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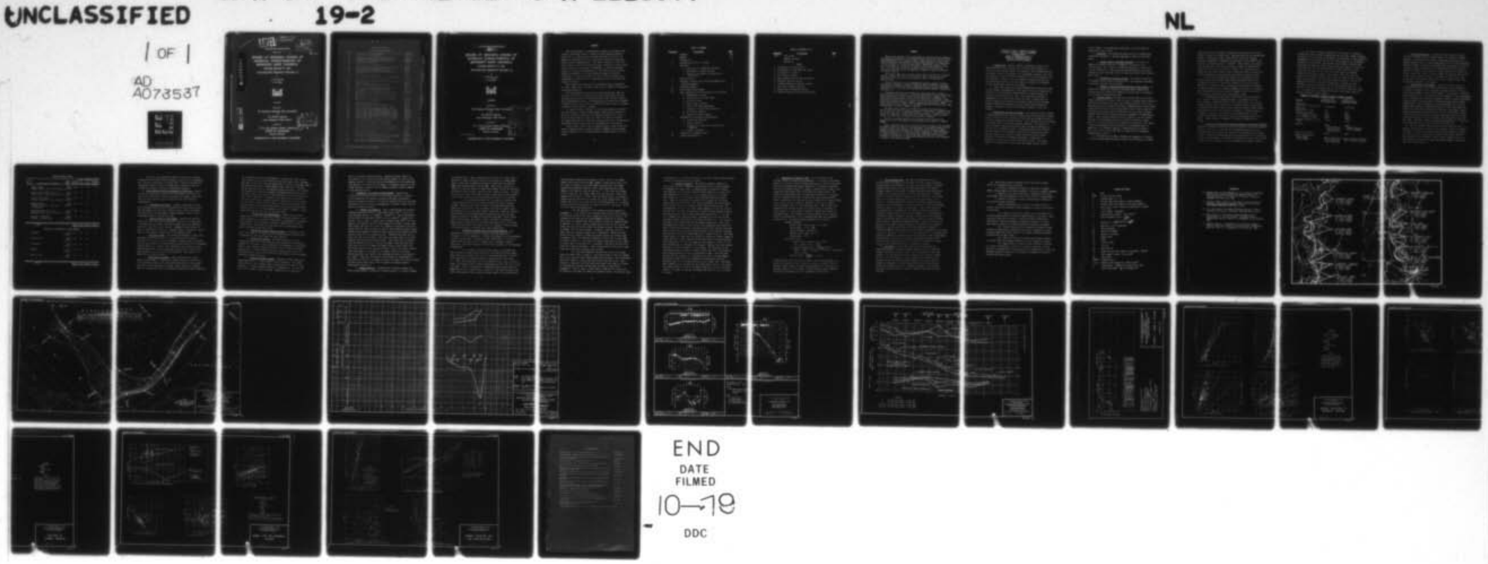

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POTAMOLOGY INVESTIGATIONS

Report 19-2

RESUME OF RESEARCH STUDIES OF HYDRAULIC CHARACTERISTICS OF MISSISSIPPI RIVER CHANNELS

INTERIM REPORT FY 1967

POTAMOLOGY RESEARCH PROJECT 10

by

P. W. Pierce III
C. M. Elliott

April 1967

Sponsored by

The President, Mississippi River Commission
and
The Division Engineer
Lower Mississippi Valley Division

Prepared by

U. S. Army Engineer District, Vicksburg
CORPS OF ENGINEERS
Vicksburg, Mississippi

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POTAMOLOGY INVESTIGATIONS REPORTS

Issued Prior To and Including This Report

Report No.	Title	Date
1-1	Instructions and Outline for Potamology Investigations	November 1947
1-2	Outline of Plans for the Potamology Investigations	December 1947
2-1	Preliminary Flume Tests of Mississippi River Revetment (1st Interim Report)	October 1947
2-2	Preliminary Tests of Mississippi River Dikes, Bank Stabilization Model	June 1950
2-3	Preliminary Tests of Experimental Baffles, Bank Stabilization Model	September 1951
2-4	Preliminary Flume Tests of Mississippi River Revetment (2d Interim Report)	November 1951
2-5	Investigation of Bank Stabilization, Miller Bend, Mississippi River	April 1953
2-6	Verification of Bank-stabilization Model	July 1953
3-1	Preliminary Laboratory Tests of Sand-asphalt Revetment	July 1948
5-1	Geological Investigation of Reid Bedford Bend Caving Banks, Mississippi River	July 1947
5-2	Field Investigation of Reid Bedford Bend Revetment, Mississippi River (3 volumes)	June 1948
5-3	Reid Bedford Bend, Mississippi River, Triaxial Tests on Sands	May 1950
5-4	Piezometer Observations at Reid Bedford Bend and Indicated Seepage Forces	May 1950
5-5	Standard Penetration Tests, Reid Bedford Bend, Mississippi River	May 1950
5-6	Undisturbed Sand Sampling and Cone Sounding Tests, Reid Bedford Bend Revetment, Mississippi River	May 1951
7-1	Soils Investigation, Bauxippi-Wyanoke Revetment	June 1951
8-1	Hardscrabble Bend, Mississippi River, Revetted Bank Failure, Soils Investigation	June 1950
9-1	Bank Caving Investigations, Kempe Bend Revetment, Mississippi River	November 1951
*10-1	Preliminary Development of Instruments for the Measurement of Hydraulic Forces Acting in a Turbulent Stream	June 1948
10-2	Turbulence in the Mississippi River	May 1950
*10-3	Evaluation of Instruments for Turbulence Measurements, 1948-1949	March 1951
*10-4	Evaluation of Instruments for Turbulence Measurements, 1949-1950	April 1951
11-0	Résumé of Conference Initiating Potamology Investigations, 11 February 1947	February 1947
11-1	Report of Conference on Potamology Investigations, 15 March 1948	March 1948
11-2	Report of First Potamology Conference with Hydraulics Consultants, 9-10 December 1948	December 1948
11-3	Minutes of Conference on Soil Studies, Potamology Investigation, 18 April 1949	April 1949
11-4	Report on Second Potamology Conference with Hydraulics Consultants, 23-24 May 1949	May 1949
11-5	Minutes of Conference with Soils Consultants, Stability of Mississippi River Banks, 5-8 October 1949	October 1949
11-6	Report of Conference on Potamology Investigations, 6-7 October 1949 (Volume 1, Volume 2*)	April 1951
11-7	Minutes of Conference on Soil Aspects of Potamology Program, 17-18 June 1950	October 1950
11-8	Minutes of Potamology Conference, 5 April 1951	April 1951
12-1	Density Changes of Sand Caused by Sampling and Testing	June 1952
12-2	Summary Report of Soils Studies	October 1952
12-3	Verification of Empirical Method of Determining Slope Stability	April 1954
12-4	Verification of Empirical Method of Determining Slope Stability - 1954 Data	June 1955
12-5	A Review of the Soils Studies	June 1956
12-6	Verification of Empirical Method of Determining Slope Stability - 1955 Data	July 1956
12-7	Verification of Empirical Method of Determining Slope Stability - 1956 Data	June 1957
12-8	Verification of Empirical Method for Determining Riverbank Stability - 1957 Data	January 1959
12-9	Verification of Empirical Method for Determining Riverbank Stability - 1958 Data	September 1959
12-10	Verification of Empirical Method for Determining Riverbank Stability - 1959 Data	December 1960
12-11	Verification of Empirical Method for Determining Riverbank Stability - 1960 Data	December 1961
12-12	Verification of Empirical Method for Determining Riverbank Stability - 1961 Data	October 1962
12-13	Verification of Empirical Method for Determining Riverbank Stability - 1962 Data	September 1964
12-14	Verification of Empirical Method for Determining Riverbank Stability - 1963 Data	April 1965
12-15	Geological Influences on Bank Erosion Along Meanders of the Lower Mississippi River	September 1965
12-16	Methods of Preventing Flow Slides	October 1965
12-17	Verification of Empirical Method for Determining Riverbank Stability - 1964 Data	May 1966
13-1	Bank Caving Investigations, Huntington Point Revetment, Mississippi River	June 1952
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15-1	Bank Caving Investigations, Free Nigger Point and Point Menoir, Mississippi River	May 1952
16-1	Development of Operating Technique for and Verification of Channel-meander Model	September 1953
17-1	Hydrographic and Hydraulic Investigations of Mississippi River Revetments	April 1954
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18-2	Verification of Cone Criteria for Determining Riverbank Stability	June 1965
19-1	Hydraulic Analysis of Mississippi River Channels, Miles 373 to 603, Fiscal Year 1964	September 1965
19-2	Resume of Research Studies of Hydraulic Characteristics of Mississippi River Channels	April 1967
20-1	Effects of River Stages on Bank Stabilization; Analysis of Field Data	December 1965
21-1	Sand-Filled Bags as Dike Material; Potamology Research Project 9	March 1967
21-2	Review of Past Experience with Contraction Works; Potamology Research Project 9	March 1967

* Not of general informational value and hence not distributed.

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FOREWORD

This interim report is presented as a resume of the progress and status of continuing studies in connection with Potamology Research Project No. 10. These studies are being conducted by the Corps of Engineers, Vicksburg District, by direction of the Lower Mississippi Valley Division Potamology Board. The project consists of office and field studies to develop criteria for proper curvature of bends; length, width, and depth of crossings; and alignment of relatively straight reaches of the Lower Mississippi River. The objectives also include: general investigation of the more important hydraulic variables, development of criteria for design of river control structures, and establishment of procedures for evaluating the effect of existing and proposed structures.

These studies were approved by the Mississippi River Commission in letter, LMVGT, dated 31 October 1963, subject: Minutes of Thirteenth Potamology Conference.

The investigations and analyses described herein were under the direction of Mr. John E. Henley, Chief, River Stabilization Section, Vicksburg District, and the general direction of Mr. George A. Morris, Chief, Engineering Division. The analyses and this report were prepared by Messrs. Paul W. Pierce, III, and Charles M. Elliott under the general supervision of Mr. Malcolm G. Anding.

Dr. Daryl B. Simons, Professor of Civil Engineering and Associate Dean for Research, College of Engineering, Colorado State University, has been retained as Consultant on Potamology Research Project No. 10 by the Vicksburg District since July 1965. Dr. Simons' assistance and suggestions have been invaluable in giving direction to the District's potamology research studies and in the preparation of this report.

Colonel James A. Betts, CE, and Colonel Felix R. Garrett, CE, were District Engineers and Lt. Colonel George L. Shumaker, CE, was Deputy District Engineer of the Vicksburg District during preparation of this report.

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SUMMARY

This report presents a brief description of field and office studies of the hydraulic characteristics of selected cross sections and reaches of the Lower Mississippi River through FY 1966. These studies are a part of the general potamology investigations for improving techniques for stabilizing the bed and banks of the Mississippi River. The general purpose of the previous studies was to analyze the hydraulic factors and elements of the river cross sections, establish allowable limits of width-depth and area-depth relations, and to determine the relation of radii of curvature to width and depth.

Since April 1966, more intensive studies have been made of six typical stable, straight, and divided flow reaches. Also, 5 reaches have been selected for detailed studies relating to the effect of existing or proposed dikes.

Current objectives of the investigations include a general study of the hydraulic variables relating directly to channel geometry; developing criteria for the design of channel stabilization structures and evaluation and prediction of the effects of existing and proposed channel stabilization structures.

A general concept of the relations of energy loss rate or slope to channel geometry and roughness is presented and related to river engineering. The concept infers that the channel bed and shape will accommodate the energy slopes either within the section or from section to section. Where flat energy slopes prevail the channel will be deep and narrow with relatively smooth bed and large sediment transport capacity for unit width. Where steep slopes occur the channel will be shallow and wide with relatively rough bed and smaller sediment transport capacity.

The basic data program is discussed including the presentation of survey data, plan maps, sections, profiles, and tabulations of computed data. The relations of the more important hydraulic variables are shown by plotted curves for comparison. These variables include those of channel geometry, energy loss, bed form and roughness, and sediment transport.

Corrective measures based on these factors are discussed and the application of the relationships are illustrated by an example of channel design.

Future considerations will be directed toward development and refinement of channel design procedures utilizing hydraulic data being obtained in the current detailed study program. The importance of determining sediment transport capacity and the relation to other variables is being emphasized. The ultimate goal of the Vicksburg District potamology program is to gain a workable knowledge of the controlling basic principles and variables involved in the transport of water and sediment and to apply this knowledge to channel stabilization problems.

MISSISSIPPI RIVER - POTAMOLOGY STUDIES
VICKSBURG DISTRICT, CORPS OF ENGINEERS
INTERIM REPORT
RESUME OF RESEARCH STUDIES OF HYDRAULIC CHARACTERISTICS OF MISSISSIPPI RIVER CHANNELS

1. Introduction. Previous channel stabilization studies of the Mississippi River have generally been concerned with recording the effects of the variables involved in streamflow. The Vicksburg District has always considered documentation of hydrographic changes in the river and detailed surveys of revetment conditions at critical locations to be most important. During recent years improved surveying and drafting techniques have permitted even more complete coverage by hydrographic surveys and gage and discharge measurements.

2. Since 1962 studies in the River Stabilization Section have been directed toward a determination of the cause of the river changes by an analysis of certain hydraulic characteristics of typical stable and unstable cross sections of the river. This permitted quantitative comparisons of the factors and elements involved. Present plans are directed toward investigations and analyses of why the river develops unstable conditions or becomes relatively stable with satisfactory hydraulic characteristics and a more uniform transport of water and sediment.

3. Description and Scope of Studies. The original hydraulic studies of Mississippi River cross sections involved limited evaluations of single typical sections in bend, crossing, divided-flow, and straight reaches of the river through the Vicksburg District. The investigations covered stable and unstable reaches and was an empirical approach to the analysis of channel geometry. These investigations also included determination of the factors in the Manning formula. Continuing studies have indicated that the limits of the original studies were too broad and that more intensive surveys were required in short reaches to provide greater continuity of data on the variables considered. Consequently, a detailed study of 6 reaches of the river was initiated. The average length of the reaches was 9 miles with study ranges located 2,000 to

3,000 ft apart. Five additional reaches have since been added for evaluation of dike effects.

4. Objectives. The purpose and objectives of the studies fall into several categories. The most important of these are described below.

a. General study of important variables. To isolate the important variables involved in streamflow, to determine their interrelations, and to develop a workable knowledge of the principles of river engineering. These studies include application of previous research on flumes and small rivers to avoid any conflict with verified basic theory.

b. Development of design criteria. To develop criteria for the design of river control structures and to plan improved performance of existing structures and revetments.

c. Analysis, evaluation, and prediction of dike effects. To analyze and evaluate the effects of existing channel stabilization structures and to forecast the changes and overall effects of proposed new structures and improvement works.

5. Previous Studies. Studies prior to April 1966, were directed toward an analysis of typical cross sections in crossing, bend, transition, and divided-flow reaches of stable and unstable portions of the river. The analysis included numerous relations of ALWP (Average Low Water Plane) stage and both effective and average channel widths, depths, and areas. The analysis was aided greatly through the use of a computer program planned by the District and developed and programmed by the WES Computer Center. Water surface profiles were also studied in selected reaches. The plan of investigations included 20 reaches and about 60 ranges. About 800 cross sections have been analyzed by the program. The results of these investigations were published by the Potamology Board in Report No. 19-1, Hydraulic Analysis of Mississippi River Channels - Miles 373 to 603 - Fiscal Year 1964, in connection with Potamology Research Project No. 10.

6. The analysis of hydraulic elements and dimensions of hundreds of cross sections emphasized known fallacies in the analysis of channel

characteristics of an unstable, nonuniform stream using factors from a formula developed for uniform flow. Study gage data were not sufficiently accurate to determine reliable energy slopes. Data were obtained permitting quantitative comparisons of the channel factor, $\Sigma AD^{2/3}$, and the slope - roughness factor, $K = Q/\Sigma AD^{2/3}$. These factors were shown to vary uniformly with stage and to be fairly constant at representative stages for a given section in stable reaches. No interrelation was established for similar channel types in different reaches, showing that slope and roughness relations change with channel location and shape.

7. Two of the most important variables are the ALWP width and maximum depth below the ALWP. ALWP widths and maximum depths below the ALWP were shown to be relatively constant at the cross sections analyzed in the stable reaches, showing that the transport of sediment is rather uniform with the existing alignment and slopes in the reaches. This relation may be used as a guide to channel restriction by dikes, particularly if correlated with average valley slopes.

8. Establishing accurate water surface and energy slopes proved to be the most difficult problem involved in the analysis of river cross sections. Study gages were located too far apart, and conditions at gage locations varied too widely to determine accurate energy slopes at individual sections. Water surface slopes in specific reaches showed variations from over 2 feet per mile to reverse or upstream slopes due to changes in velocity head; however, the average slopes over long reaches are generally constant with rising or falling and high or low stages. These slopes are presumably the average determined by the valley.

9. Relations of Energy Loss, Bed-Form Roughness and Sediment Transport. Comparative studies of individual sections in various reaches and experience with the effects of revetment and dike installations have led to the conclusion that more detailed and theoretical investigations are required in order to better understand and apply the principles of river engineering to channel stabilization. An attempt is being made to relate energy slopes, channel geometry, resistance to flow, bed forms, and sediment transport.

10. The current concept and approach to the analysis of hydraulic variables are directed toward showing that the bed forms, channel alignment, and geometry of an alluvial stream provide the resistance to flow required to accommodate the energy loss rate for the total stream and for incremental subsections of the stream. The studies are also aimed at showing that these same bed forms and energy losses control the transport or deposition of bed material. Due to the large width to depth ratio there may be considerable variation in the bed form, energy slope, and sediment transport rate across a channel cross section. The energy slope is believed to exercise more direct control over the other factors than any other single variable. The following tabulation indicates some of the apparent effects and relations of energy slope or energy loss rate, resistance to flow or roughness, bed form, and sediment transport. It should be noted that the energy slope at a section may change with stage, i.e., be steeper in the crossings and flatter in the bends during low stages, reversing at higher stages.

SUMMARY OF PERTINENT VARIABLES RELATED TO ENERGY GRADIENT

Factors	Channels With Flat Energy Slope	Channels With Steep Energy Slope
Energy Head (Relative to Valley Slope)	Increasing	Decreasing
Energy Loss (Resistance to Flow)	Low	High
Roughness (Over all n)	Low	High
n' = Relative to Grain	Higher	Lower
n" = Relative to Form	Lower	Higher
Sediment Transport per unit width	Greater	Lesser
Bed-Form	Lower (Lower Dunes, or Sand Waves and Longer Lengths)	Higher (Higher Dunes and Shorter Lengths)
Velocities (Average)	Higher	Lower
Channel Configuration		
Lower Stages	Narrow & Deep (Pool)	Wide & Shallow (Crossing)
Higher Stages	Wide & Relatively Deep (Crossing)	Wide & Restricted (Pool)

11. Corrective Measures. Corrective structures should constrict and deepen crossings at low to medium stages, thus decreasing overall roughness, and flattening the slope or decreasing energy loss rate. A deeper, narrower channel at lower stages would tend to increase deposition behind and between structures and increase slope and energy loss rate at the higher stages. Structures in the narrow pools and bends would be designed to decrease depths, widen the cross sections, and increase the energy slope at low stages. At higher stages the increased widths would provide a more efficient channel and decrease the energy slope. The overall corrective measures would result in more uniform energy slopes and sediment transport at all stages.

12. Revised Basic Data Program. In order to properly carry out the objectives and the more detailed studies above, it was necessary to obtain more complete survey coverage of limited reaches of the river. It was also necessary to obtain large amounts of field data in relatively short periods of time if the data were to be comparable. These requirements could be satisfied by utilizing the improved methods of making hydrographic surveys using an electronic means of measuring distance with a moving sounding boat. The data obtained include hydrographic surveys, water surface gage readings, discharge measurements at each study range, bed profiles and float current directions across each study range, current direction and magnitude measurements at 0.2 and 0.8 fractions of depth across selected study ranges, continuous longitudinal profiles through crossings and pools at selected locations, and bed material samples at each range. Suspended sediment discharge measurements at 2 - 4 selected study ranges in each reach were initiated in January 1967.

13. The six detailed study reaches include at least two types of problem reaches and were selected as the extremes of stable or unstable conditions. The five additional reaches which were added to evaluate the effects of stone training dikes include reaches where dikes have been constructed or are planned. Plate 1 shows a general plan of the study reaches. The following tabulation shows a summary of pertinent data for the study reaches:

DETAILED STUDY REACHES

Reach No.	Location and Description	1962 Miles	Length: Miles	Number of Ranges	Number of Gages	Current Direction Ranges
1	Ozark - Eutaw (Stable Reach - Short Radius Bends)	564.8 to 577.0	12.2	17	24	3
2	Belle Island to Milliken Bend (Stable Reach - Long Radius Bends)	451.6 to 460.4	8.8	13	11	2
3	Cottonwood Bar Reach (Divided Flow Reach - Uncontrolled)	461.4 to 472.2	10.8	19	27	4
4	Ajax Bar Reach (Divided Flow Reach - Partially Controlled)	479.0 to 485.4	6.1	10	12	3
5	Baleshed Landing Dike Field (Straight Reach - Effect of Dikes)	485.4 to 495.2	9.8	17	19	3
6	Cracraft to Carolina (Typical Straight Reach)	506.8 to 514.2	7.4	12	10	2
	TOTALS		55.1	88	103	17

REACHES FOR EVALUATION OF DIKE EFFECTS

Reach No.	Location and Description	1962 Miles	Length: Miles	Number of Ranges	Number of Gages	Current Direction Ranges
1.	Greenville	531.3 to 549.0	17.7	11	56	4
2.	Terrene-Ozark	594.0 to 580.6	13.4	16	24	-
3.	Choctaw Bar	551.0 to 565.9	14.9	20	23	-
4.	Lakeport	524.0 to 531.3	7.3	12	15	-
5.	Kentucky Bend	514.2 to 524.0	9.8	11	15	-
	TOTALS		63.1	70	133	4

The basic data program with limited cross-section coverage throughout the Vicksburg District portion of the river is being phased out. Periodic measurements of divided flow at critical locations and intermittent surveys of selected ranges will be made where data are required for design, operations, or maintenance purposes.

14. Basic Hydraulic Studies and Analysis of Field Data. Complete coverage of survey data is planned for the detailed study reaches at about 10-ft intervals in rising and falling river stages. Data being collected and documented are discussed briefly in the following subparagraphs:

a. Hydrographic plan maps. A complete hydrographic survey and hydrographic plan map are being prepared for each detailed survey. The hydrographic plan map shows contours, surface floats and current direction without the hydrographic range elevations. Plate 2 shows a hydrographic plan of the Ajax Bar reach.

b. Cross sections at study ranges. Cross-section data are plotted for each study range showing mean velocities, bed forms, mean bed material sizes, average stream power (γDSV) values, and Manning's n values for subsections of the channel. Comparative plottings may be made in evaluating the effects of changing stages or conditions. Plate 3 shows a cross section of Range 482.2 in the Ajax Bar reach.

c. Bed profile data. Bed profile data showing bed forms from approximately 500 feet above to 500 feet below the study ranges at intervals of 500 or 1,000 feet are obtained. Surface current directions are also being obtained for these profiles and are shown on the hydrographic plan map (Plate 2). Reference data tabulated on the profiles include average depth, mean velocity, approximate energy slope, average stream power, Manning's n, and the bed form designation. Bed profiles for Range 482.2 are shown on Plate 4.

d. Water surface profiles. Gage locations are as closely spaced as practicable. Accurate water surface and energy profiles are very difficult to obtain, and slope variations across the study ranges have proven almost impossible to obtain. These profiles are showing some very interesting trends in the Ajax Bar reach where a good conparison of the extremes of channel configuration (crossings and pools) exists. They confirm previous indications that slopes are steep in the crossings and flat in the bends during low stages and the reverse during high stages. The profiles also show a concave pattern from a pool into a crossing during high stages and a convex pattern during low stages. This confirms the concept that slopes are constantly changing and adjusting and that the rate of change is greater in some portions of the reach which may in itself prove important. In addition to the water surface and energy profiles, several other variables which are expected to vary with slope and the type of channel will be plotted. These include maximum depth, effective depth, and average depth profiles; total channel stream power (γQS) profile; and the slope-roughness coefficient $K = Q/\Sigma AD^{2/3}$. Plate 5 shows these data for one survey of Ajax Bar reach.

e. Current direction measurements. Current direction and magnitude at 0.2 and 0.8 fractions of depth are being measured at 2 or 3 selected ranges in each detailed study reach. The measurements are made with a magnetic direction meter developed at WES attached to a Price current meter. These data are being plotted on the hydrographic plan maps to indicate changes with stage.

f. Tabulation of basic data and factors. A tabulation of all basic field data and the more pertinent computed hydraulic factors will be prepared for each study range and survey period.

g. Bed material samples. Bed material samples at about 4 locations across each study range are being obtained and a mechanical analysis of each sample is being prepared by the Foundation and Materials Branch. This permits relating bed material size to sediment transport and bed form. A profile showing D_{15}, D_{50}, and D_{85} sizes through the Vicksburg District portion of the river is also being plotted to determine variations through this reach.

h. Suspended sediment samples. Suspended sediment samples are being obtained at 2 - 4 study ranges in each study reach. The channel cross section at each sediment range is divided into four parts of equal discharge. A sediment sampling station is established at the center of each of the 4 areas of equal discharge. Sampling at each station is done by the point-integration method. Suspended sediment samples at five points in the vertical and a bed material sample are taken at each sampling station. A parts per million determination for both coarse and fine material is obtained for each sample. A mechanical analysis of the coarse material is obtained for the combined suspended sediment samples at the sampling station.

15. Morphometric and Hydraulic Relationships. Somewhat more technical and theoretical factors are now being considered in addition to the geometrical and hydraulic variables previously investigated. Those which appear pertinent to the Lower Mississippi River are described and discussed in the following subparagraphs. Available factual data are plotted on curves and charts.

a. General investigations. These considerations have included relating stage and discharge to the channel factor, $\Sigma AD^{2/3}$, and to the slope-roughness factor, $K = Q/\Sigma AD^{2/3} = 1.49\ S^{1/2}/n$. Plate 6 illustrates the procedures for obtaining $\Sigma AD^{2/3}$ and other hydraulic variables and factors. Fig. 1, Plate 7, shows curves of stage versus $\Sigma AD^{2/3}$ for three ranges in the Ajax Bar reach and three ranges in the Ozark to Eutaw reach. These ranges were selected to show the extremes in variations of relative channel factors. Pool sections are shown to have relatively higher channel factors at low stages and relatively lower values at high stages, with the opposite being true for crossing sections. Transition sections vary the least, and vary more uniformly. This plate also shows values of K versus stage for the same ranges discussed above. This factor varies inversely with the channel factor for a constant discharge; therefore, pools have lower values of K at low stages and higher values at high stages, with the reverse being true for crossing sections. Plate 7 also shows computed curves portraying the relations of the channel factors to effective widths and depths, and computed curves showing relations of discharge, K, and $\Sigma AD^{2/3}$. Data from the detailed study reaches are superimposed on these charts to indicate the limits of values for stable and unstable reaches. Ultimately these charts may be used as guides in designing channel stabilization structures.

b. Channel geometry. Considerations of channel geometry are being confined mainly to relations of various widths to low stage, average, and maximum depths. These relations will show that for a given slope a decrease in channel width will result in an increase in average depth. Plate 8 shows width at ALWP versus effective depth and also width at ALWP versus maximum depth below the ALWP. These charts indicate the limits of widths and depths for stable and unstable reaches and also show the general limits of pool, transition, and crossing sections. It should be noted that transition sections are more nearly ideal and that design criteria may be based on the characteristics of this type of section.

It is generally believed that the radii of curvature have a controlling influence on the depths and widths of bends of natural streams. However, almost all the bends of the Lower Mississippi are protected by articulated concrete mattress and stone or asphalt upper bank paving and do not represent natural conditions. Radii of curvature for 43 bends in the Vicksburg District portion of the river has been related to widths at the ALWP for the period 1962-1964. Plate 8 shows plots of these data. No apparent trend or relation is established. These charts do establish the wide variations which exist in relatively stable revetted bends in the lower river. The relation of W/D to radius of curvature was also considered with similar indications.

c. Relations of energy loss, bed form and roughness. The variations of width and depth with energy slope and roughness are considered to be very important. If these relationships can be established, it will be practicable to establish design methods based on control of channel width and depths with the proper type of permanent training structures. Pertinent relations and factors are described in the following subparagraphs.

(1) A method of predicting the form of bed roughness has been developed by Simons and Richardson (1) for small rivers and flumes. This method may be modified and used for the Mississippi River to aid in predicting relative roughness related to stream power per unit area, $\tau V = \gamma DSV$, and average grain size of bed material, D_{50}. Fig. 1, Plate 9, shows these relations which indicate practically all bed forms to be in the dune range. This is in agreement with Mississippi River data related to Engelund's (2) curve shown on Fig. 4, Plate 10. The dunes falling in the lower regime appear to have relatively large height to length ratios and

provide greater roughness or resistance to flow. Dunes in the higher regime seem to have relatively small height to length ratios and to lie in a range of transition to a much higher sand wave with flat slopes upstream and downstream from the crests. These waves may have dunes imposed on the upstream slope and may be 20 - 30 feet high with lengths of 400 to 600 feet. The higher regime bed forms generally provide less roughness and resistance to flow. The term higher regime flow applies to stream power and should not be confused with "upper regime" flow. Upper regime flow seldom if ever can occur in the Mississippi River. It should be noted that the Froude number is always less than 0.3 and rarely exceeds 0.2 in the lower Mississippi River.

(2) The importance of the energy slope was discussed in paragraph 10. It is believed that average widths, depths, and roughness are directly related to the total energy loss rate at each section. The relation of the slope with the slope-roughness coefficient K requires the K factor to increase with slope or with a decrease in roughness based on Manning's n. Fig. 2, Plate 9, shows slope in feet per mile plotted versus the K factor for both stable and unstable reaches. The chart shows an average curve for these reaches. Ultimately, limiting curves for stable pool and crossing sections may be established. These curves may then be used as a guide in setting up design criteria for varying slopes and channel types. The relative variation of K with slope is also shown in profile on Plate 5. This plate also shows stream power per unit length of channel γQS in ft.lbs./sec./ft., in profile. γQS varies directly with slope for a constant discharge. Plate 6 shows how the K factor and stream power are obtained for a typical cross section.

(3) The slope-roughness factor K also varies with average depth, as shown in Fig. 3, Plate 9. This relation may be used as a design tool or as a check on other design methods and procedures. Since width also varies with depth, it follows that width should vary with slope. This relation is obscured by the fact that slope varies with stage and reverses for crossing-type sections and pool-type sections, as described in paragraph 10. Fig. 4, Plate 9, shows width at ALWP plotted versus slope at relatively low stages for stable and unstable reaches. No definite trend

is indicated for this relation indicating that other variables must partially control or outweigh the effect of slope.

d. Sediment transport. The sediment transport capacity or rate is one of the most important variables and is also closely related to roughness and energy slope. No measurements of sediment discharge have been made for the studies reported herein; however, in January 1967 measurements were initiated at 2 to 4 sections in each of the reaches under detailed study to determine total suspended sediment discharge rates. Sand discharge has been computed for 10 stages and discharges during 1937-1938 at mile 496.5 (3). Sand discharge at this range varied from 560 tons per day to a maximum of about 230,000 tons per day. The corresponding silt load at the same stages amounted to 29,000 and 315,000 tons per day. Unit sand discharges in the same location amounted to about 80 tons per day per foot of width with a mean velocity of 4 - 5 ft. per sec., probably for a rough bed form. Discharges up to 800 tons per day per foot of width were indicated for mean velocities of 6 - 7 ft. per sec., presumably with a smooth bed form and maximum stream power. These sand discharges were related to mean velocity and stream power after Colby (4). Plate 10 shows sand discharge versus mean velocity for available data with Colby's curve for the upper Mississippi imposed. These sediment discharge data were also related to stream power and is shown on Plate 10. The total stream power of a stream indicates the rate at which the stream's energy is being converted to heat. Bagnold (5) has also related sediment discharge and stream power. The unit discharge and stream power is greater in deep bend sections than in crossings at low stages. However, the total sediment discharge is believed greater in the crossings. The difference in the transport potential of adjacent channel sections can result in navigation and alignment problems at low and intermediate stages. Providing more uniform sediment transport is an important objective of channel design. Bed material samples have been obtained for representative sections throughout most of the Vicksburg District since 1 April 1966. The median grain diameter of the bed material has varied from 0.25 mm to 0.48 mm with an average of about 0.40 mm in the upper reaches and 0.35 mm in the lower reaches. The range of material has ranged from clays to 1-1/2 in. gravel or larger.

16. **Application of Hydraulic Data.** One of the goals of the Vicksburg District Potamology investigations is to be able to accurately predict the effects of river training structures on a reach of the river. Once this is accomplished channel design will be a matter of choosing the type of structure required to produce a desired effect. Many of the curves and relationships given above have design implications. The curves and relationships used in design applications will be developed with data obtained from stable reaches of the river having desirable channel characteristics. The energy slope utilized in the channel design of a reach of the river should be equivalent to the valley slope or within desirable limits for that particular reach. This satisfies the assumption that the most stable river conditions will occur when the total energy of a stream remains relatively constant with respect to the valley floor. The discharge used in the design of river channels should be representative of low to medium stages when most navigation problems occur. One possible design procedure is as follows:

Design conditions -

Energy slope = valley slope = 0.3 ft./mi.

Design Stage = 7.0 ft. ALWP

Design Discharge = 290,000 cfs

Minimum Depth - ALWP = 20.0 ft.

Design depth = 27 ft.

Design procedure -

Figure 2, Plate 9, gives a K = 0.385 for a design slope = $0.3 \frac{ft.}{mi.}$

Figure 3, Plate 7, gives a channel factor $\Sigma AD^{2/3} = \Sigma WD^{5/3} = 750{,}000 \text{ ft.}^{8/3}$ for Q = 290,000 cfs and K = 0.385

$$\text{Required width} = \frac{750{,}000}{27^{5/3}} = 3{,}100 \text{ ft.}$$

A similar design procedure could be based on other relationships, i.e., average depth versus K, Fig. 3, Plate 9; or W_o vs. S, Fig. 4, Plate 9. The best overall design of a reach would possibly be a trial and error procedure based on several different design methods based on different curves and relationships that are independent of each other.

17. Future Considerations. All future considerations will be directed toward development and refinement of channel design procedures utilizing data being obtained in the data collection program. A complete design procedure should certainly include consideration of sediment transport capacity. The sediment transport through a stable reach would necessarily be constant throughout the reach longitudinally. Designed reaches of the river should be analyzed for this condition. The ultimate goal of the sediment sampling program in the Vicksburg District is to isolate the controlling variables involved in sediment transport and to understand their interrelation in order to accurately predict the sediment transport capacity of a channel cross section. Once a river reach has been designed (as in paragraph 16) the sediment transport capacity of individual channel cross sections would be computed. If any significant variation in sediment transport capacity is discovered between adjacent channel sections the channel characteristics should be altered to obtain uniform sediment transport throughout the reach. Figure 3, Plate 10, is analogous to the Moody resistance diagram for uniform flow in conduits. Manning's n has been substituted for the Darcy-Weisbach resistance coefficient, $\frac{\Delta D}{D}$ has been substituted for the relative roughness, and the variation in the kinematic viscosity in the Mississippi River is considered to be negligible compared to variations in velocity and depth. This relationship, when developed, could be used to predict the relative roughness given velocity, depth, and energy slope of a section or to predict the energy slope given the bedform, velocity, and depth of a section.

18. Conclusions. The ultimate goal of the Vicksburg District Potamology program is to gain a workable knowledge of the controlling variables and basic principles involved in the transport of water and sediment. The interrelations of these variables are extremely complex and some of the data may not show any definite trends; however, the intensive surveys and analyses should establish acceptable limits of geometrical dimensions to furnish guidelines for the design of river control and training structures. Improved performance from existing revetments and dikes and more efficient dredging operations may also be obtained.

19. These studies should establish within practicable working limits the following general relations:

a. Effects of variations of stage and discharge on widths, depths, energy slopes, bed forms, resistance to flow, and sediment transport.

b. Effects of free and forced bends, crossings, divided flow and straight reach configurations on the factors listed in subparagraph a.

c. Effects of revetments, dikes, and maintenance dredging on the variables being considered.

With an understanding of the above, we should be able to properly design for a planned ultimate alignment the types of structures listed below:

(1) Control structures in bendways and around point bars to afford proper widths and desirable maximum depths at low water. These structures would also be planned to provide increased roughness and resistance to flow at low stages and decreased resistance to flow at high stages as required for uniform slopes and transport of sediment.

(2) Control structures for crossings and straight reaches designed to obtain proper contraction and reduced roughness to provide increased depths and flatter slopes at low stages and improved channel characteristics at high stages.

(3) Control structures for divided flow reaches designed to develop either the bendway channel or the chute channel as desired.

(4) Supplementary training structures designed to improve the channel characteristics adjacent to existing revetments or dikes. This may be accomplished by increasing overall roughness where a wider and shallower channel is required or decreasing the roughness to provide a narrower and deeper channel.

SYMBOLS AND TERMS

A	Area
ALWP	Average low water plane
D	Average depth = D' + D"
D'	Average depth with respect to grain roughness
D"	Average depth with respect to bed form roughness
D_x	Grain size of which x percent of particles by weight are finer
F	Froude number = $Vm/(gD)^{\frac{1}{2}}$
g	Gravitational constant = 32.2 ft/sec^2
K	Slope-roughness factor = $\frac{Q}{\Sigma AD^{2/3}}$
n	Manning's n = $\frac{1.49}{V} D^{2/3} S^{\frac{1}{2}} = \frac{1.49S^{\frac{1}{2}}}{K}$
n'	Manning's n for a subsection
Q	Water discharge
Q_s	Sediment discharge
R_c	Radius of curvature
S	Energy slope
W	Width
W_o	Width at ALWP
V	Velocity
V_m	Mean velocity
V_*	Shear velocity with respect to the grain = $(gD'S)^{\frac{1}{2}}$
γ	Unit weight of water = 62.4 lb/ft^3
ΔD	Dune height
$\Sigma AD^{2/3}$	Channel factor
τ or T	Shear on the channel bed = γDS in lb/ft^2
Ω	Stream power = $\gamma DSVW$ in ft.lb/sec./ft (= γQS)
ω	Unit stream power = $\frac{\Omega}{W}$ in ft.lb/sec.ft^2

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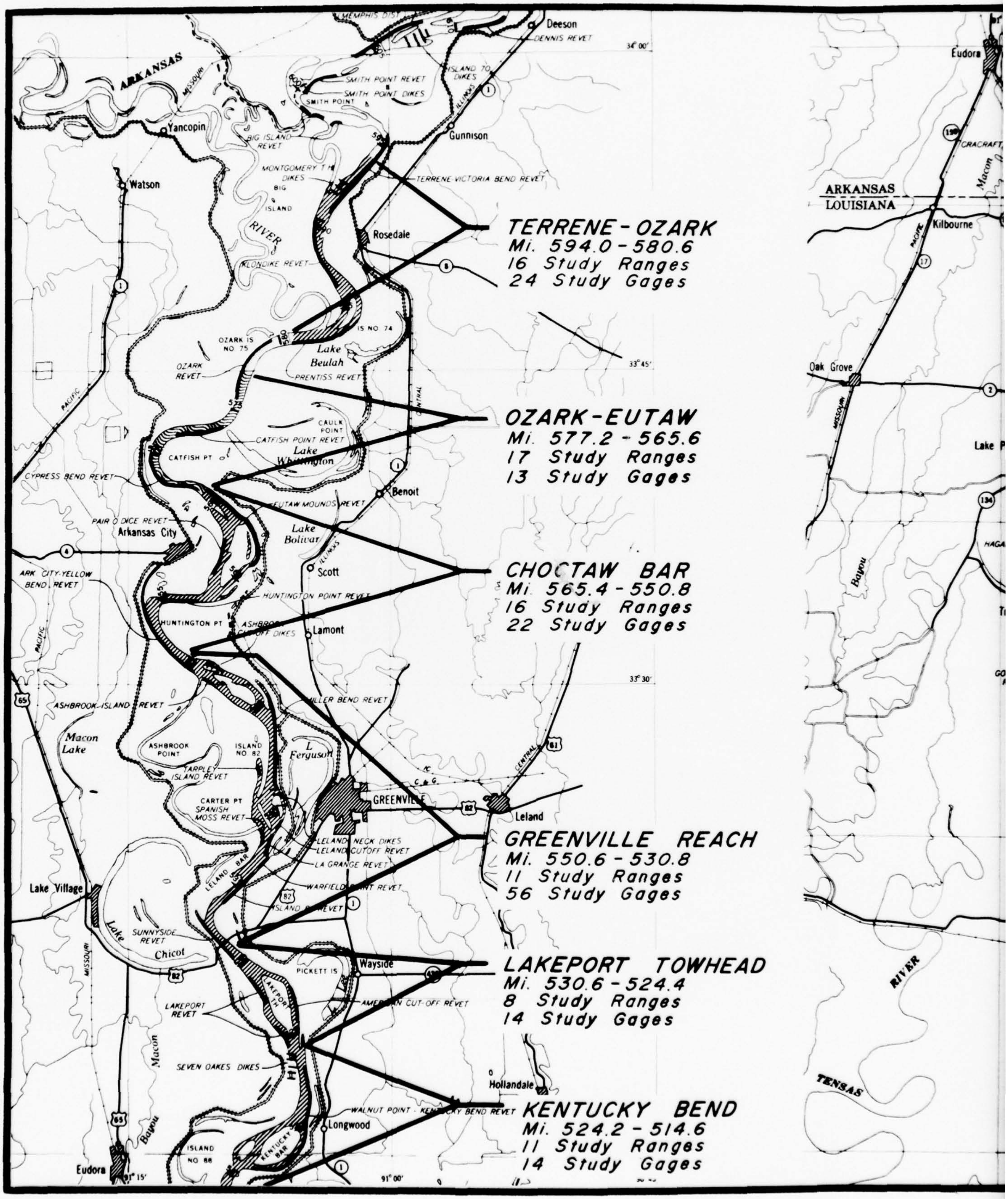
(1) Simons, Daryl B. and Richardson, E. V., "A Study of Variables Affecting Flow Characteristics and Sediment Transport in Alluvial Channels," Proceedings of the Federal Interagency Sedimentation Conference, 1963.

(2) Engelund, Frank, "Hydraulic Resistance of Alluvial Channels," Journal of the Hydraulic Division, ASCE, Vol. 92, No. HY2, Proc. Paper 4739, March 1966, pp. 317-326.

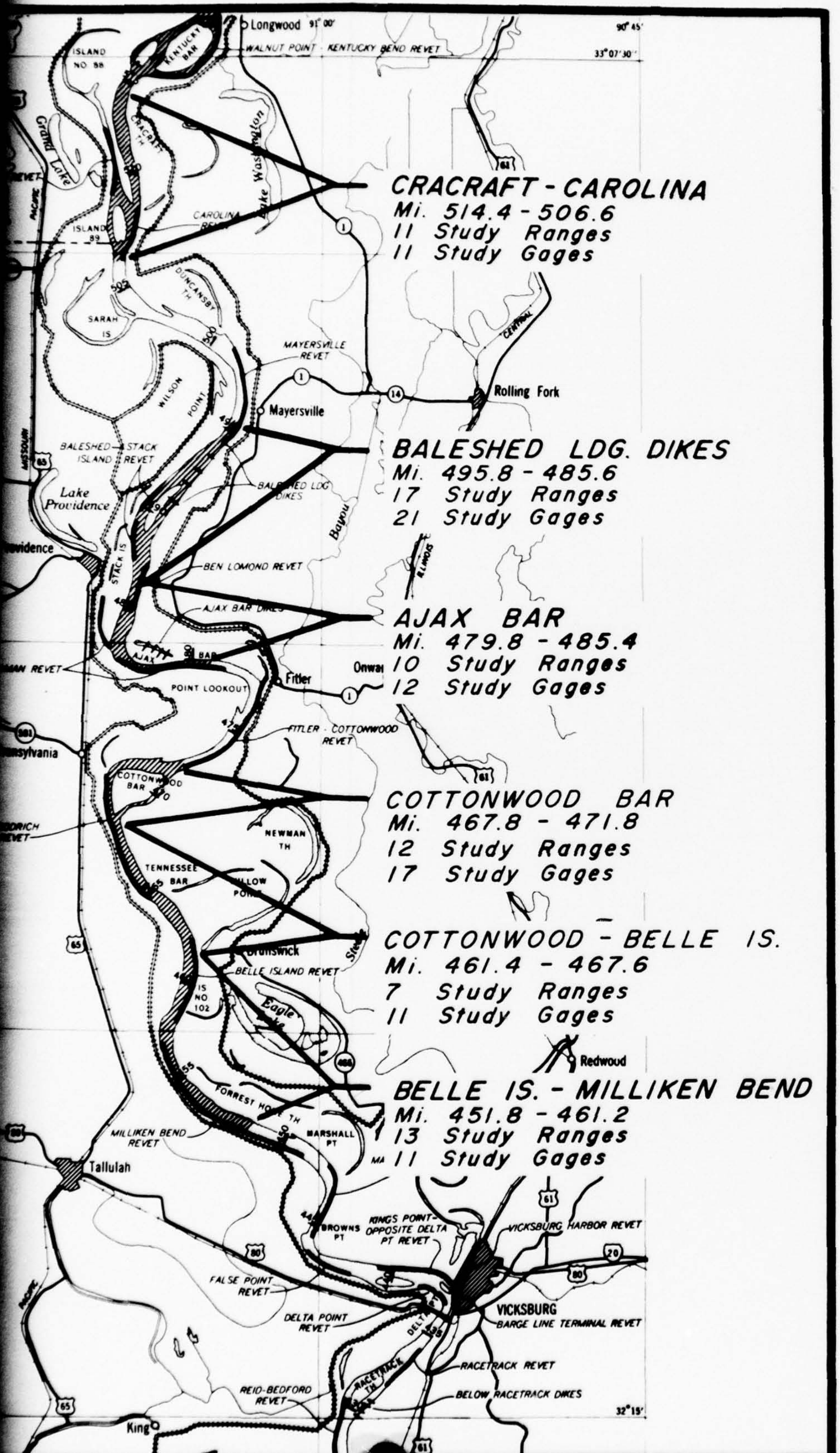
(3) U. S. Army Engineer Waterways Experiment Station, "Study of Materials in Suspension, TM-122-1, Vicksburg, Miss., 1939.

(4) Colby, Bruce R., "Discharge of Sands and Mean Velocity Relationships in Sand-Bed Streams," Geological Survey, Professional Paper No. 462-A, U. S. Department of the Interior, 1964.

(5) Bagnold, Ralph A., "An Approach to the Sediment Transport Problem from General Physics," Geological Survey Professional Paper No. 422-I, U. S. Department of the Interior, 1966.



TERRENE - OZARK
Mi. 594.0 - 580.6
16 Study Ranges
24 Study Gages
OZARK - EUTAW
Mi. 577.2 - 565.6
17 Study Ranges
13 Study Gages
CHOCTAW BAR
Mi. 565.4 - 550.8
16 Study Ranges
22 Study Gages
GREENVILLE REACH
Mi. 550.6 - 530.8
11 Study Ranges
56 Study Gages
LAKEPORT TOWHEAD
Mi. 530.6 - 524.4
8 Study Ranges
14 Study Gages
KENTUCKY BEND
Mi. 524.2 - 514.6
11 Study Ranges
14 Study Gages
ARKANSAS
Deeson
DENNIS REVET
SMITH POINT REVET
SMITH POINT DIKES
SMITH POINT
ISLAND 70 DIKES
Yancopin
BIG ISLAND REVET
Gunnison
Watson
MONTGOMERY I.H. DIKES
BIG ISLAND
TERRENE VICTORIA BEND REVET
RIVER
Rosedale
KLONDIKE REVET
OZARK IS NO. 75
IS NO. 74
Lake Beulah
OZARK REVET
PRENTISS REVET
CAULK POINT
CATFISH POINT REVET
CATFISH PT
Lake Whittington
CYPRESS BEND REVET
Benoit
EUTAW MOUNDS REVET
PAIR O DICE REVET
Arkansas City
Lake Bolivar
ARK CITY-YELLOW BEND REVET
Scott
HUNTINGTON POINT REVET
HUNTINGTON PT
Lamont
ASHBROOK ISLAND REVET
MILLER BEND REVET
Macon Lake
ASHBROOK POINT
ISLAND NO. 82
L Ferguson
YARPLEY ISLAND REVET
CARTER PT
SPANISH MOSS REVET
GREENVILLE
Leland
LELAND NECK DIKES
LELAND CUTOFF REVET
LA GRANGE REVET
LELAND BAR
WARFIELD POINT REVET
Lake Village
ISLAND REVET
SUNNYSIDE REVET
Lake Chicot
PICKETT IS
Wayside
LAKEPORT REVET
LAKEPORT T.H.
AMERICAN CUT-OFF REVET
SEVEN OAKES DIKES
Hollandale
WALNUT POINT - KENTUCKY BEND REVET
Longwood
ISLAND NO. 88
KENTUCKY BAR
Macon
Bayou
Eudora
91° 15'
91° 00'
34° 00'
33° 45'
33° 30'
PACIFIC
MISSOURI
ILLINOIS
CENTRAL
C. & G.
Eudora
CRACRAFT
ARKANSAS
LOUISIANA
Kilbourne
Oak Grove
Lake P
Bayou
RIVER
TENSAS



CRACRAFT - CAROLINA
Mi. 514.4 - 506.6
11 Study Ranges
11 Study Gages
BALESHED LDG. DIKES
Mi. 495.8 - 485.6
17 Study Ranges
21 Study Gages
AJAX BAR
Mi. 479.8 - 485.4
10 Study Ranges
12 Study Gages
COTTONWOOD BAR
Mi. 467.8 - 471.8
12 Study Ranges
17 Study Gages
COTTONWOOD - BELLE IS.
Mi. 461.4 - 467.6
7 Study Ranges
11 Study Gages
BELLE IS. - MILLIKEN BEND
Mi. 451.8 - 461.2
13 Study Ranges
11 Study Gages
Longwood
WALNUT POINT - KENTUCKY BEND REVET
Grand Lake
Lake Washington
CAROLINA
Rolling Fork
Mayersville
MAYERSVILLE REVET
BALESHED - STACK ISLAND REVET
Lake Providence
BEN LOMOND REVET
AJAX BAR DIKES
Fitler
POINT LOOKOUT
FITLER - COTTONWOOD REVET
COTTONWOOD BAR
NEWMAN TH
TENNESSEE BAR
Brunswick
BELLE ISLAND REVET
Eagle Lake
Redwood
MILLIKEN BEND REVET
Tallulah
MARSHALL PT
BROWNS PT
KINGS POINT-OPPOSITE DELTA PT REVET
VICKSBURG HARBOR REVET
FALSE POINT REVET
DELTA POINT REVET
VICKSBURG
BARGE LINE TERMINAL REVET
RACETRACK REVET
BELOW RACETRACK DIKES
REID-BEDFORD REVET
King

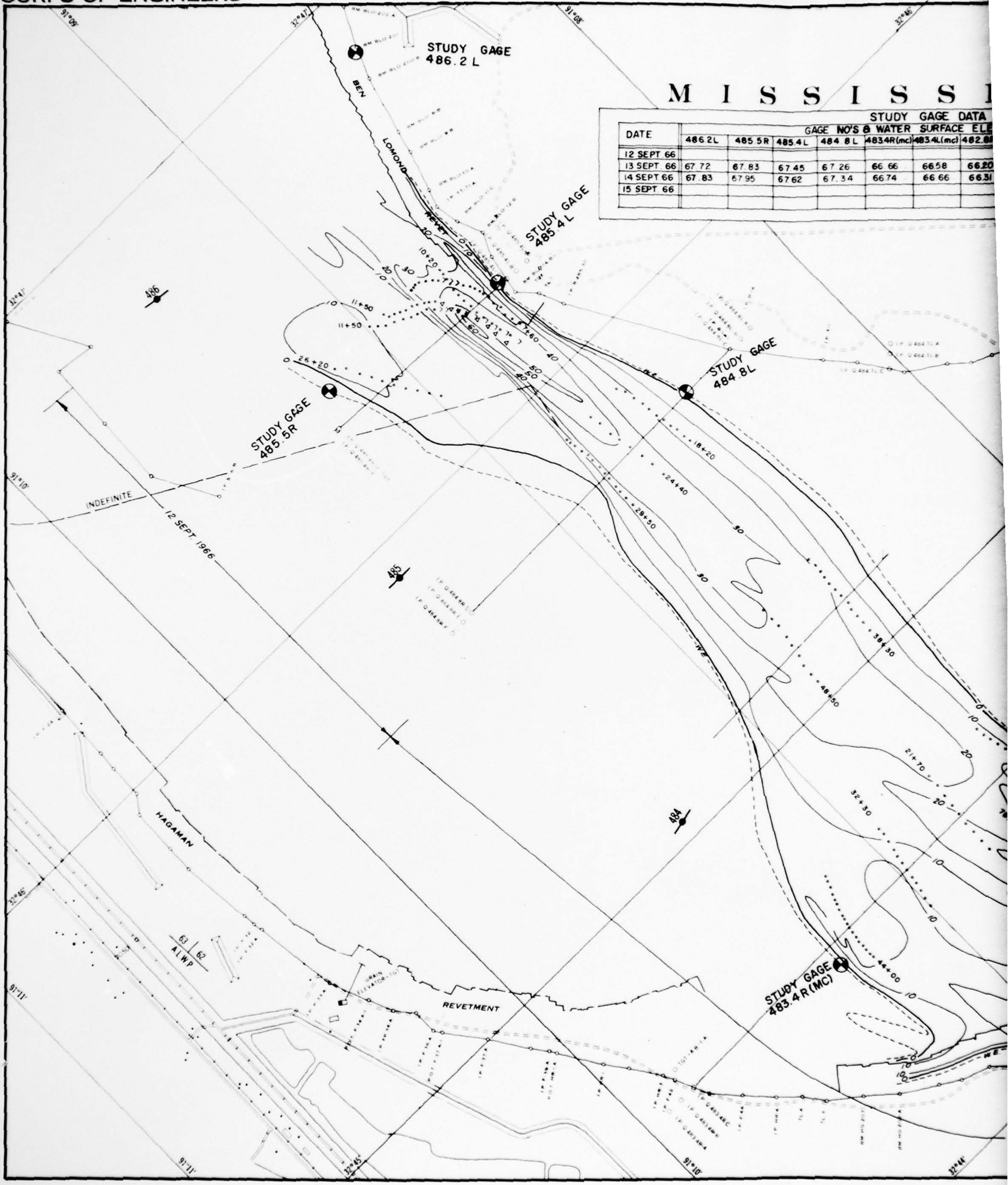
PLATE 1

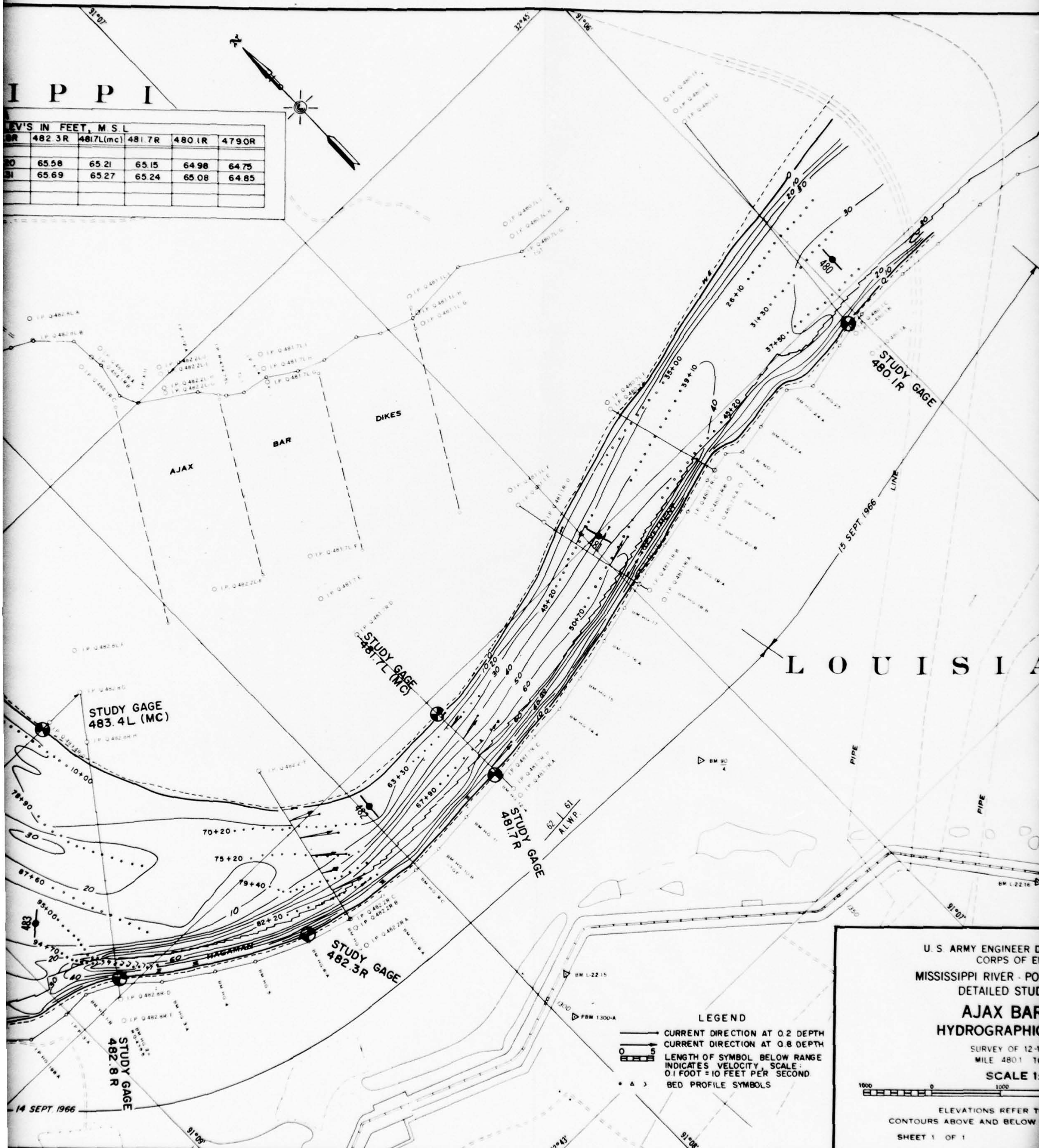
CORPS OF ENGINEERS

M I S S I S S I

STUDY GAGE DATA

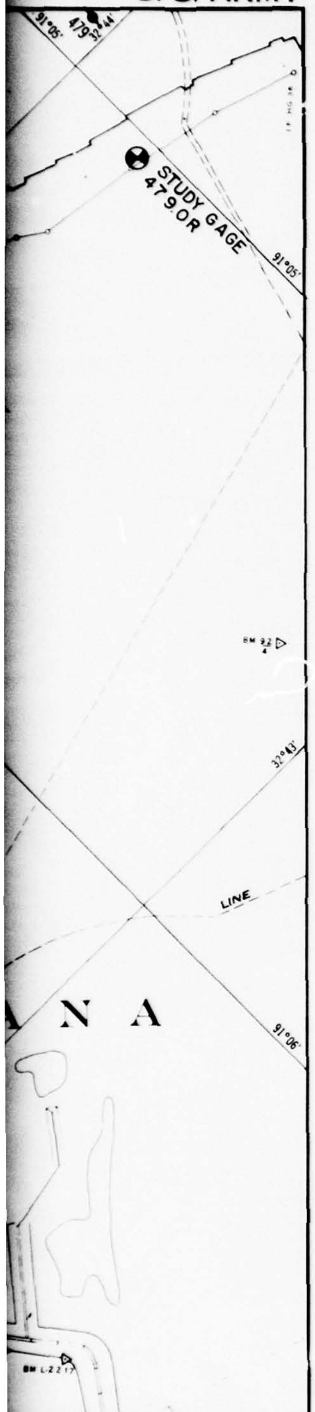
DATE	GAGE NO'S & WATER SURFACE ELE						
	486.2L	485.5R	485.4L	484.8L	483.4R(mc)	483.4L(mc)	482.8[illegible]
12 SEPT 66							
13 SEPT 66	67.72	67.83	67.45	67.26	66.66	66.58	66.20
14 SEPT 66	67.83	67.95	67.62	67.34	66.74	66.66	66.31
15 SEPT 66							





IPPI
LEV'S IN FEET, M.S.L.
482.3R
481.7L(mc)
481.7R
480.1R
479.0R
65.58
65.21
65.15
64.98
64.75
65.69
65.27
65.24
65.08
64.85
AJAX
BAR
DIKES
STUDY GAGE 480.1R
STUDY GAGE 481.7L (MC)
STUDY GAGE 483.4L (MC)
STUDY GAGE 481.7R
STUDY GAGE 482.3R
STUDY GAGE 482.8R
LOUISIA
15 SEPT 1966
LINE
PIPE
PIPE
14 SEPT 1966
HAGAMAN
A.L.W.P.
LEGEND
CURRENT DIRECTION AT 0.2 DEPTH
CURRENT DIRECTION AT 0.8 DEPTH
LENGTH OF SYMBOL BELOW RANGE INDICATES VELOCITY, SCALE: 0.1 FOOT = 10 FEET PER SECOND
BED PROFILE SYMBOLS
U.S. ARMY ENGINEER DIST
CORPS OF ENG
MISSISSIPPI RIVER - POTA
DETAILED STUDY
AJAX BAR
HYDROGRAPHIC
SURVEY OF 12-16
MILE 480.1 TO
SCALE 1:10
ELEVATIONS REFER TO
CONTOURS ABOVE AND BELOW A
SHEET 1 OF 1

U. S. ARMY



ISTRICT VICKSBURG
NGINEERS

TAMOLOGY STUDIES
Y REACHES

R REACH
C PLAN MAP

S SEPT. 1966
D MILE 485.4

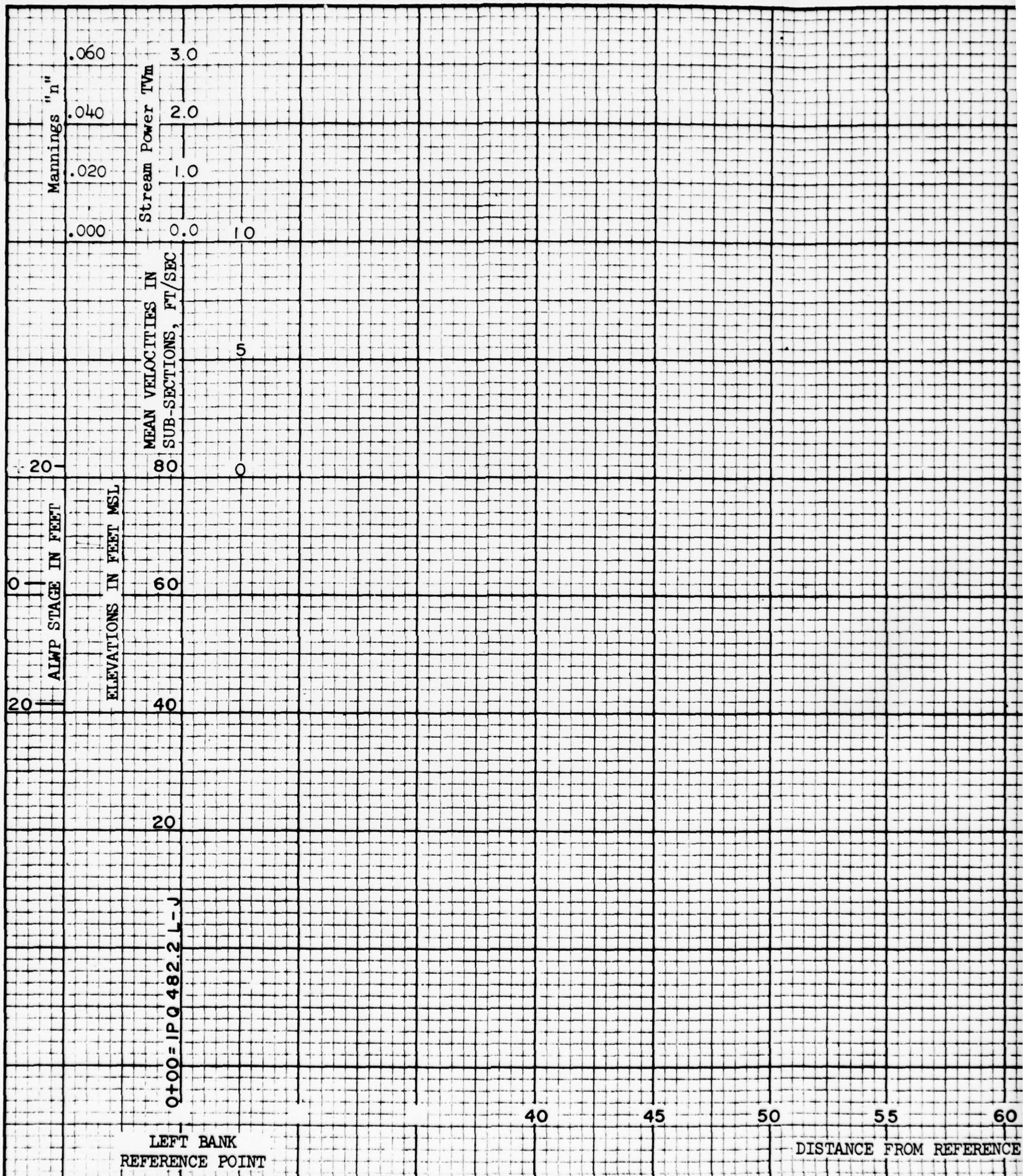
:10,000

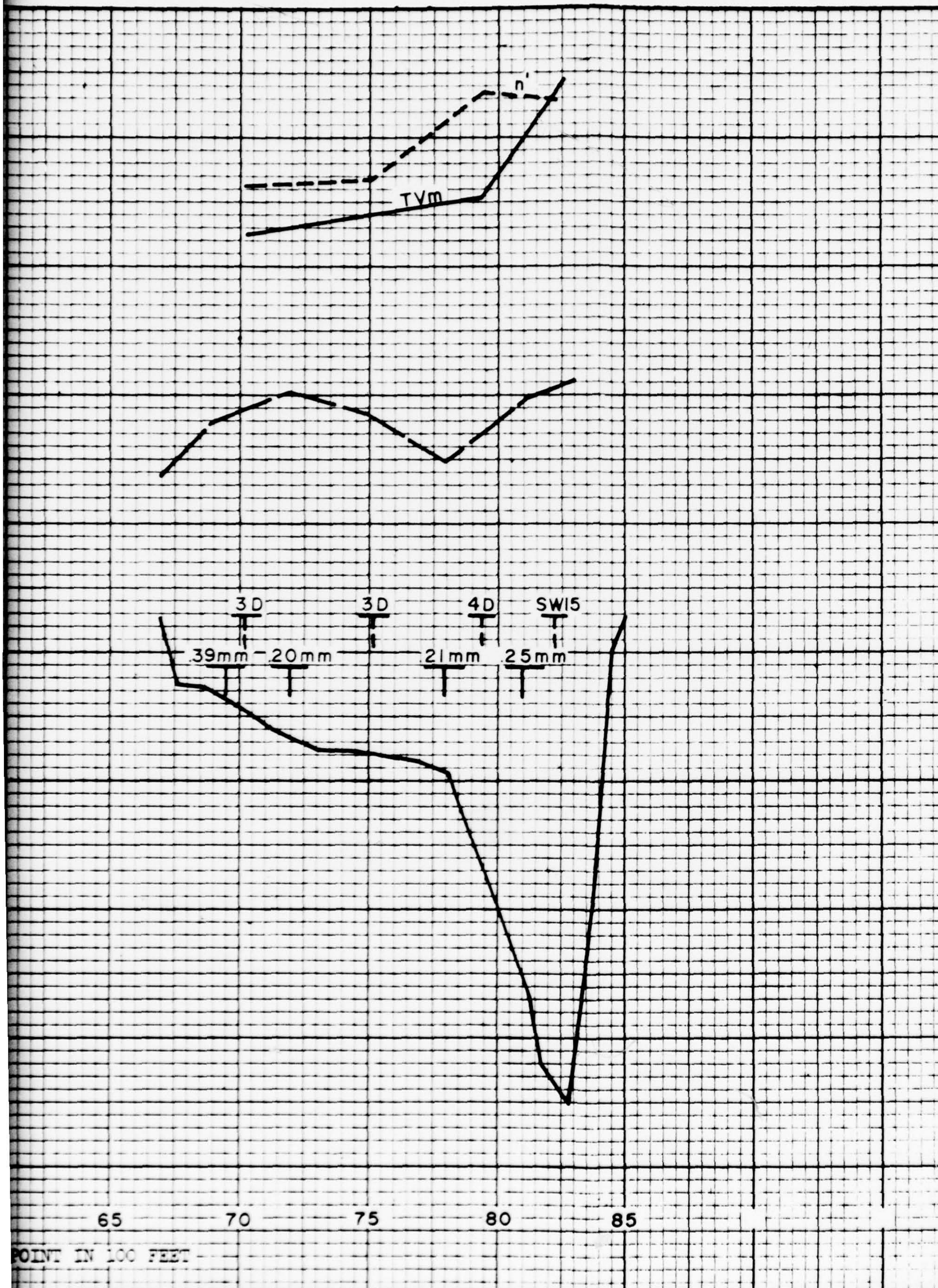
2000 3000 4000 FEET

D MEAN SEA LEVEL
AVERAGE LOW WATER PLANE

FILE NO. M-3.1-13

PLATE 2


Mannings "n"
.060
.040
.020
.000
Stream Power TVm
3.0
2.0
1.0
0.0
10
5
0
MEAN VELOCITIES IN SUB-SECTIONS, FT/SEC
20
0
20
AIWP STAGE IN FEET
ELEVATIONS IN FEET MSL
80
60
40
20
0+00=IPQ 482.2 L-J
40
45
50
55
60
LEFT BANK REFERENCE POINT
DISTANCE FROM REFERENCE



WS Elev= 65.55
Slope, ft/ft: LT=

Average Velocity= 4.22

1-5D — Bed Profile St
Amplitude in F
Dune, P=Plane,
Wave

B-0.40 — Bed Material S
Grain Size

U. S. ARMY ENGINEER D
CORPS OF EI

MISSISSIPPI RIVER-POT
DETAILED STU

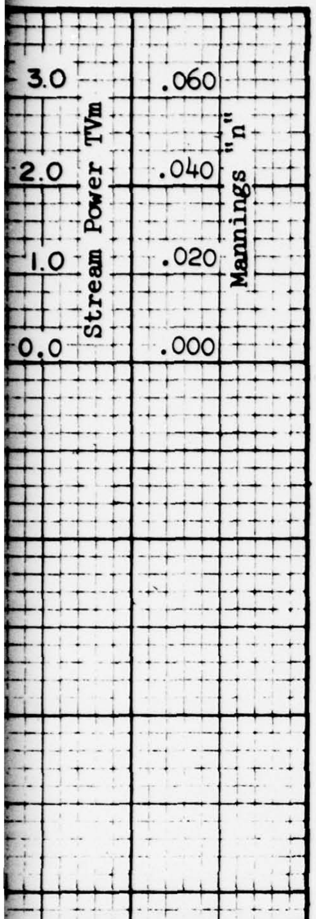
AJAX BAR

CROSS SECT

TYPE OF REACH DIVIDED FLO

RANGE Q 482.2 DA

SHEET 6 OF 10



Stage ALWP= 3.55
RT=
Mean=0.000124
2 fps (Total Sec.)

tation and Bed Form.
Feet, R=Ripples, D=
, and SW=Standing

Sample and Median

DISTRICT, VICKSBURG
NGINEERS
TAMOLOGY STUDIES
DY REACHES

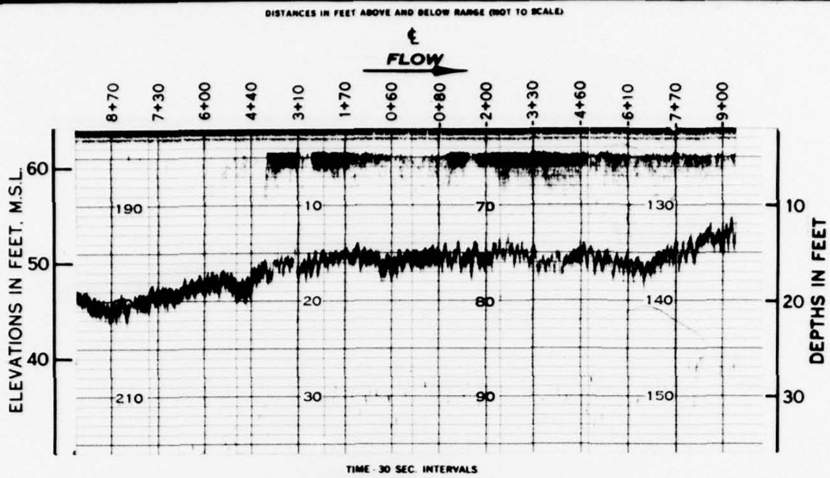
R REACH

TION DATA

W PARTIALLY CONTROLLED
ATE OF SURVEY 13 SEPT. 66
FILE NO. M-3.1-13

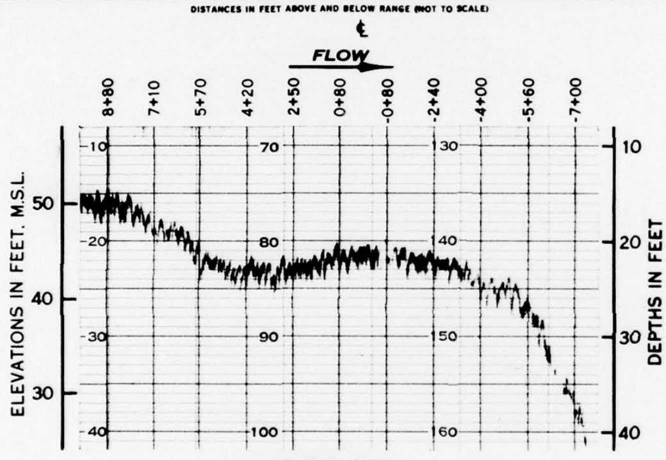
PLATE 3

CORPS OF ENGINEERS



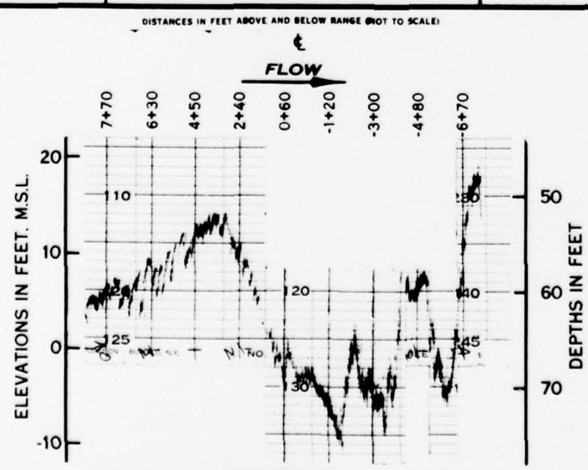
PROFILE NO. 7
RANGE STA. 70+20

Avg. Depth 16.0 ft.	Slope 0.000124 ft./ft.	Mannings n' 0.0259
Mean Velocity 4.08 f.p.s.	TVm 0.51	Bed Form D-3



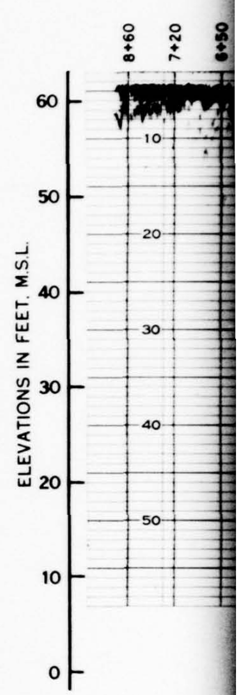
PROFILE NO. 8
RANGE STA. 75+20

Avg. Depth 22. ft.	Slope 0.000124 ft./ft.	Mannings n' 0.0270
Mean Velocity 4.8 f.p.s.	TVm 0.82	Bed Form D-3



PROFILE NO. 10
RANGE STA. 82+20

Avg. Depth 70. f.p.s.	Slope 0.000124 ft. ft.	Mannings n' 0.0522
Mean Velocity 5.4 f.p.s.	TVm 2.92	Bed Form 15-SW



Avg. Depth 38.	
Mean Velocity 3.46 f.p.s.	

W.S. Elevation = 66'
Elevation of A.L.W.P. = 62'

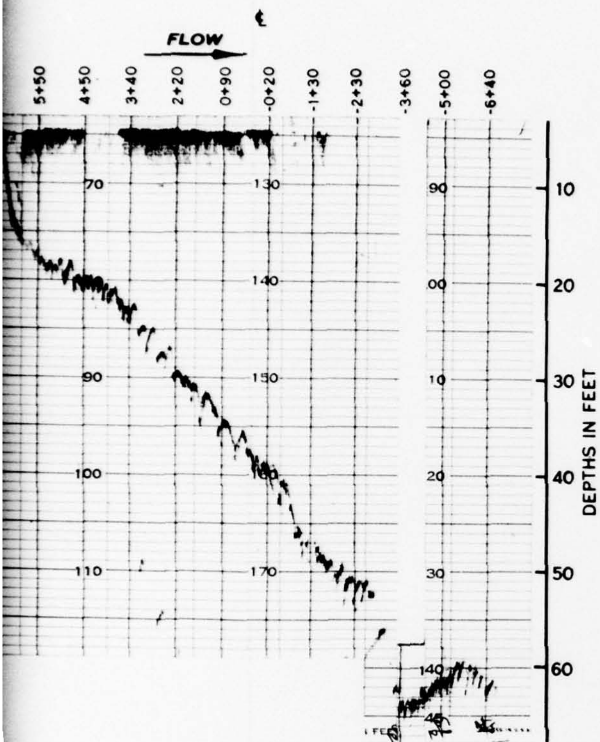
NOTES:

TVm = Stream Power in ft. - lb per second per sq. ft.
= γ DSVm

Where:

γ = 62.4 lbs./cu.ft.
D = Average depth, ft.
S = Energy Slope, ft./ft.
Vm = Mean Velocity, ft./sec.

DISTANCES IN FEET ABOVE AND BELOW RANGE (NOT TO SCALE)



TIME 30 SEC. INTERVALS

PROFILE NO. 9
RANGE STA. 79+40

Slope 0.000124 ft./ft.	Mannings n' 0.0544
TVm 1.02	Bed Form D-4

DISTANCES IN FEET ABOVE AND BELOW RANGE (NOT TO SCALE)

S.

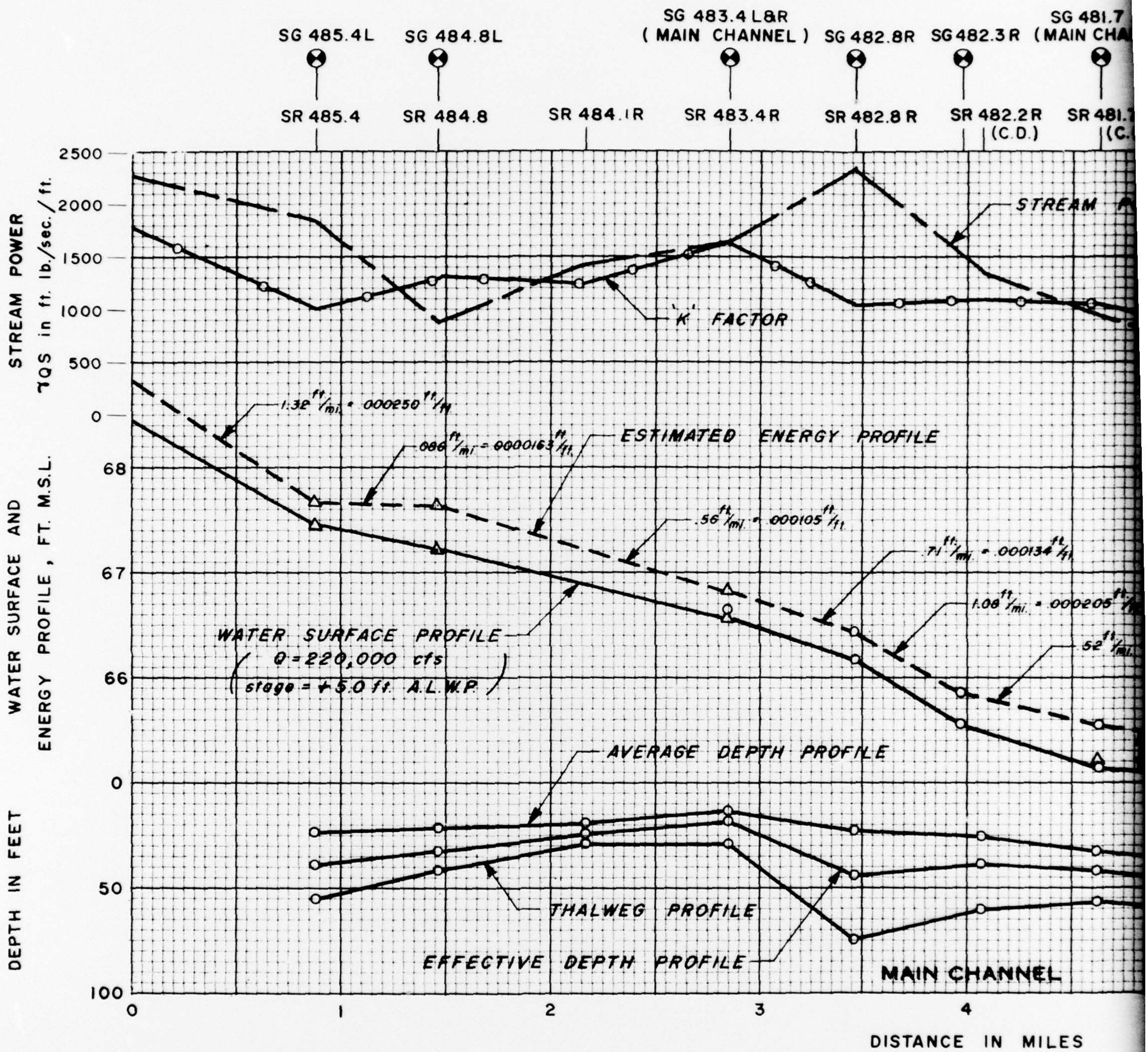
U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS

MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

AJAX BAR REACH
BED PROFILES DATA

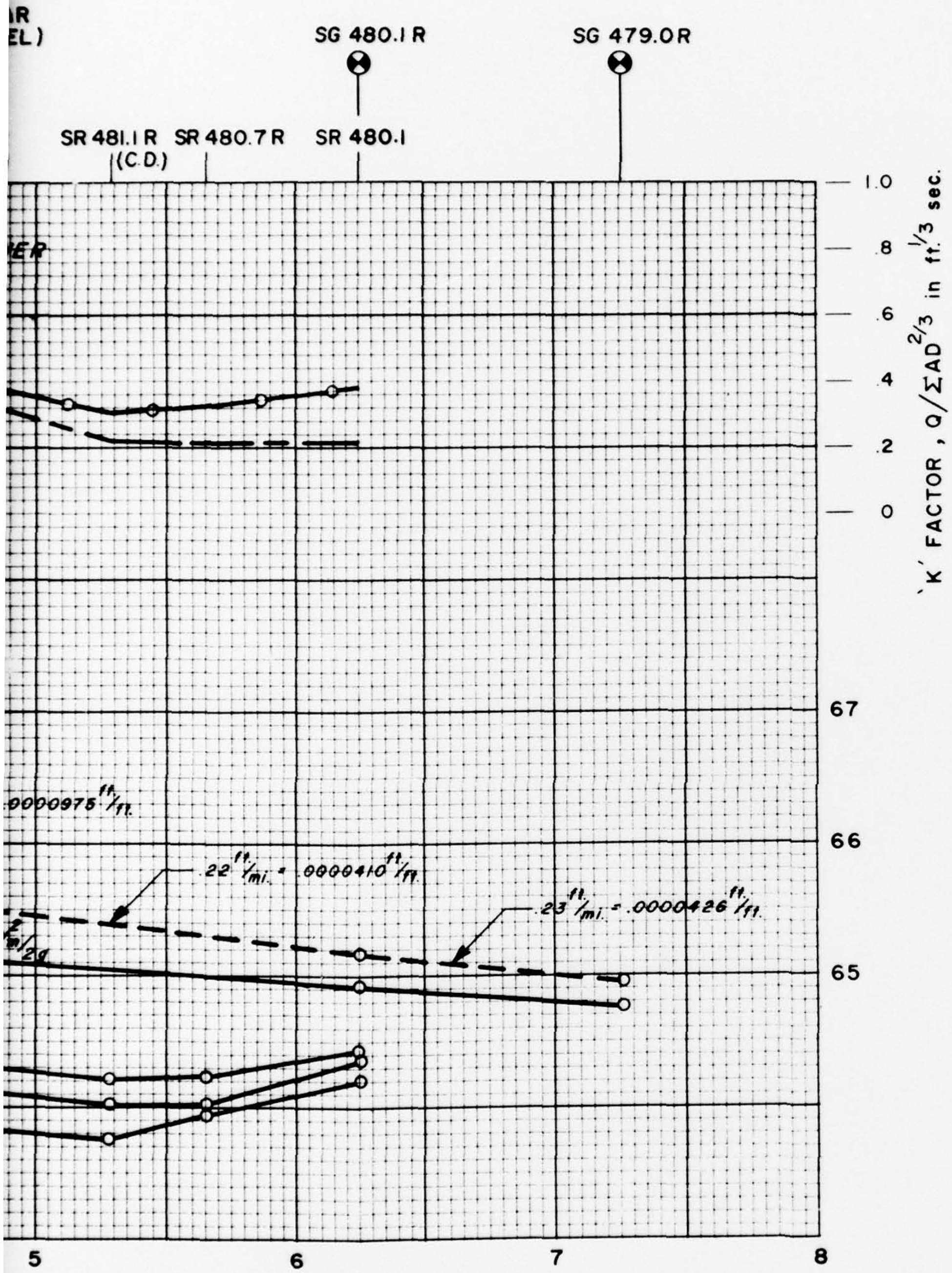
TYPE OF REACH DIVIDED FLOW PARTIALLY CONTROLLED
RANGE 0-482.2 DATE OF SURVEY 14 SEPT 1966
SHEET 6 OF 10 FILE NO. M-31.13

PLATE 4



LEGEND

- ○ Right Bank Gage Reading 13 Sept. 1966
- △ Left Bank Gage Reading 13 Sept. 1966
- ——— Estimated Water Surface 13 Sept. 1966
- — — — Estimated Energy Gradient 13 Sept. 1966



U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS

MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

AJAX BAR REACH

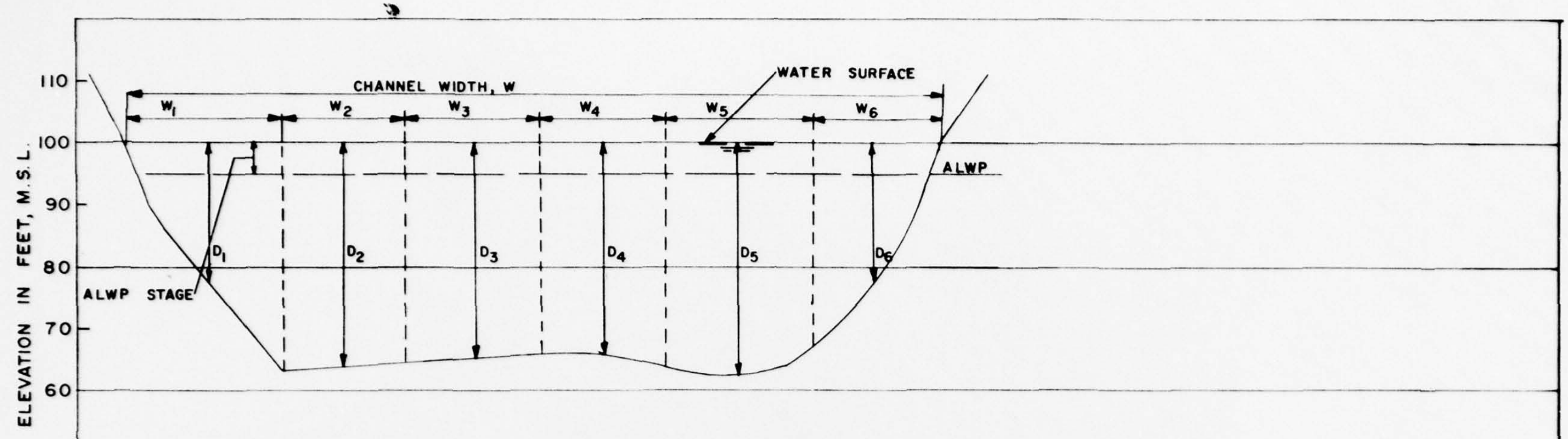
WATER SURFACE PROFILES

TYPE OF REACH DIVIDED FLOW PARTIALLY CONTROLLED

DATE OF SURVEY

SHEET OF FILE NO.

PLATE 52



SUB-SECTION	WIDTH	DEPTH	VELOC-ITY	AREA	$D^{2/3}$	$AD^{2/3} \times 10^{-3}$	$AD^{5/3} \times 10^{-3}$	AV	$S \times 10^4$	$\gamma DSVW$
1	500	23	4.00	11,500	8.1	94	2160	45,900	.53	151
2	400	36	4.50	14,400	10.9	157	5650	64,900	.53	214
3	500	34	4.75	17,000	10.5	178	6050	80,600	.53	266
4	500	34	5.00	17,000	10.5	178	6050	85,000	.53	280
5	600	37	4.00	22,200	11.2	248	9200	89,000	.53	293
6	500	23	2.50	11,500	8.1	94	2160	28,800	.53	95
TOTAL	3000			93,600		849	31,270	3[illegible],200		1299

DISCHARGE, $Q = \Sigma\ WDV = 394{,}000\ ft.^3/SEC.$

MEAN DEPTH, $D = \frac{A}{W} = 31.2\ ft.$

AVERAGE VELOCITY, $V_m = \frac{Q}{A} = 4.21\ ft./SEC.$

CHANNEL FACTOR, $\Sigma\ AD^{2/3} = 849{,}000\ ft.^{8/3}$

EFFECTIVE DEPTH, $D_E = \frac{\Sigma AD^{5/3}}{\Sigma AD^{2/3}} = 36.8\ ft.$

SLOPE-ROUGHNESS FACTOR, $K_1 = \frac{Q}{\Sigma AD^{2/3}} = .46\ ft.^{1/3}/SEC.$

MANNING'S "n": $\frac{1.49 S^{1/2}}{K} = .0236$

STREAM POWER, $\mathcal{N} = \Sigma\ \gamma DSVW = 1299\ ft\ lb/sec.\ ft.$

UNIT STREAM POWER, $\omega = \frac{\mathcal{N}}{W} = .43\ ft.\ lb/sec.\ ft.^2$

U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS

MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

HYDRAULIC TERMS & FACTORS

JANUARY 1967

PLATE 6

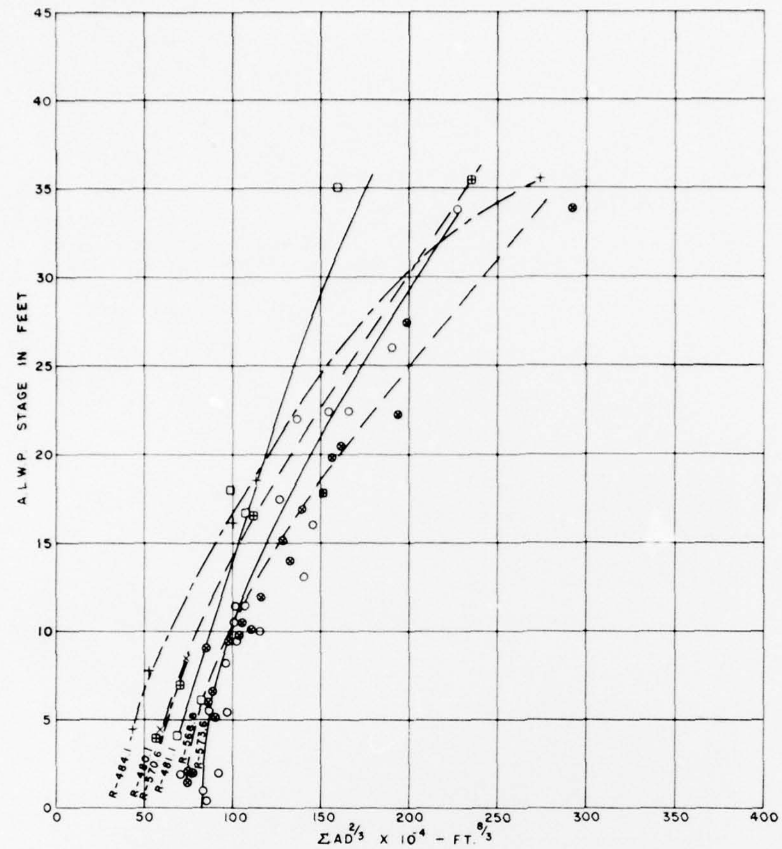


FIG. 1 - RELATIONS OF $\Sigma AD^{2/3}$ TO A.L.W.P. STAGE

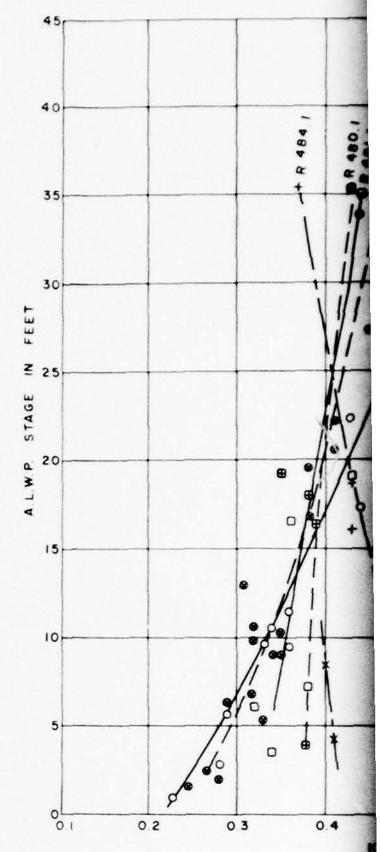


FIG. 2 - RELATIONS OF K TO A.

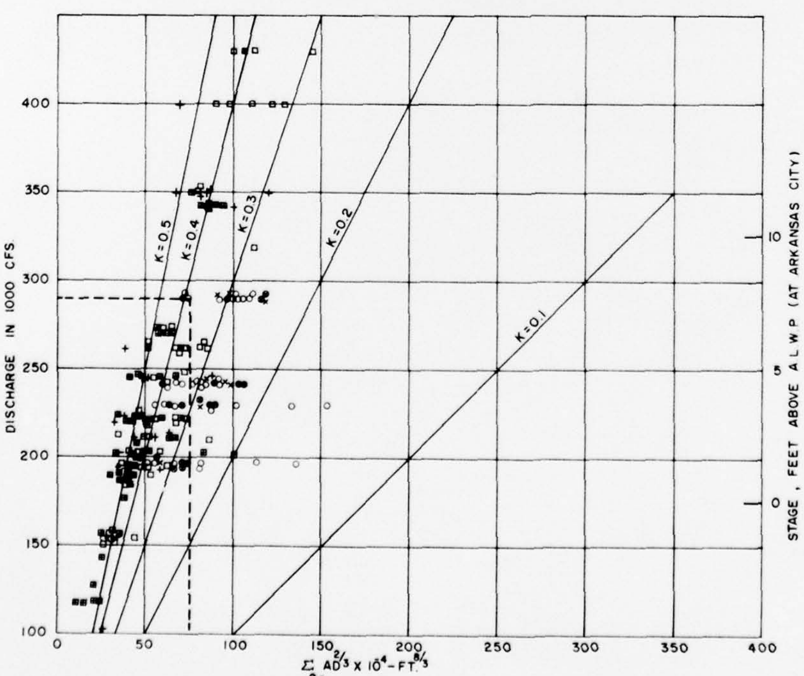


FIG. 3 - RELATIONS OF $\Sigma AD^{2/3}$ TO DISCHARGE

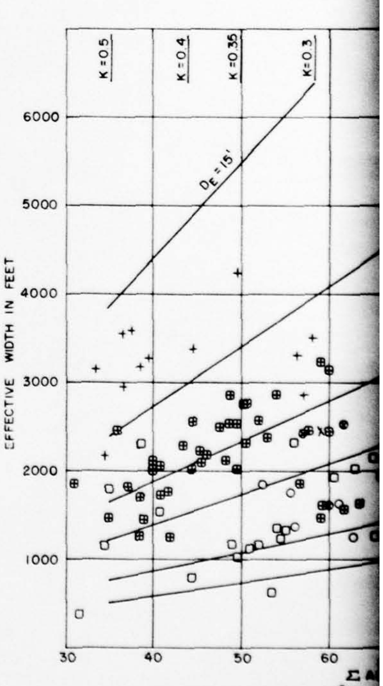
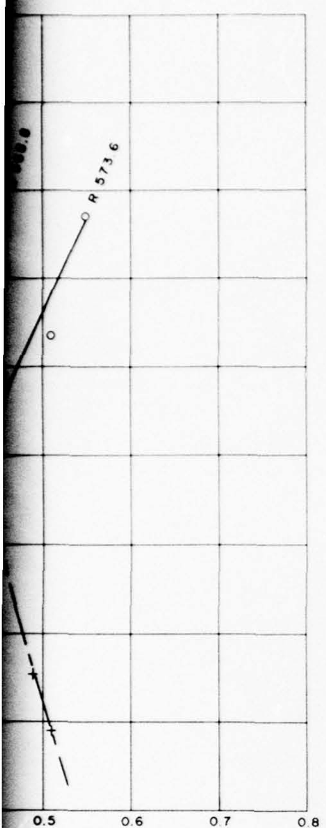
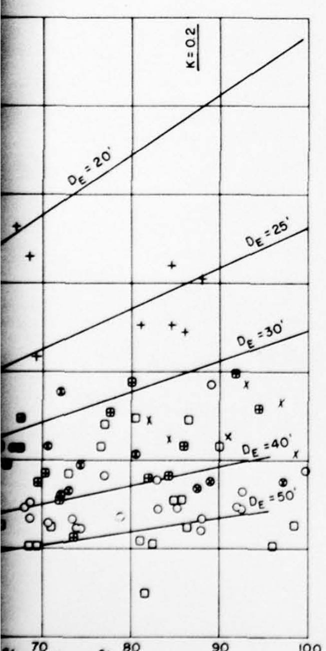


FIG. 4 - RELATIONS OF $\Sigma AD^{2/3}$



= $Q/\Sigma AD^{2/3}$

L.W.P. STAGE



x 10^4 - $FT^{8/3}$

TO EFFECTIVE WIDTH

LEGEND

——— Pools
– – – – Transitions
——— - ——— Crossings

STABLE REACH

○ Pool
● Transition
× Crossing

UNSTABLE REACH

□ Pool
⊞ Transition
+ Crossing

NOTES

1. Stable Reaches are Ozark - Eutaw and Belle Island - Milliken Bend.
2. Unstable Reaches are Ajax Bar, Baleshed Landing, Cracraft - Carolina, Cottonwood Bar, and Greenville.
3. Data for Figs 1 and 2 are for Ajax Bar and Ozark - Eutaw Reaches.
4. Data for Figs. 3 and 4 are for All Detailed Study Reaches.

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CORPS OF ENGINEERS

MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

GENERAL RELATIONS OF HYDRAULIC FACTORS

JANUARY 1967

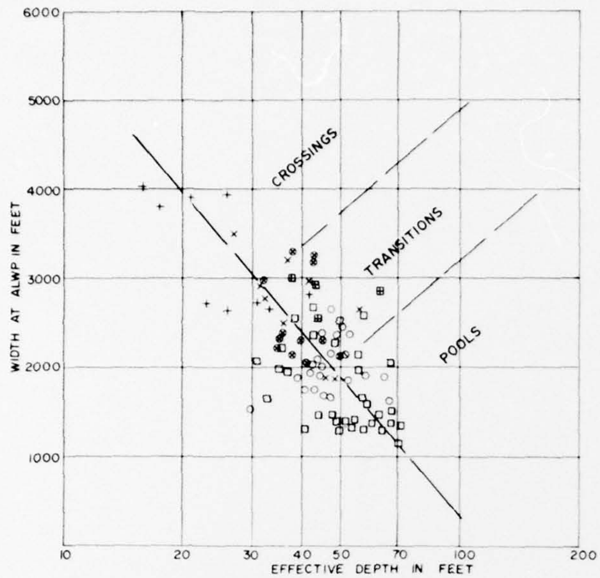


FIG. 1- RELATIONS OF WIDTH AT ALWP EFFECTIVE DEPTH

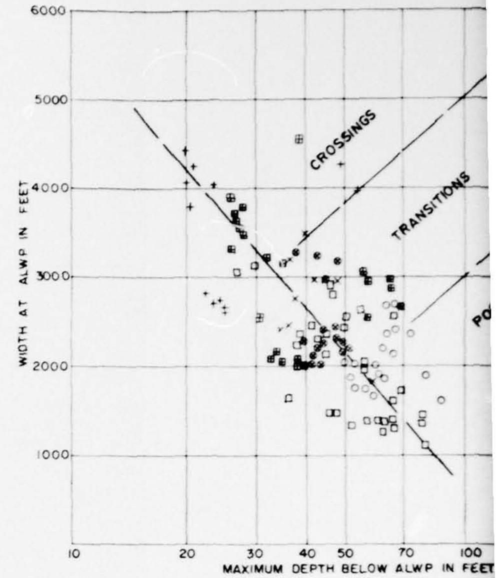


FIG. 2- RELATIONS OF WIDTH AT ALWP TO MAXIMU

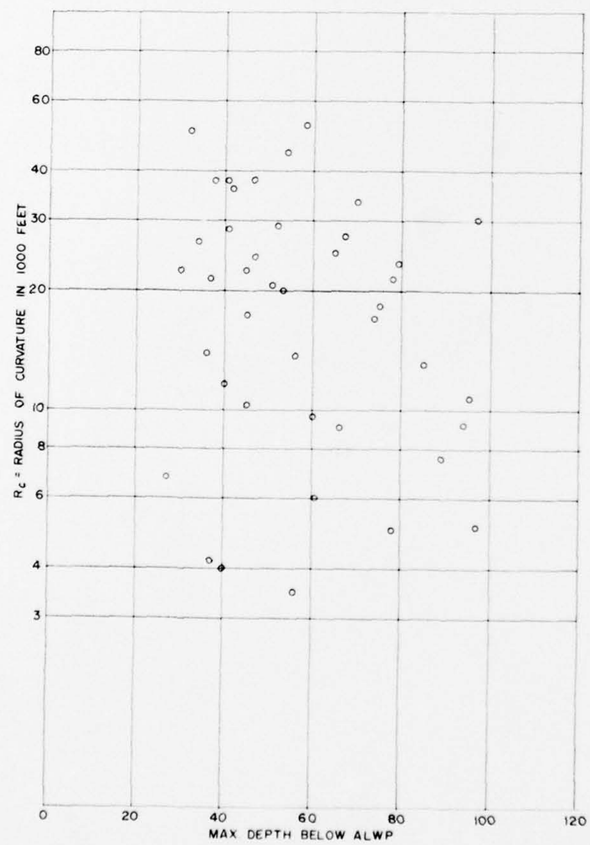


FIG. 3- RELATION OF RADIUS OF CURVATURE OF BENDS TO MAXIMUM DEPTH BELOW ALWP

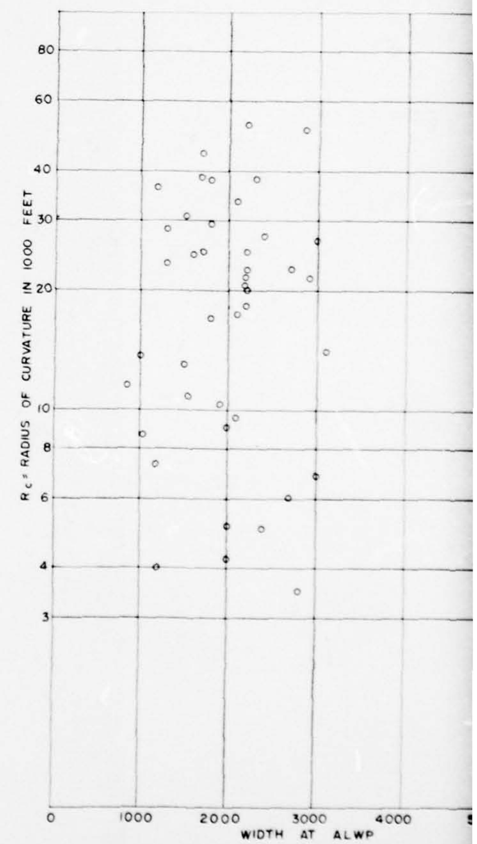
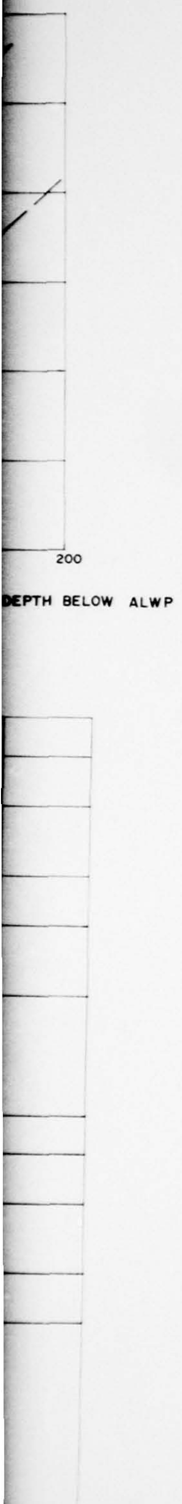


FIG 4- RELATION OF RADIUS OF CURVATURE OF TO WIDTH AT ALWP



LEGEND

STABLE REACH

- ○ Pools
- ⊛ Transitions
- × Crossings

UNSTABLE REACH

- □ Pools
- ⊞ Transitions
- + Crossings

NOTES

1. Stable Reaches are Ozark-Eutaw and Belle Island-Milliken Bend.
2. Unstable Reaches are Ajax Bar, Baleshed Landing, Cracraft-Carolina, Cottonwood Bar, and Greenville.
3. Data for Fig. 1 are for Ajax Bar, Belle Island-Milliken Bend, and Ozark-Eutaw Reaches.
4. Data for Fig. 2 are for Ajax Bar, Belle Island-Milliken Bend, and Greenville Reaches.
5. Data for Figs. 3 & 4 are for 43 Relatively Stable, Revetted Bends in Vicksburg District Portion of Lower Mississippi River, Mile 612.0 - 329.0

U. S. ARMY ENGINEER DISTRICT, VICKSBURG
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MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

RELATIONS OF CHANNEL GEOMETRY

JANUARY 1967

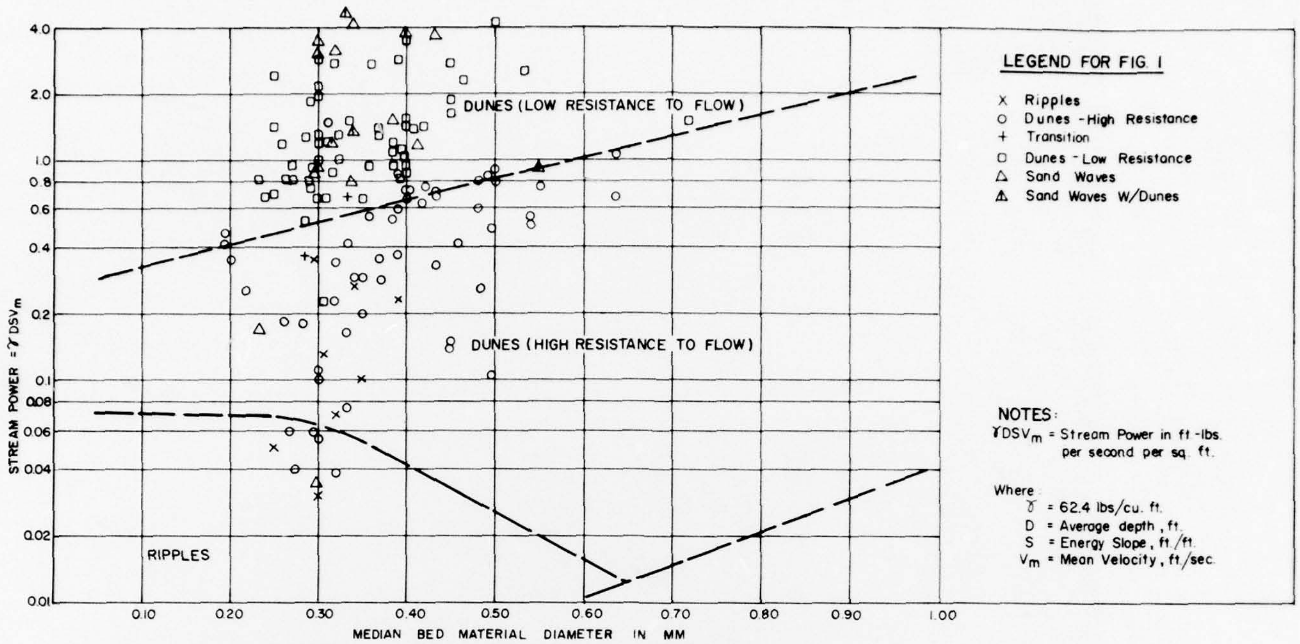


FIG. 1 - RELATIONS OF STREAM POWER, MEDIAN GRAIN SIZE, AND BED FORM

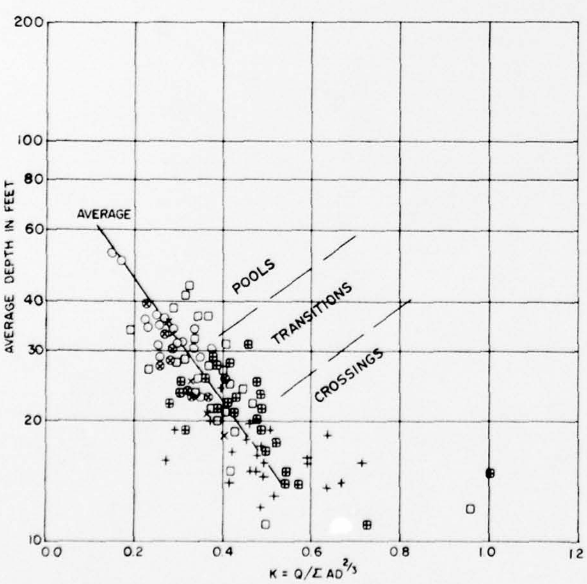


FIG. 3 - RELATION OF K AND AVERAGE DEPTH

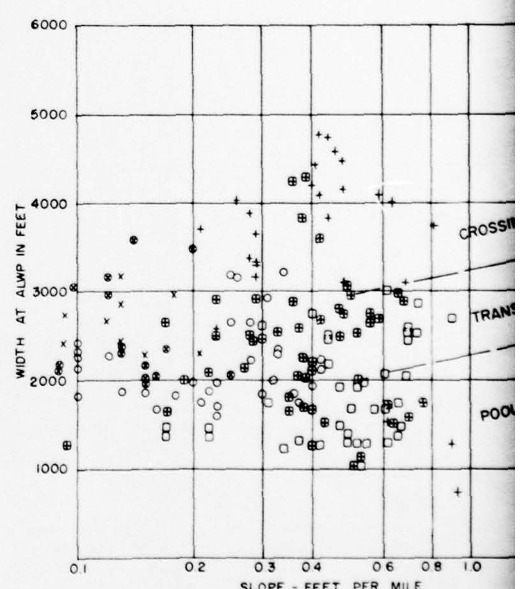


FIG. 4 - RELATION OF S AND WIDTH

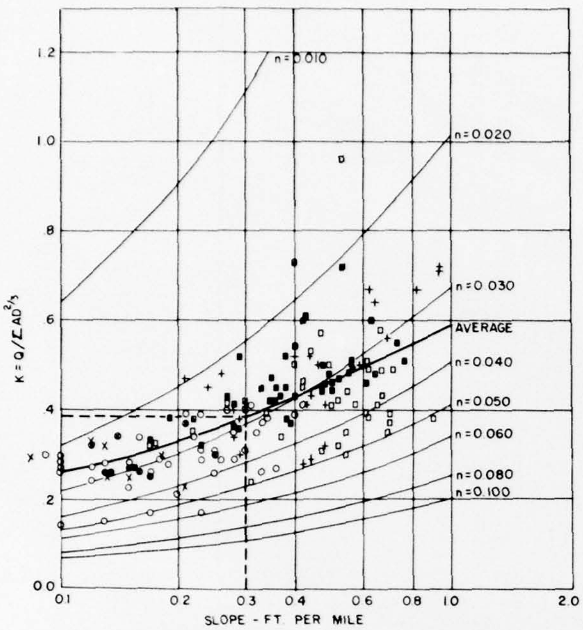


FIG. 2 - RELATION OF K AND SLOPE

LEGEND FOR FIGS. 2, 3, AND 4

STABLE REACH
- ○ Pools
- ⊗ Transitions
- × Crossings

UNSTABLE REACH
- □ Pools
- ⊞ Transitions
- + Crossings

NOTES

1. Stable Reaches are Ozark - Eutaw and Belle Island - Milliken Bend.
2. Unstable Reaches are Ajax Bar, Baleshed Landing, Cracraft - Carolina, Cottonwood Bar, and Greenville.
3. Data for Fig. 1 are for the Ajax Bar and Ozark-Eutaw Reaches.
4. Data for Figs. 2, 3, and 4 are for all detailed study reaches.

SSINGS

NSITIONS

OOLS

2.0

U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

ENERGY LOSS AND ROUGHNESS FACTORS

JANUARY 1967

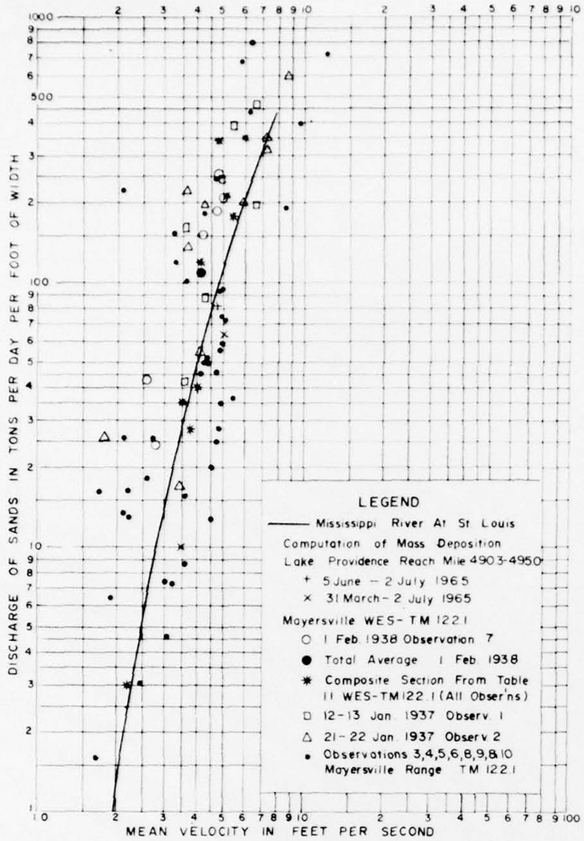


FIG. 1 – RELATION OF DISCHARGE OF SAND TO MEAN VELOCITY

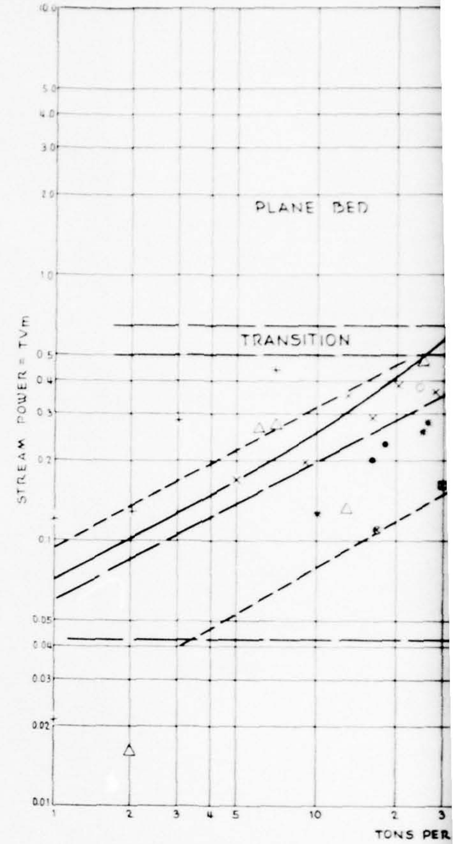


FIG. 2 – RELATION OF DISCHARGE OF SAND

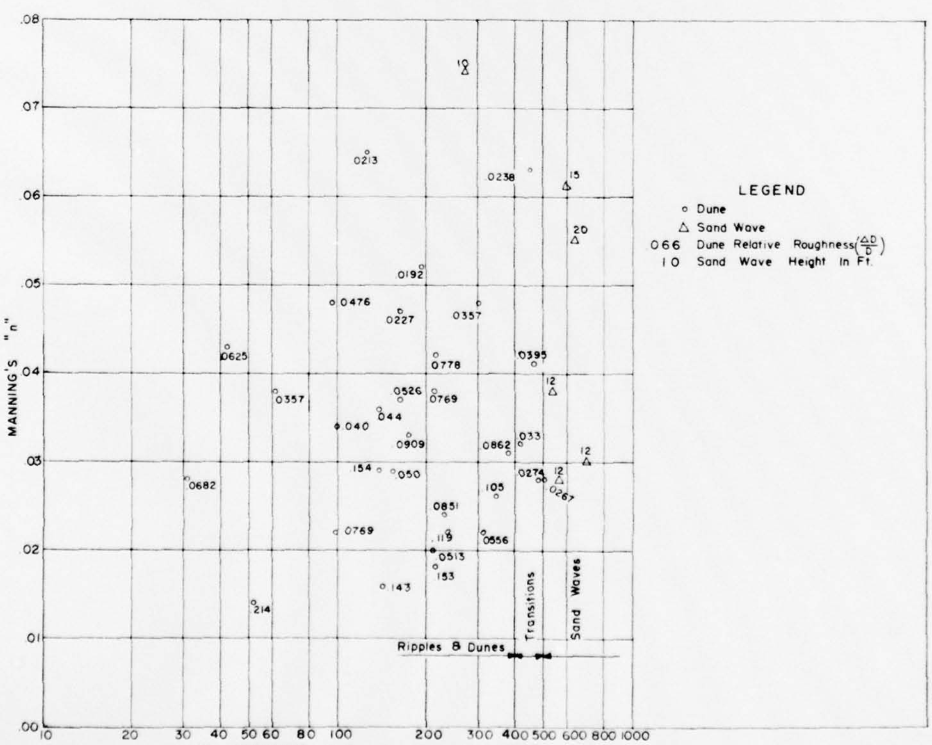


FIG. 3 – RELATION OF MANNING'S "n", UNIT DISCHARGE OF WATER, AND BED FORM

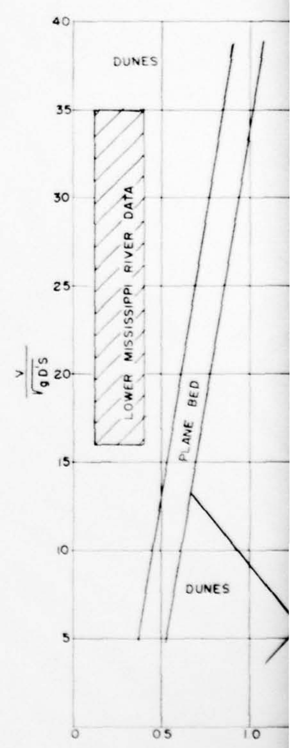
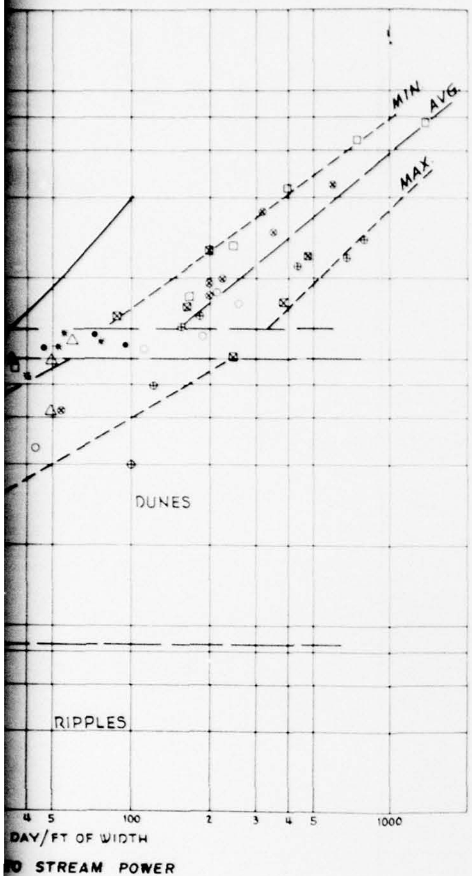


FIG. 4 – RELATION OF V/√

U. S. ARMY

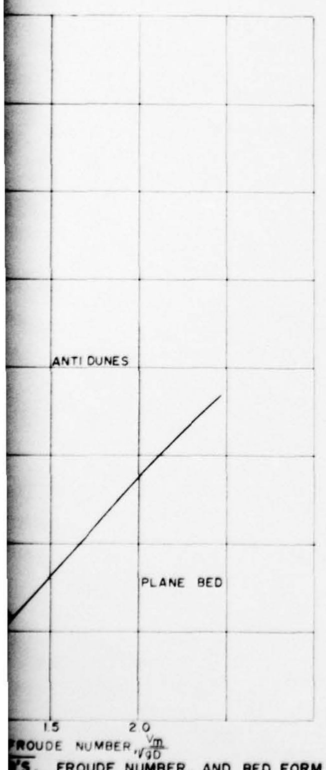


LEGEND

			APPROX. STAGE
⊠	Obs. No. 1	Jan. 1937	20 (R)
⊗	Obs. No. 2	Jan. 1937	28 (R)
□	Obs. No. 3	Feb. 1937	45 (S)
△	Obs. No. 4	June 1937	13 (S)
×	Obs. No. 5	July 1937	6 (S)
+	Obs. No. 6	Sept. 1937	-3.5 (F)
○	Obs. No. 7	Feb. 1938	15 (R)
⊕	Obs. No. 8	Feb. 1938	24 (R)
•	Obs. No. 9	May 1938	16 (F)
•	Obs. No. 10	May 1938	12 (F)

—— From U.S.G.S. Professional Paper 462-A by Colby.

NOTE:
Break in Bed Form for D_{50} = 0.4 mm Grain Size (Simons and Richardson). Observations from WES TM No. 122-1, Study of Materials in Suspension, February 1939.



U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

SEDIMENT TRANSPORT AND
BED FORM RELATIONS

JANUARY 1967

PLATE 10

ASSOCIATED REPORTS*

Study of Materials in Suspension, Mississippi River; T. M. No. 122-1	February 1939
Study of Materials in Transport, Passes of the Mississippi River; T. M. No. 158-1	September 1939
Geological Investigation of the Alluvial Valley of the Lower Mississippi River; Mississippi River Commission	December 1944
A Laboratory Study of the Meandering of Alluvial Rivers	May 1945
Fine-grained Alluvial Deposits and Their Effects on Mississippi River Activity	July 1947
Report of Conference on Sand-asphalt Revetment, 12 August 1948	August 1948
Geological Investigation of Mississippi River Activity, Memphis, Tenn., to Mouth of Arkansas River; T. M. No. 3-288	June 1949
Bank Caving Investigations, Morville Revetment, Mississippi River; T. M. No.3-318	September 1950
Investigation of Free Nigger Point Crevasse, Mississippi River; Mississippi River Commission	December 1950
Mississippi River Revetment Studies; St. Anthony Falls Hydraulic Laboratory Project Report No. 21	June 1951
Investigation of Mass Placement of Sand Asphalt for Underwater Protection of River Banks; T. M. No. 3-329	August 1951
Mississippi River Revetment Studies - Tests on a Double Layer Articulated Concrete Mattress; St. Anthony Falls Hydraulic Laboratory Project Report No. 28	May 1952
Potamology Barrel Samples; Miscellaneous Paper No. 3-9	August 1952
Torsion Shear Study; Miscellaneous Paper No. 3-10	August 1952
Study of Variability of Sand Deposits; Miscellaneous Paper No. 3-12	August 1952
Flume Investigation of Prototype Revetment; Miscellaneous Paper No. 2-35	September 1952
Investigation of Bituminous Cold Mixes for the Protection of Upper River Banks; T. M. No. 3-362	April 1953
Feasibility Study of Improved Methods for Riverbank Stabilization; Contract Report No. 3-81 by Harza Engineering Co.	November 1964

* Unless otherwise noted, all reports listed are publications of the Waterways Experiment Station.