VI. MORPHOLOGY

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Morphology is defined in part as "the scientific study of form and structure". In order to study the form and structure of so vast an area as the Mississippi River, one must become familiar with a few basic morphological features which may appear throughout the area under consideration. A brief description and summary of the more common forms and features is included.

A. Stages of Stream Development

All streams may be classified geomorphically in the following stages: young, mature, and old. The young or youth stage of a stream is characterized by the ability of the system to dissect its own channel--river deepening. Stream gradients are high with consequently high velocities which transport the load. The drainage system is coarse in texture. Floodplains and meanders are not found. Valleys are steep-sided and V-shaped; rapids and waterfalls are common. When erosive action from river deepening to river widening occurs, the stream is said to be mature. A mature stream has a reduced gradient with velocities sufficient only to transport the load within the system. Lateral migration of the stream (meandering) occurs. Also occurring are planation (widening of the valley floor), cut-bank erosion (sculpturing of the valley sides), and floodplain accretion (deposition on the widened valley floor). Old age streams are either completely graded, or in equilibrium where erosion equals deposition. Their floodplains are extensive. Low gradients and meandering are characteristic of the rivers. Topography is flat or gently undulating.

B. Floodplains

A floodplain is that portion of a river valley adjacent to the river channel which is built of sediments during the present regime of the stream and which is covered with water when the river overflows its banks at flood stages. All floodplains are level, or almost level, plains of low topographic situation existing at the level of (or slightly above or below) an adjacent parent stream. They are characterized by distinctive remnants of erosion and deposition. The type of floodplain is dependent upon the dominant type of flood which the stream experiences and on whether the stream has predominantly single- or multiple-channel flow. Floodplains associated with streams of single-channel flow are known as meander floodplains, covered floodplains, or composite floodplains. Those associated with streams of multiple-channel flow are bar meander or bar plains.

Meander floodplains are created as a result of "bankfull" floods, where there is lateral erosion and lateral deposition of coarse materials. Characteristics of the meander floodplain include well-developed and intricate patterns composed of closely-spaced, often overlapping, series of channel scars, meander scars, oxbow lakes, etc. The surface is at or slightly higher than the present channel.

Vertical deposition of fine materials by "over-the-bank" floods create covered floodplains. Finer sediments (silts and clays) are carried over the plains and dropped only when the stream velocity becomes very low. Considerable thicknesses of fine-grained alluvium may be built up in this way. Natural levees are formed by sudden decrease of stream velocity in the vicinity of the natural banks and resulting deposition of medium (silty) to coarse-grained sediments.

Composite floodplains are the result of both bankfull and over-the-bank floods, and features of both are present.

When multiple-channel flow exists in a stream valley, bar meander plains are formed. These consist of level surfaces scarred with evidences of past irregular bar deposition adjacent to a slightly lower stream channel which is partially braided with the greatest amount of braiding occurring at the bends. Valley alluvium is largely sand and gravel from the surface to the floor of the plain.

C. Terraces

Terraces are relatively flat, horizontal or gently-inclined surfaces that usually represent former levels of the valley floor or floodplain. They may be located at more or less constant heights above the present floodplain and are usually separated by low bluffs, rises, or scarps. Their origin may be alluvial, marine, or rock.

There are two fundamental categories of fluvial terraces: erosional and depositional. Erosional terraces are formed in bedrock or former sedimentary valley fill when a river meanders from one side of its floodplain to the other, eroding laterally into the bedrock valley slopes. Depositional terraces are the result of the accumulation of stream deposits on the valley floor.

Drainage characteristics are variable. In granular materials, there may be no surface drainage developed. Dendritic patterns are common in fine-textured soil. Infiltration basins, meander scrolls, and other evidences of past currents may also be present. Erosion occurs mainly on the bluffs or scarps which separate the terraces. In granular materials, V-shaped gullies with short, steep gradients are found along the terrace face. In fine-grained materials, severe gully erosion may develop, forming broad saucer-shaped gullies with long uniform gradients.

D. Deltas

Deltas are alluvial deposits that have been built outward from the shoreline of a large body of water by deposition of sediments carried by streams. Three basic types of deltas have been identified. They are the arcuate, estuarine, and bird's foot deltas.

Arcuate deltas are built by streams carrying and depositing a load of coarse sediments. Their characteristic fan shape is convex toward the sea. The delta itself is a flat, gently-sloping plain. The outlet of the major stream is through many shallow channels with considerable braiding. There is also considerable internal drainage through the granular material.

When the mouth of a stream is submerged beneath the main body of water, estuarine deltas are formed. The delta is parallel to the stream gradient. The surface is highly irregular, forming many islands and inlets. The deltas are comparatively narrow with long boundaries parallel to the water flow.

Bird's foot deltas (also called lobate deltas) occur in association with streams which are carrying and depositing considerable amounts of fine-textured soils in a large body of quiet or relatively protected water. Water flow is confined to one or two main channels or distributaries. The channels may have sharp bends or meanders, and numerous lakes and lagoons are usually present. Deposition occurs at levees along the banks and at the mouth of the distributaries. The delta forms a broad, flat surface with a low ground slope. The Mississippi River Delta is an example of this type.

Many other small landform features may develop in the fluvial system.

These are described in the following section.

E. Abandoned Courses and Channels

Abandoned courses are the stream courses left in disuse with the diversion of the stream to a new course. The abandoned course becomes plugged at the point where the flow was diverted by coarse-grained sediment, and the rest of the course gradually fills with clay and silt deposited in the flood stage of the river.

The abandoned course can be recognized by its long, meandering pattern. The topography is low relief, marked by natural levees to either side of the stream bed and the ridge and swale topography of point bar scars. The size of the stream bed can vary from a few feet in width to a mile or more, depending on the size of the original stream. The soils of an abandoned course are relatively impermeable clays and silts. Because the soil is difficult to work, the land is usually left in timber or used for grazing in the areas near oxbow lakes where there may be extensive areas of grass or reeds. Drainage usually consists of a small stream following the original course of the stream. Cross section is gently undulating. Roads and railroads are usually aligned at right angles to the course if a crossing is necessary. Abandoned courses contain remnants of all the landforms which characterize fluvial, including meander scars, point bar scars, oxbow lakes, and natural levees.

Abandoned channels are longer segments of a stream that have been abandoned by the stream in the diversion of the flow through a cutoff. Two main types of cutoff can occur: the neck cutoff and the chute cutoff. In a neck cutoff, the stream breaches the neck of a meander loop, usually during flood stage. The chute is formed when the stream flows through a large swale between two point bar deposits. The points where the abandoned channel meets the cutoff becomes silted up with coarse-grained sediment. When the abandoned channel has been completely blocked at the cutoff, further sedimentation occurs only during over-the-bank floods, and only the finer materials are deposited.

F. Oxbow Lakes

Oxbow lakes are the result of the neck cutoff of the meander loop of a river. These lakes are recognized by their arcuate shape and their location in the meander belt of the flood plain. Meander scrolls and natural levees may be evident, marking the progress of the river course.

G. Clay Plugs

When an oxbow lake has been filled by sediment deposited by the flood waters of the adjacent river, it becomes a clay plug. Only the finer-grained particles are left to settle after the sands and silts were deposited with the decrease in velocity that occurs when the river overflows its banks. These clays are relatively impermeable and resist erosion. When a stream bank is eroding a clay plug, the underlying coarser materials are scoured out first, causing the bank to slump due to undercutting. This produces a scalloped pattern along the bank. The general land use of clay plugs is cultivation or natural timber cover.

H. Point Bar Deposits

Point bars are formed by the lateral migration of a meandering river. They begin as sandbars following the curvature of the convex bank. As the sandbar receives additional sediments, it grows in length, forming a small channel or slough between it and the river bank. Eventually, blockage of the slough is caused by lateral migration of the stream and further sand deposition. The slough then becomes a water-filled swale which is eventually filled with fine sediments carried into it by floodwaters. Meander scrolls are the products of the cycle being repeated as the stream continues to migrate, leaving behind a series of ridges and swales. The contract between the ridges and swales is due to two causes. First is soil moisture, the swales being wettest. Secondly, the overall dark tone of the swales, even when dry, is due also to an accumulation of organic material. Even though relief between ridges is small, particularly those areas used for agriculture, the swales are lower and surface water carries the organic debris into the swales. Low-order drainage is generally collinear, with the drainage ways following arcuate swales. Some swales may not exhibit developed scour channels; some may be basins, which form shallow elongate lakes or ponds after rain.

Vegetation increases in size and age with the age of the point bar deposits. Newly-formed ridges and swales may be barren, but these surfaces are then colonized by small herbs and grasses, then shrubs, and finally by dense forest. However, some swales remain water-logged, and will support only dense growths of marsh grass and reeds.

Although newly-formed meander scrolls are rarely cultivated, older surfaces of this type are commonly cultivated. The normally sharp distinction between drainage conditions and soil types from ridge to swale commonly results in a field pattern consisting of elongate rectangles oriented parallel to the trend of the topography. The parent materials of the point bar's surface are generally sandy or gravelly on the ridges, with finer-grained materials forming the swales. There is considerable variation from region to region, or even along different segments of the same floodplain. In some cases (e.g., where the parent stream has a steep gradient and swift current), ridges may be composed of silty sand.

The surface soils of this landscape chiefly are relatively impermeable silty sands, clay silts and silty clays. Soils tend to be slightly coarser on the ridges and finer in the swales. Highly organic silts and clays occur in relatively infrequent, exceptionally poorly-drained swales.

I. Natural Levees

Natural levees are low, alluvial ridges of varying widths and elevations that normally flank both sides of a stream channel. They are caused by overbank flooding. As the stream overflows its banks, a loss in velocity allows the coarsest and greatest quantity of suspended sediment to drop out in areas nearest the stream bank. Successive flooding over a period of time adds additional materials forming low alluvial ridges which slope gradually away from the channel into the floodplain back of the levee.

The levees are low-relief, sinuous features which are relatively well drained. The larger levees are normally cultivated and the fields are aligned with their long dimensions perpendicular to the adjacent stream, forming a distinctive pattern. The borders of the narrow and broad rectangular fields appear as thin dark lines criss-crossing the levee surface. When not cleared for agriculture, the levees support stands of hardwood trees.

The height and lateral extent of natural levee deposits are an indication of the stream size and maturity. Cross-sectional shape is undulating or blocky. The levees consist of asymmetric ridges of very low relief parallel to a stream channel. The steep slope faces the water, and the very gentle reverse slope faces away from the stream. Relief may be from a few inches to as much as 15 or 20 feet, although these extremes are rare. The ridges range from a few yards to a mile or more in width. Changes in river courses may leave natural levees abandoned and far from the present course. Old levees may be intercepted or truncated by newer ones. Backswamps frequently occur on the landward side of a levee.

The soils are usually well drained, encouraging diversified agriculture. Roads parallel the trend of the ridge where these features are fairly large. Natural levees often are used as the basis for artificial levee systems. Borrow pits for construction of road, railroad, and levee embankments are common.

Low-order drainage of the natural levees is usually of the parallel type, with the channels draining the gentle reverse slope of the ridge, and thus oriented roughly at right angles to the trend of the ridge and river. Such drainage is usually straightened and deepened by Man to improve drainage.

Erosion in levees on the active course is negligible, but in abandoned levees the steep face of the ridge may develop gully systems. In general, these are of the "v" type with steep gradients. When floodwaters overtop the natural levees, they tend to scour the reverse slope; the marks left are indefinite, consisting of poorly-defined streaks of light and dark photo tones produced by minor differences in vegetation cover and soil type.

Crevasses are short channels which are formed initially as breakthroughs in the natural levee during flood stage with flow through the crevasses increasing with successive floods. Crevasse channels are characterized by thin, dark sinuous lines, many of them branching, crossing the levee surface from these river surfaces to the backswamps.

J. Backswamps

Backswamps are low, flat basins that occur between natural levee systems, or between natural levees and higher ground. Backswamps are distinguished from marshes by the extensive growth of trees. Under natural conditions, these low tracts are periodically inundated by overbank flow during stream flooding. Fine-grained sediments carried by the floodwater eventually settle out, forming extensive deposits of silty clays and clays. Organic matter in the backswamp deposits is high because debris from the trees builds up; locally, peat deposits may form.

The gross drainage pattern is dendritic, but also may exhibit some of the features of the reticulate type and deranged types. There may be no obvious trend to the drainage as a whole. Channels are commonly contorted. Lakes with exceedingly irregular outlines are not unusual. Where cultivated, the patterns are usually either (or both) ditched or tiled.

The cross-sectional shape is undulating, and is often very nearly plane; relief is normally only a few inches or at most a few feet. Areas of backswamp are extremely variable in size. They may range from a few hundred square yards to several square miles. They are normally bounded on at least one side, and frequently on all, by natural levees. Usually there is at least one drainage exit. The surfaces rarely exhibit evidence of local erosion. However, in some cases where local relief for some reason exceeds a few feet, gullies may develop.

Backswamps are usually forested, although in some places extensive areas of marsh grass and reeds occur, especially in and near the lakes, similar to those occurring in deltaic plains.

The soils of backswamps are normally poorly drained and difficult to work. As a result, this environment is commonly left in timber; where cleared, it is frequently used for grazing. However, in many places backswamps have been either naturally or artificially drained, in which case the field patterns are rectangular and tend to be independent of topography. Roads and railroads avoid backswamps where possible. Where it is necessary to cross them, both cut across without regard to topography. Where backswamps are used for agriculture, ditching is usually required. The surface soils are generally thin and relatively poorly developed. They are dense, highly organic, impermeable clays and silty clays.

K. Marshes

Marshes occupy a large portion of the land area in the deltaic plain and are low tracts of periodically inundated land supporting grasses, reeds, and rushes. The marsh surface is generally featureless and seldom more than two feet above mean sea level.

The marshes are drained by bayous which are influenced by tides near the coast. Where changes in water salinity occur, the vegetation will reflect that change. The vegetation patterns are broken by areas of open water and lakes which often have a characteristic circular shape. The marshes are uninhabited by humans and are utilized primarily as game preserves. Man's activity in the marsh is evidenced by numerous canals which comprise the major transportation network and by the tracks of swamp buggies and the traces of oil pipelines.

The marsh soils are primarily organic clays and silts with high moisture content. Organic sedimentation is interrupted periodically by the introduction of fine sand during flooding.

L. River Bars and Islands

River bars are short, oval-shaped deposits of sand located within the confines of stream channels and along the banks of channels. They exhibit some relief but are rarely more than one meter above low water level and are barren of vegetation. Islands tend to be long and narrow and pointed at the downstream end when formed from river bars. Islands may be colonized by vegetation, but neither river bars nor islands are cultivated or otherwise occupied by Man in the Mississippi Delta due to the large fluctuations in water level. River bars and islands consist of fine and silty sands with some occurrence of clays. The coarse materials usually will be found at the upstream nose of these features.

M. Objectives of Study

The objectives of the morphology study are as follows:

1. To the extent possible with existing data, document and map significant changes in meander pattern, and bar and chute development through the reach.
2. Document and map significant changes in vegetation and other energy dissipaters.
3. Document and map significant changes in river thalweg, cross section and channel invert with time.
4. To the extent possible with existing data, analyze the changes in river morphology with respect to causal factors.

Each of the above listed objectives requires that significant changes in the river's morphology be delineated in order to accomplish these objectives. The first requirement was to outline periods when significant changes in the morphology of the river might have occurred. The time periods which were chosen were the early 1930's, middle 1940's, early 1960's, 1973 (prior to the flood in 1973) and 1974 (post flood). This span of years (approximately 40) is very small in comparison to the length of time the river has required for significant changes. However, this period was chosen for two reasons: (1) The study was accomplished primarily with aerial photography which began to be widely used in the early 1930's, and (2) The times selected represent periods of definite changes in the river. The early 1930's was selected as a period when much of the levee construction had been completed along the river. The period of 1944 and later was selected as the time at which all the cut-offs in the river had been completed. The early 1960's represents a period when the dike construction began to be primarily of rock type rather than pile dikes. The final two periods were selected in order to delineate any significant changes which might have occurred as a result of the 1973 flood.

Various means of outlining the changes in the river's morphology are available: topographic maps, navigation charts, hydrographic surveys and aerial photography.

Aerial photography and hydrographic surveys were the two sources chosen to provide the main portion of information in this study. Both the aerial photography and hydrographic surveys covered a relatively brief span of time. In many cases, the photography was not controlled; however, sufficient landmarks (i.e. roads, levees, structures, etc.) were distinguishable for marking the outline of the river channel on a topographic map.

1. Documentation of Bar and Chute Development and Meander Pattern. The method of presenting changes in meanders and bar and chute development was accomplished through graphical means. Appendix

C consists of a series of overlays at a scale ratio of 1:62,500 which will match the 15-minute United States Geological Survey topographic quadrangle sheet for each segment of the Mississippi and Atchafalaya Rivers. These sheets were developed from overlays which have been traced on frosted acetate from the aerial photography for each of the selected year periods. The river channel, vegetated bars, sand bars, chutes, dikes and islands were transferred from the photography to the frosted acetate. The photographs were at various scales ranging from 1:10,000 to 1:62,500. Some of the photography was available in controlled mosaics while in many cases with the older photography, individual pictures were fastened on large fiber boards to produce a mosaic for tracing. The tracings were then reduced to a 1:62,500-scale photographically. The reduced tracings were placed on the 15' USGS topographic quadrangle sheet and aligned with existing land features. A final tracing was then produced for the report, and a copy of each tracing bearing the year and title of the topographic quadrangle was enclosed in the appendix. The overlays provide a graphic chronological summary of changes in the river's morphology with time and are keyed to the USGS topographic quadrangles with a scale of 1:62,500. This means of portraying the river's outline provides a basis for investigating the influence of the river's morphology on the flow regime of the river.

2. Changes in Vegetation and Other Energy Dissipaters.

The changes in energy dissipaters within the confines of the channel are displayed on the morphological overlays in Appendix

C. The time periods over which the changes are displayed are noted on each overlay sheet. The sheets note all the dikes and man-made features which were visible from the photography. In many cases, a dike which was active during one period of time has subsequently been buried and would be no longer visible on the later photography. All the vegetation within the channel is noted, as well as islands, towheads etc. The vegetation on the islands is represented either as low undergrowth or high, topped-out vegetation, primarily trees. The distinction between low undergrowth and higher vegetation was interpreted from the aerial photography and in some cases, especially with the older photography, required careful interpretation. The low-water features such as sandbars are also noted on the over-lays. The energy dissipaters outside the channel and in the adjacent floodplain were evaluated for the Fall of 1974. The overlays contained in Appendix E were prepared from the color infrared photography supplied by the Corps of Engineers. This overlay provides an up-to-date presentation of the vegetation in the area adjacent to the channel. This series of overlays would have direct application for the revision of the energy dissipaters in the large scale model of the Mississippi River operated by the Corps of Engineers.

Microfilm copies of photographic mosaics prepared by the U.S. Soil Conservation Service covering the entire river from St. Louis to New Orleans for two time periods, the 1940's to early 1950's, and the 1960's were purchased and catalogued. These copies were used to prepare overlays of the vegetative cover for the time period of the late 1940's and 1950's. The 1974 & 1940-50's overlays are prepared at identical scale ratios and a direct comparison of the two provides a graphic portrayal of significant changes in energy dissipater for the time period. A significant reduction in the vegetative cover was noted in the upper reaches of the river. The forested areas adjacent to the river in the Memphis District and the upper part of the Vicksburg District have been largely removed during the period of the 1940's to the present time. This reduction in the vegetative cover may have accounted for some of the erosion and scour problems during the 1973 flood.

3. Changes in River Thalweg, Cross Section and Channel Invert. The significant changes in the thalweg are shown on the overlays of the river channel. The 1973 thalweg is shown as a dashed line, and where significant changes have occurred in the past are indicated on the overlays for the particular year period in which the change occurred. The changes in river cross section are shown on the cross-section sheets in the appendix. The cross sections are shown at approximately thirty-mile intervals down the river. A listing of problem reaches by river mile was requested from each district and the cross sections were located in those areas of the river. Each sheet contains the river cross section for the same general time periods as the overlay sheets. The cross sections were prepared from the hydrographic surveys supplied by each district. In most cases, the cross sections are not at exactly the same location on the river since the hydrographic surveys were not taken at the same location over the forty-year time span under consideration. A small section of the river plan is shown, indicating the location of each cross section. The elevations

have all been corrected to mean sea level and the average low-water plane elevation is also shown. All the cross sections have been taken from hydrographic surveys at lower than bankfull river stages. The invert profiles were also prepared from the hydrographic surveys at approximately the same time periods as the overlay sheets. Each sheet displays approximately thirty miles of the river with the time periods as indicated. The invert profiles are all based on mean sea level elevation with the average low-water plane plotted for reference. The datum points plotted are the lowest elevation in the navigable channel of the river. Thus, the invert profile portrays the lowest elevation in the main channel, although a lower elevation may exist outside the main channel due to scour, etc. A combined study of the invert profiles, cross sections and morphology overlays certainly provides considerable insight into the river's behavior. However, insufficient time was available to attack the problem of selecting specific reaches wherein a series of closely spaced cross sections might be studied in detail. The selection of the spacing presented was quite large due to the constraints of time. A further study of selected reaches utilizing detailed cross sections, invert profiles and the morphology overlays would certainly provide useful information and is recommended for further study.

4. Documentation of Morphology in the Reach of the Mississippi River from Cairo, Illinois to Alton, Illinois.

   a. Significant changes in minimum, maximum, and average top bank width of channel for the reach above Cairo, Illinois. Aerial photography from the following years was used to meet this requirement:

10/29-30/35
12/14/47 - 2/9/48
8/2-3/65
1/30/70
9/5/74

Measurements were taken at every second river mile at the narrowest dimension of the channel through each river mile. Top bank was defined as the line of permanent vegetation.

b. Significant changes in minimum, maximum, and average radius of curvature, meander length, and meander width for the reach above Cairo, Illinois. Hydrographic surveys and aerial photographs were used to meet this requirement for the one meander (mile 11.0 - mile 26.0) in river reach above Cairo, Illinois. Measurements were taken for the following years:

1876-1881	(Survey)
1919	(Survey)
1929	(Survey)
1931	(Photography)
1937	(Survey)
1942	(Survey)
1948	(Photography)
1965	(Photography)
1968	(Survey)

Meander parameters were defined as in Fluvial Processes in Geomorphology by Leopold, Wolman, and Miller. Meander axis was drawn from mile 11.0 through mile 26.0. Meander width was measured from bend to bend from lines through channel invert and parallel to axis. Radius of curvature was measured from best fit of curve through channel invert of the bends.

c. Documentation, to the greatest extent possible, of annual bank caving volumes for the reach above Cairo, Illinois. Bank caving volumes were taken from hydrographic surveys for the following intervals:

1937-1944	$45{,}458.0 \times 10^3$ yd^3	Trend of decreasing bank caving w/years
1944-1956	$42{,}180.6 \times 10^3$ yd^3	
1956-1965	$30{,}374.7 \times 10^3$ yd^3	

River plan views were traced on frosted acetate for each year from the hydrographic surveys. These were then overlayed to indicate progressive recession or inundations of bank lines in the main channel and chutes. Changes in bank lines correlated well with areas marked on the surveys as subject to caving banks. Areas on the overlay changes were computed by planimetry. Height of caving banks was computed by taking the mean of the interpolated "average low-water reference plane" river elevations for the upstream and downstream gages for the year intervals, then subtracting these ALWP means from the average bank elevations; bank caving volumes were computed by multiplying bank areas times computer heights.

N. Conclusions

1. The information on morphology in the form of maps, charts and aerial photographs on file in each District Office of the Corps of Engineers can provide valuable insight into the behavior of the Mississippi River. This project has just begun to uncover and relate this material from each district to provide an overall view of the river's behavior. The information on morphology from each district should be kept current and available for use in evaluating changes in the river.

2. The study of energy dissipaters in the channel and floodplain can provide useful information on the flow regime of the

Mississippi River. Additional study in this area, including a land use study, would be useful for predicting the river's behavior.

O. Recommendations

As a logical extension of this study, a detailed analysis of selected reaches of the river, wherein the information presented on the morphology overlays, invert profiles, cross section and vegetative cover overlays is recommended. The study would certainly provide useful information on the river's behavior with time and the influence of physical changes such as channel configuration, vegetative cover, etc.

P. Bibliography*

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*Note: These entries are additional to those listed in the general bibliography section at the end of the report.