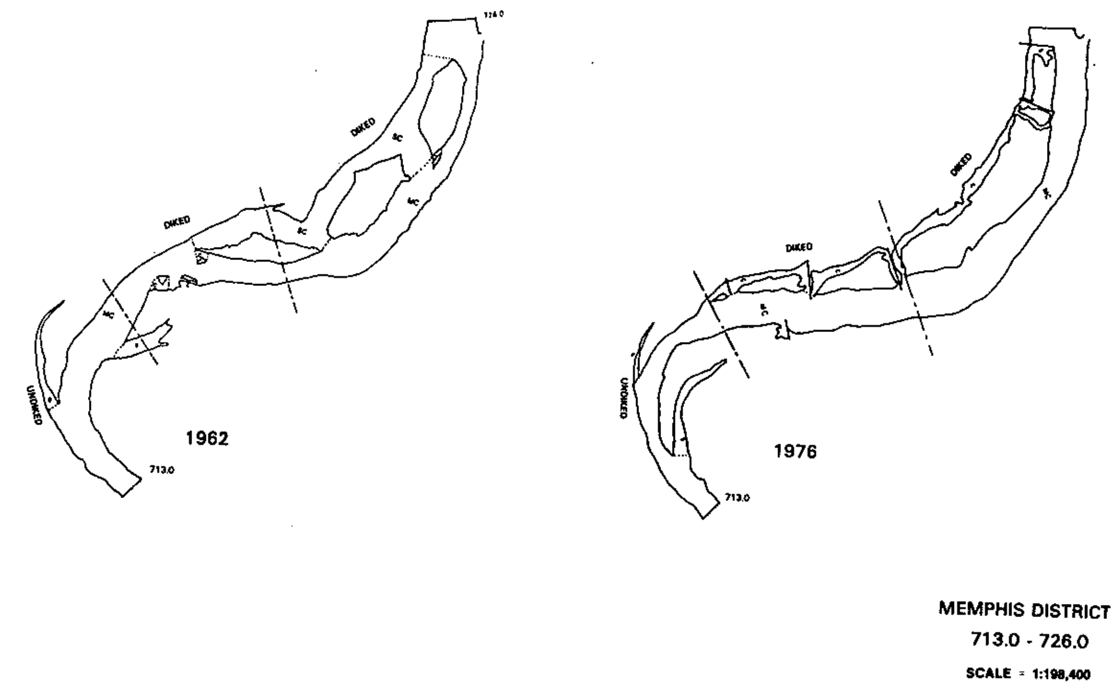


Figure A24. Water surface area and aquatic habitat types in the Mississippi from mile 713.0 to 726.0 AHP (Memphis District) in 1962 and 1976

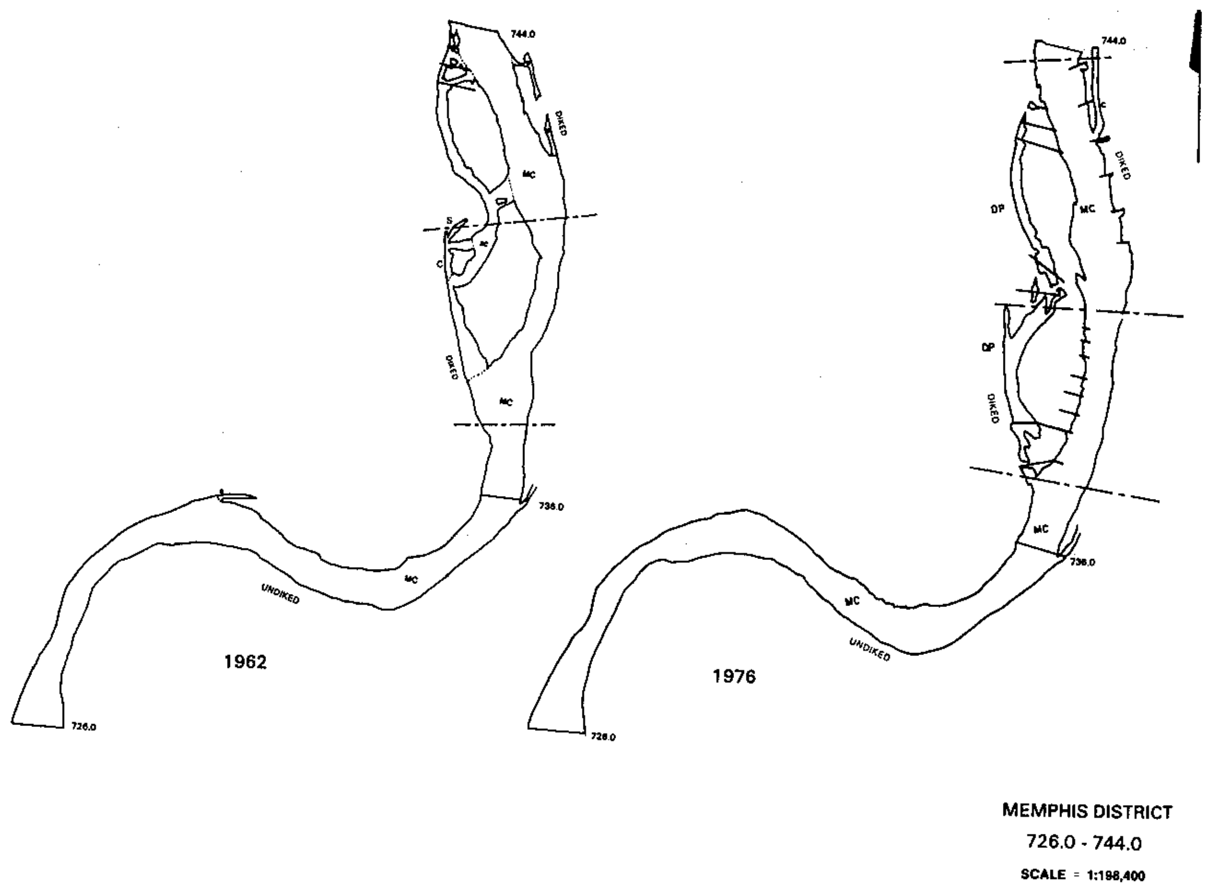


Figure 25. Water surface area and aquatic habitat types in the Mississippi from mile 726.0 to 744.0 AHP (Memphis District) in 1962 and 1976

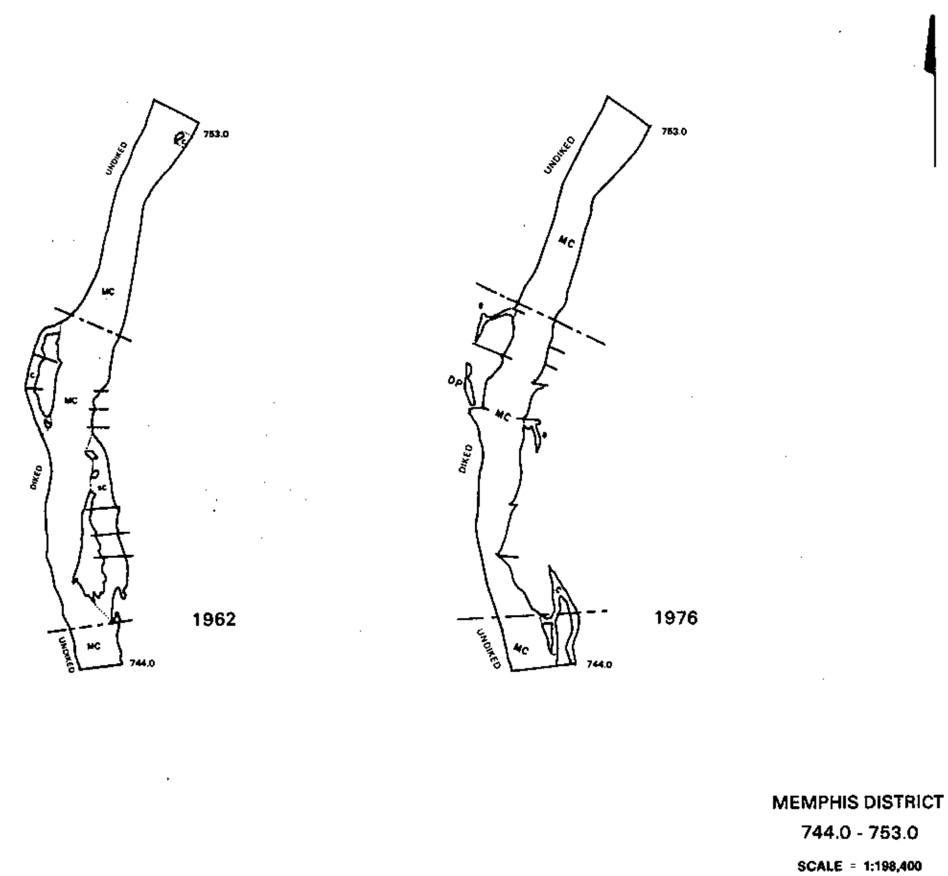


Figure A26. Water surface area and aquatic habitat types in the Mississippi from mile 744.0 to 753.0 AHP (Memphis District) in 1962 and 1976

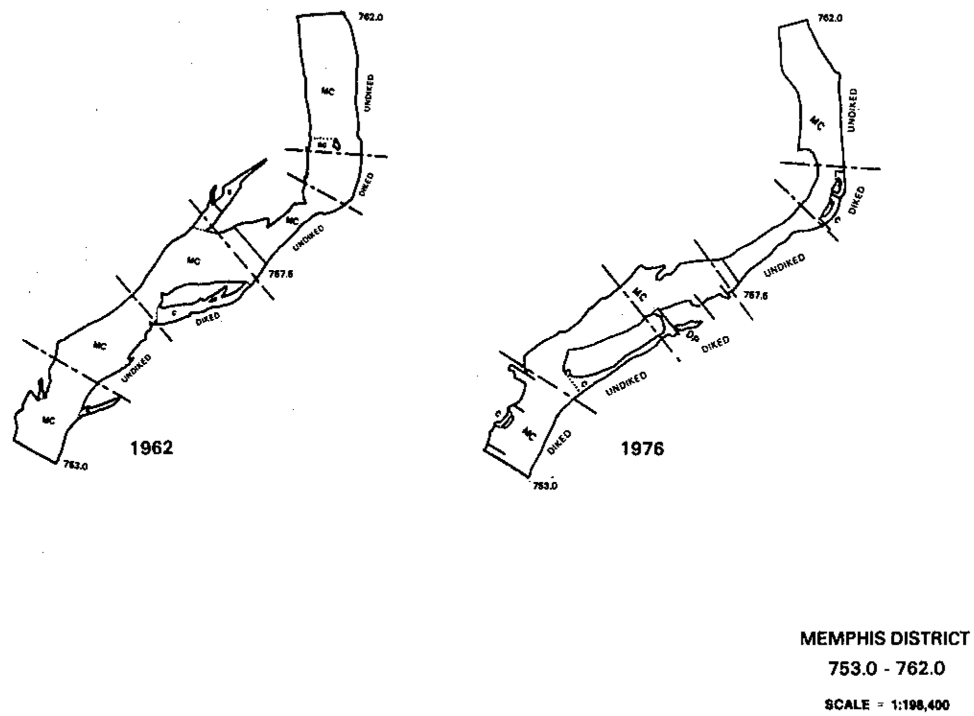


Figure A27. Water surface area and aquatic habitat types in the Mississippi from mile 753.0 to 762.0 AHP (Memphis District) in 1962 and 1976

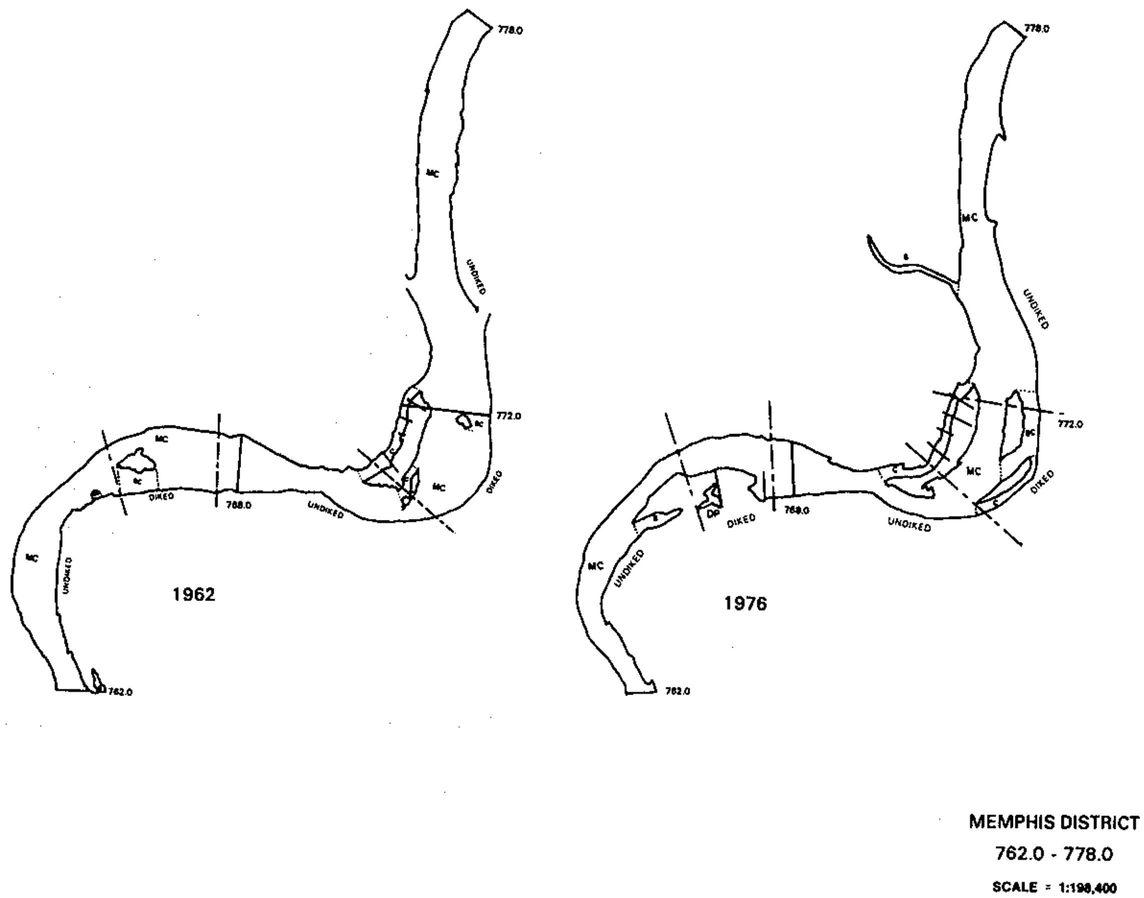


Figure A28. Water surface area and aquatic habitat types in the Mississippi from mile 762.0 to 778.0 AHP (Memphis District) in 1962 and 1976

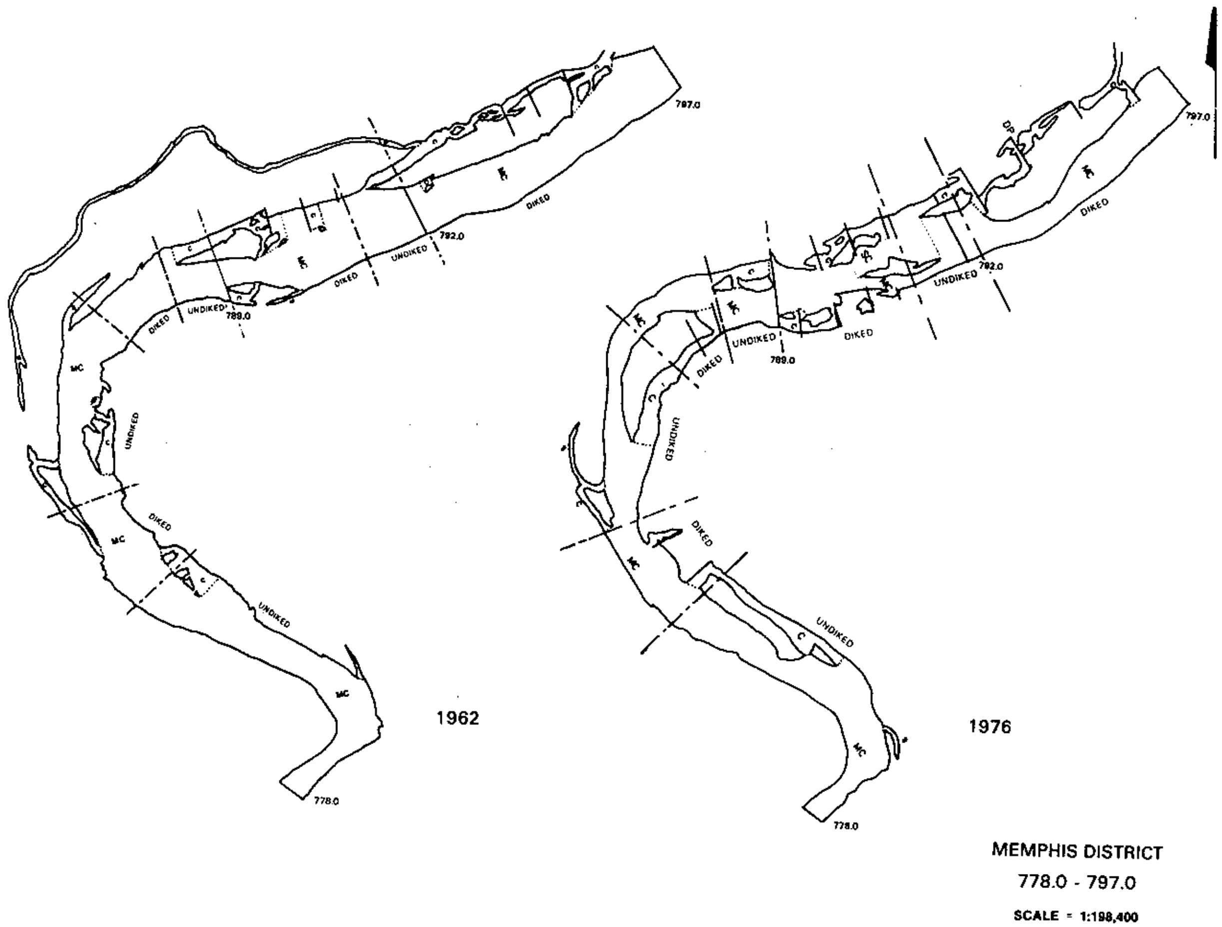


Figure A29. Water surface area and aquatic habitat types in the Mississippi from mile 778.0 to 797.0 AHP (Memphis District) in 1962 and 1976

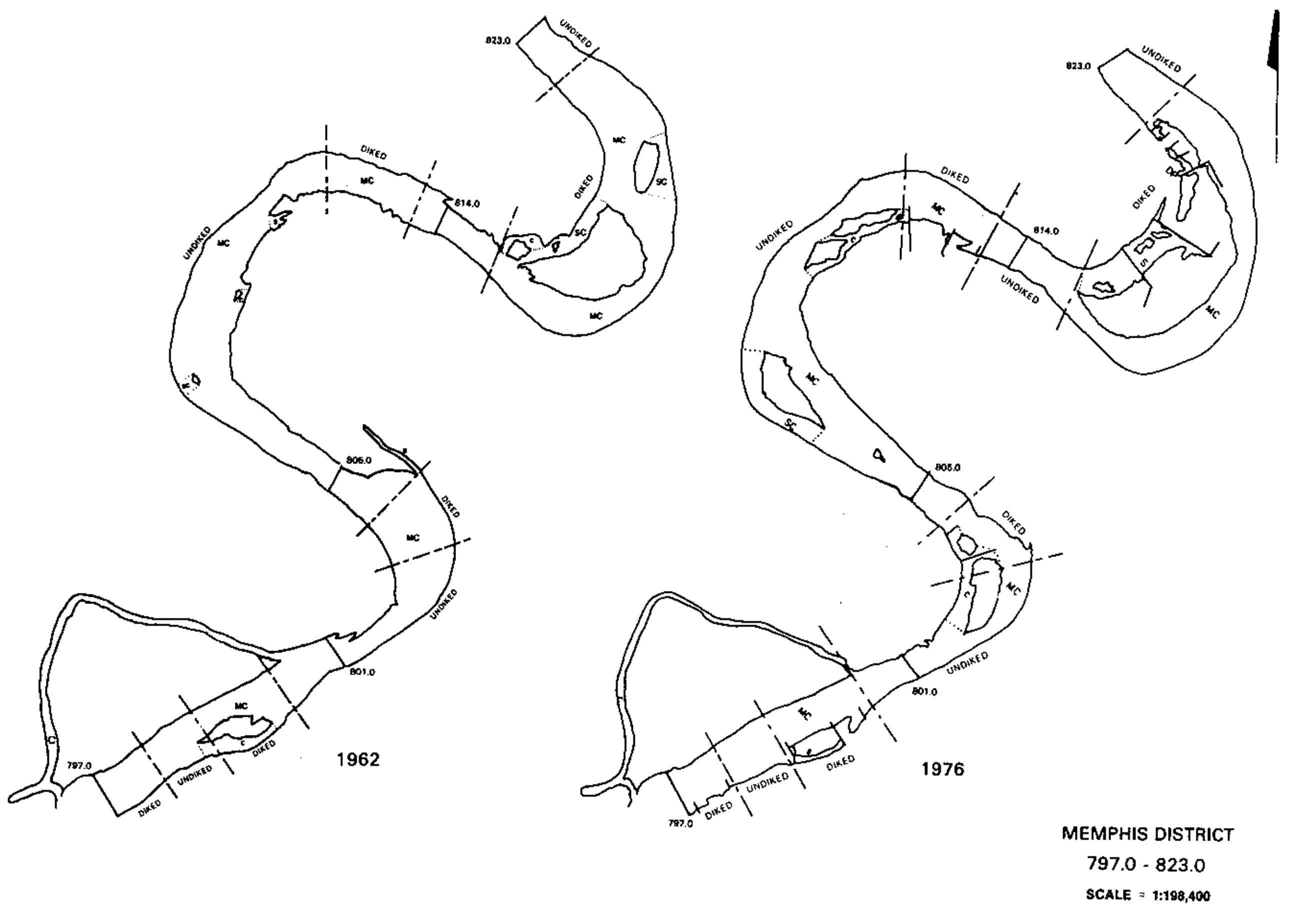


Figure A30. Water surface area and aquatic habitat types in the Mississippi from mile 797.0 to 823.0 AHP (Memphis District) in 1962 and 1976

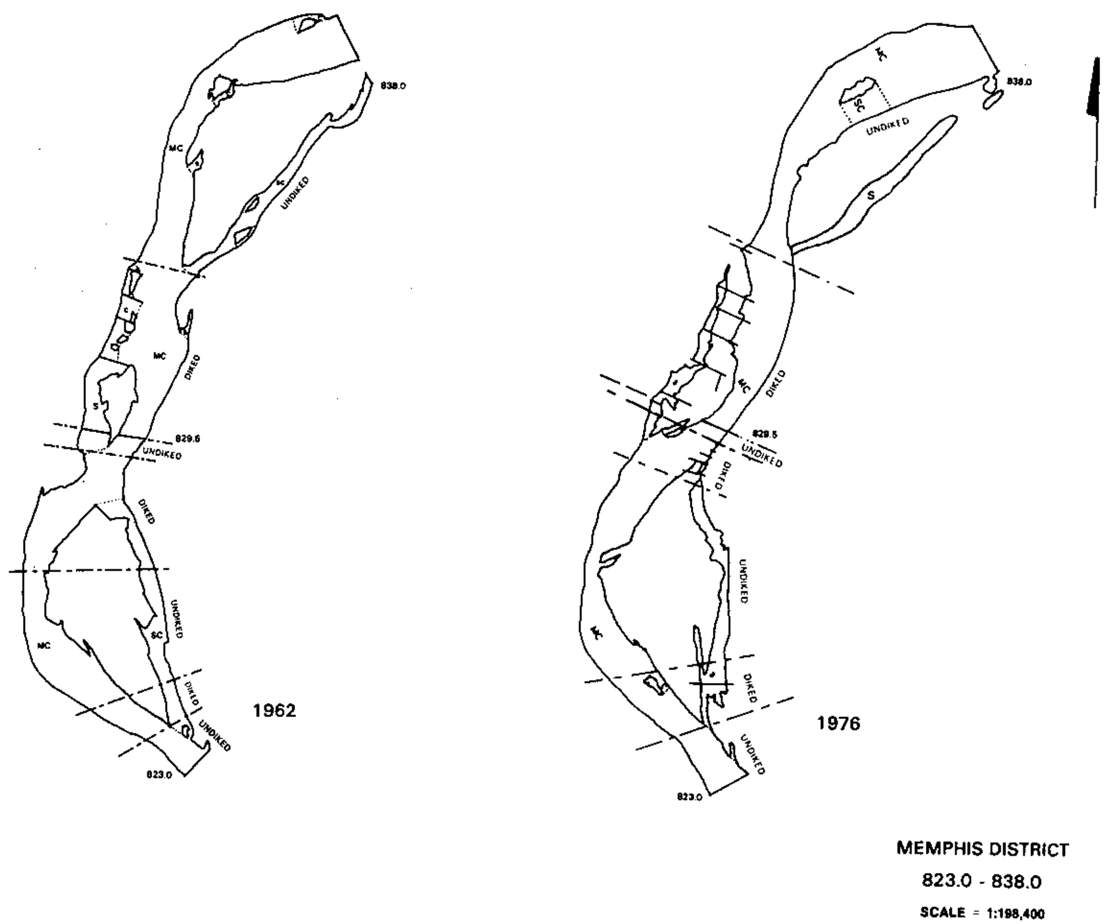


Figure A31. Water surface area and aquatic habitat types in the Mississippi from mile 823.0 to 838.0 AHP (Memphis District) in 1962 and 1976

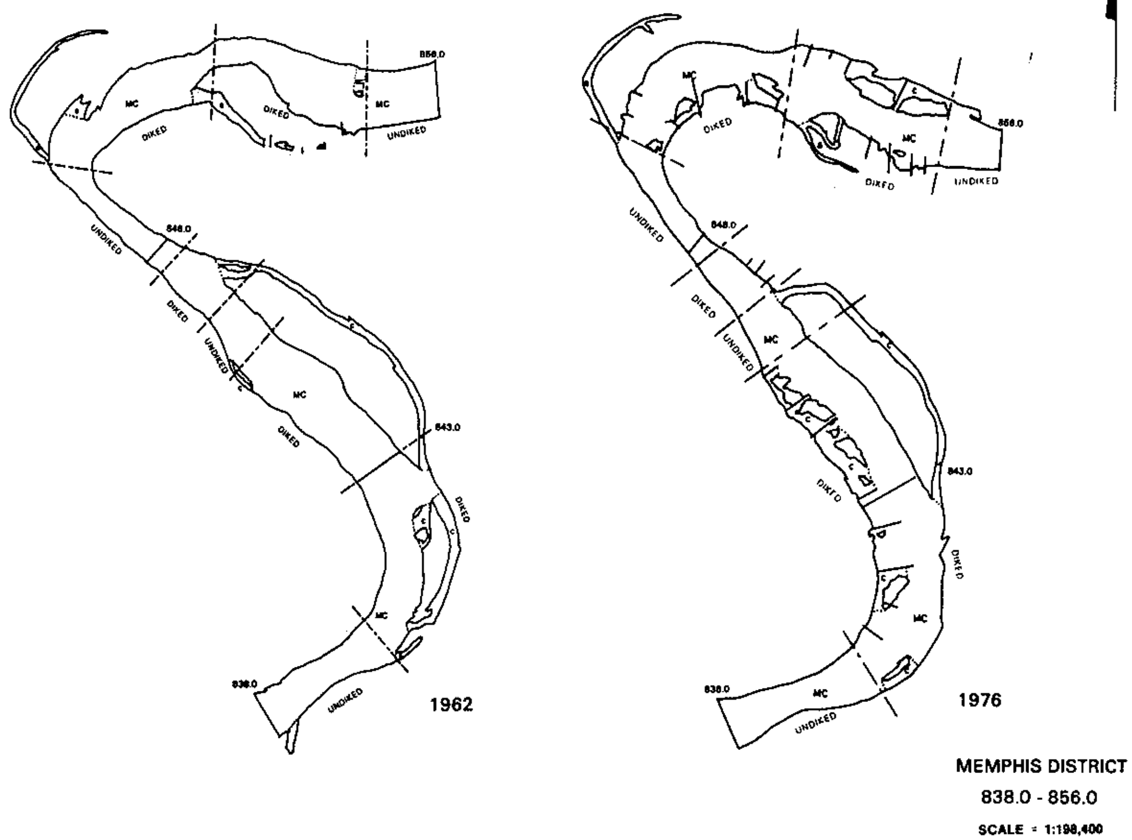


Figure A32. Water surface area and aquatic habitat types in the Mississippi from mile 838.0 to 856.0 AHP (Memphis District) in 1962 and 1976

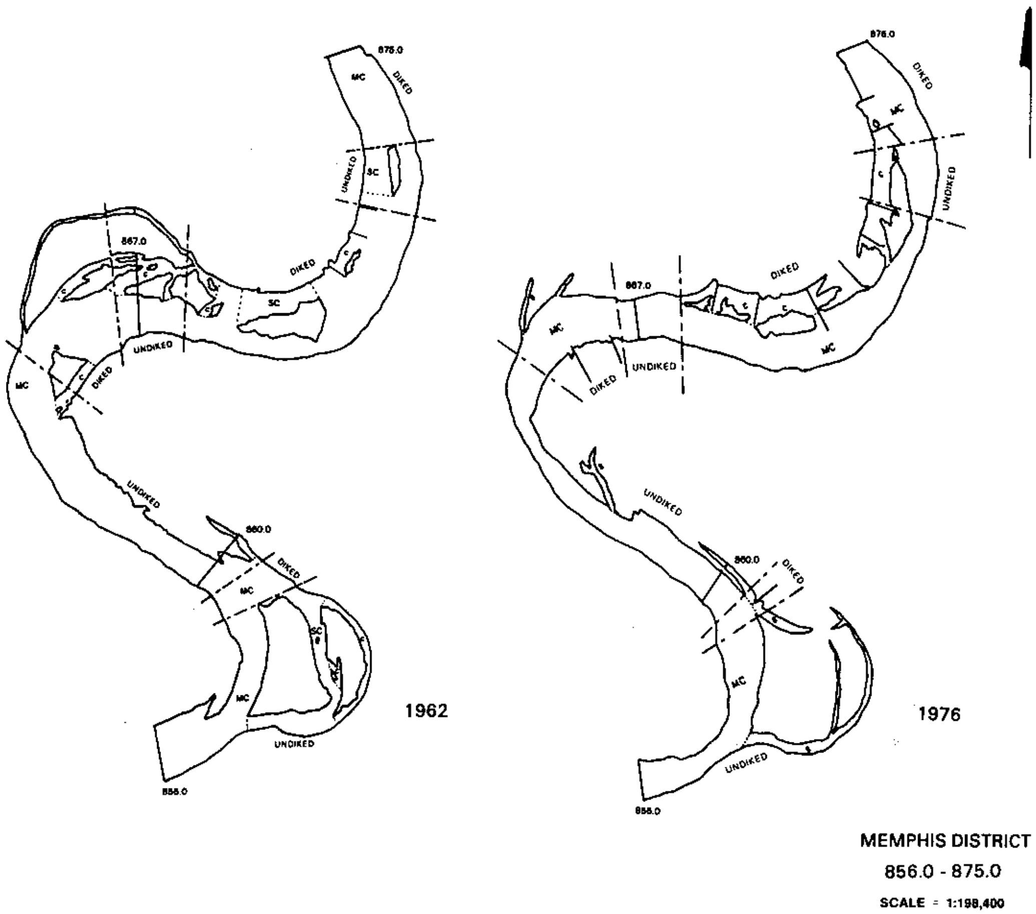


Figure A33. Water surface area and aquatic habitat types in the Mississippi from mile 856.0 to 875.0 AHP (Memphis District) in 1962 and 1976

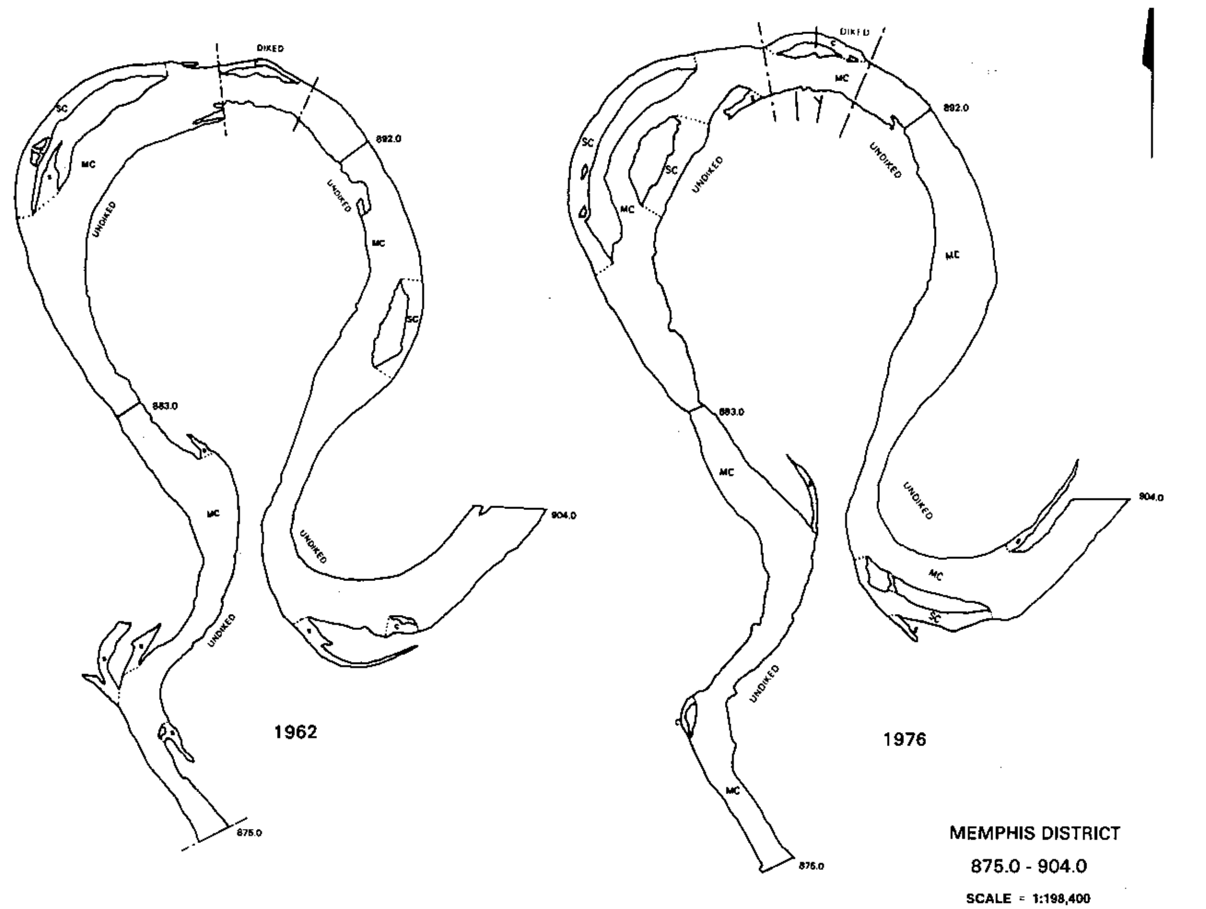


Figure A34. Water surface area and aquatic habitat types in the Mississippi from mile 875.0 to 904.0 AHP (Memphis District) in 1962 and 1976

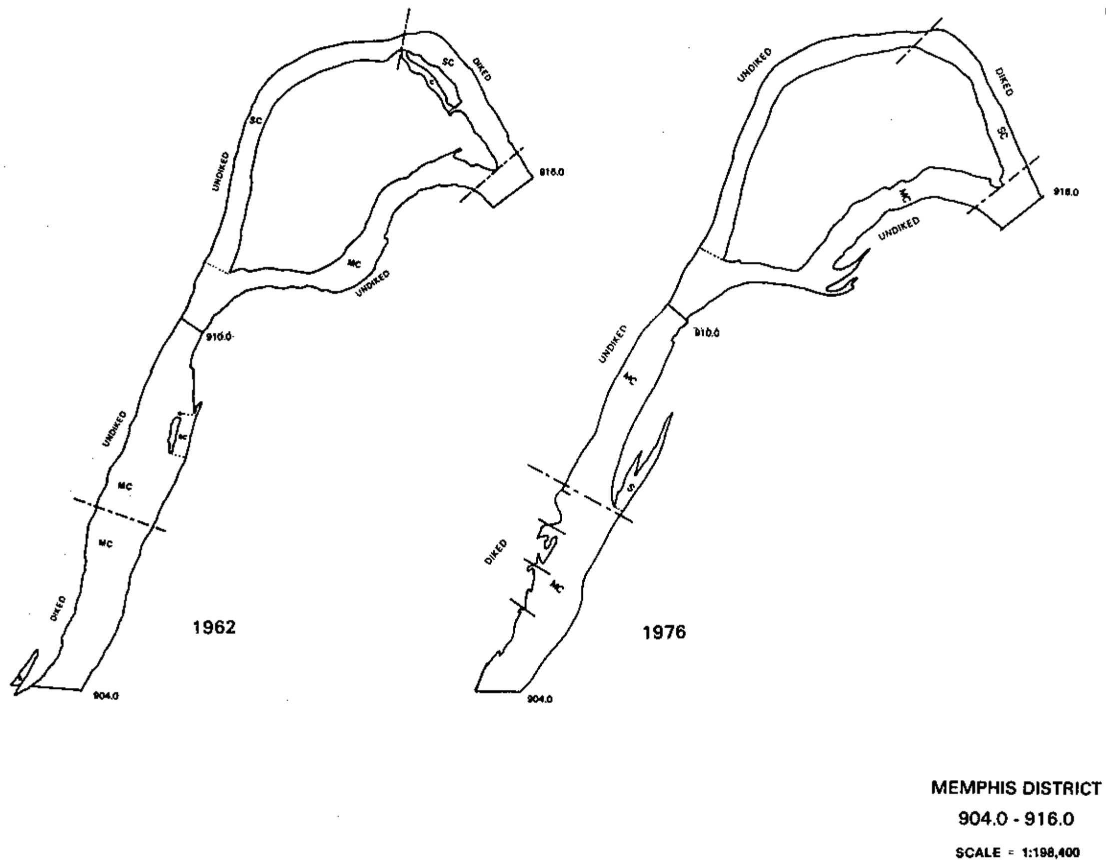


Figure A35. Water surface area and aquatic habitat types in the Mississippi from mile 904.0 to 916.0 AHP (Memphis District) in 1962 and 1976

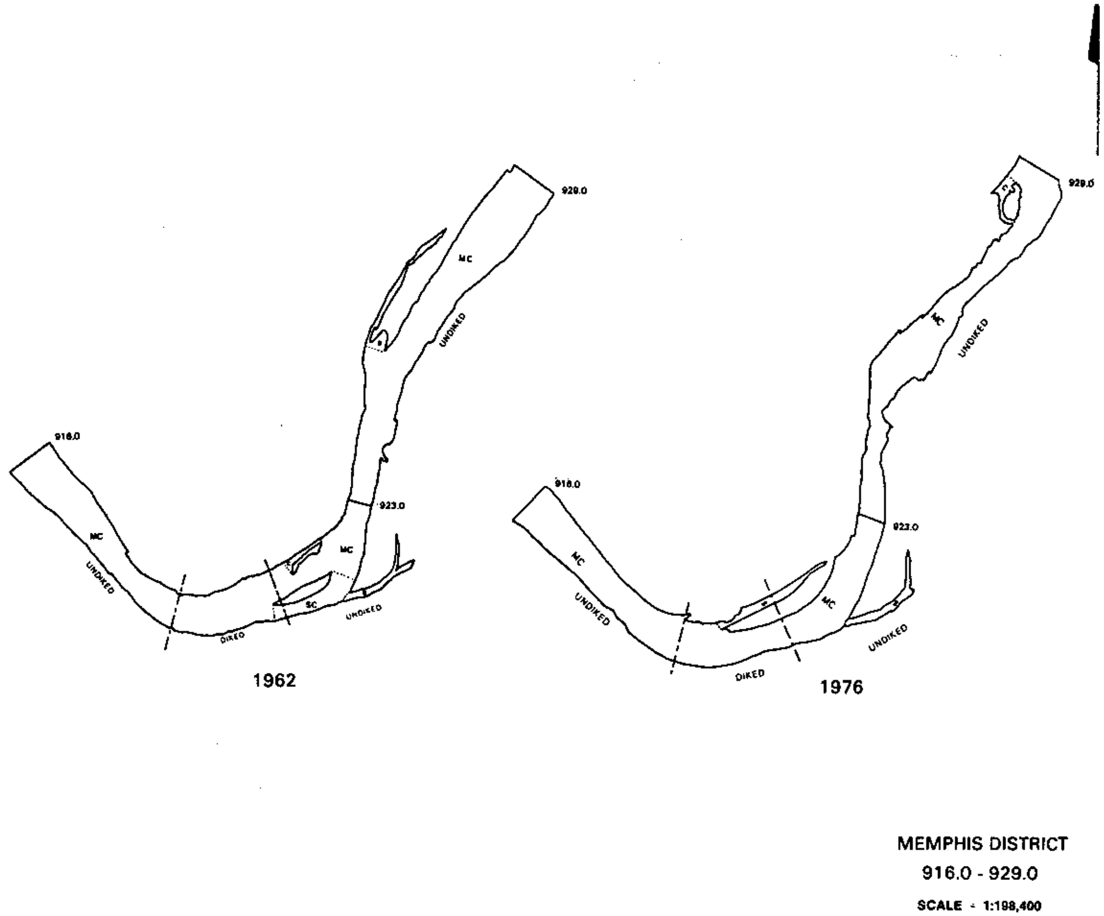


Figure A36. Water surface area and aquatic habitat types in the Mississippi from mile 916.0 to 929.0 AHP (Memphis District) in 1962 and 1976

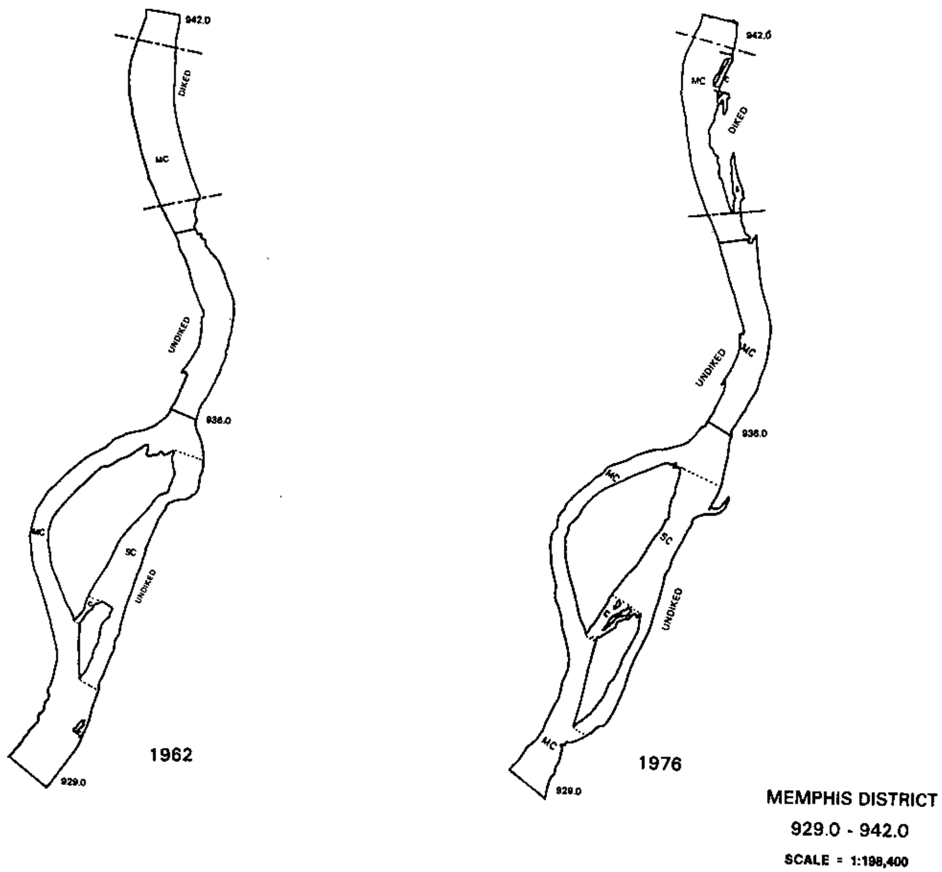


Figure A37. Water surface area and aquatic habitat types in the Mississippi from mile 929.0 to 942.0 AHP (Memphis District) in 1962 and 1976

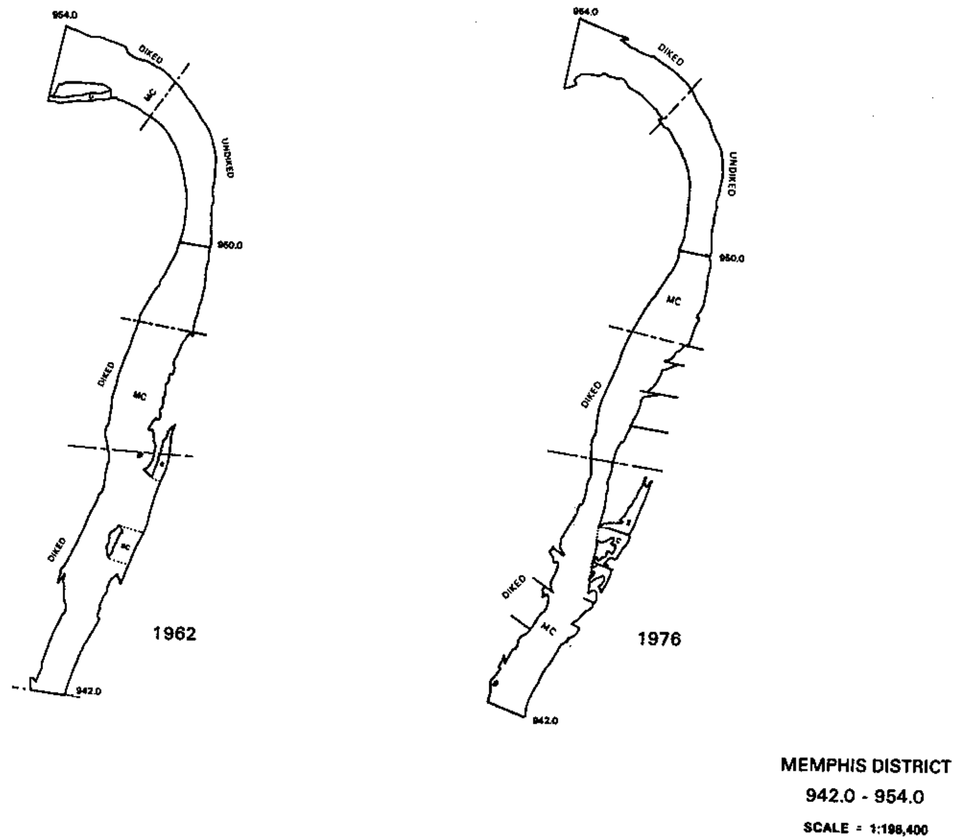


Figure A38. Water surface area and aquatic habitat types in the Mississippi from mile 942.0 to 954.0 AHP (Memphis District) in 1962 and 1976